User-Centered Hardware Re-Design for Improved User Experience

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MASTER THESIS

General

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Abstract

User experience design is most associated with human-computer interaction (HCI) but is highly applicable to analogue man-machinery interactions (MMI) as well. In Europe, millions of workplace accidents and incident occur every year. [1] Studies show, that about 50% of workplace accidents and incidents are a result of bad design. [2] Therefore, the relevance of UX design in man-machinery interactions should be evident.

This thesis evaluates the MMI when using a Tetra Pak cardboard packer machine from the perspective of a machine operator. The evaluation is based on the usability components as defined by Jakob Nielsen [10], such as learnability, efficiency, and user satisfaction. The thesis identifies improved task accuracy during the configuration of hardware settings as a design opportunity, and the development of a simple solution to address that follows.
The development takes a holistic, user-centered perspective, while adhering to the established Double Diamond [3] approach. A final, high-fidelity prototype of a setting's marker is presented and evaluated in terms of its usability. The marker provides a visual reference for the operators during setting's configuration, which lessens their mental load and speeds up the configuration process of with up to 11.5 seconds per setting in the final usability test.

The thesis introduces the term "physical UX" to describe the user experience inherent in MMIs and concludes with the formulation of five design guidelines that are especially tailored to the field of physical UX design. The guidelines conclude that usability should be considered early on in a design process and highlights the importance of both internal and external design consistency.

Keywords: man-machinery interaction, user experience, usability, user-centered design, Double Diamond

Sammanfattning

Användarupplevelsedesign (UX-design) är starkt förknippat med människa-datorinteraktion (HCI) men är också relevant för analog människa-maskininteraktion (MMI). I Europa inträffar miljontals arbetsplatsolyckor och tillbud varje år.[1] Studier visar att cirka 50 % av alla olyckor och tillbud kan kopplas till dålig design.[2] Betydelsen av god UX-design i interaktioner mellan människa och maskiner borde därför vara uppenbar.

I detta examensarbete utvärderas MMI:n ur maskinoperatörens perspektiv vid användning av en av Tetra Paks kartongförpackningsmaskiner. Utvärderingen utgår från de användbarhetskomponenter som definierats av Jakob Nielsen [10], såsom lärbarhet, effektivitet och användarnöjdhet. Rapporten identifierar förbättrad noggrannhet under konfiguration av hårdvaruinställningar som en designmöjlighet, och därefter följer utvecklingen av enkel produktlösning med detta i åtanke. Produktutvecklingen har ett holistiskt, användarcentrerat perspektiv och följer den etablerade Double Diamond[3] -metoden. Slutligen presenteras en verklighetstrogen prototyp av en inställningsmarkör, och dess användbarhet utvärderas. Markören erbjuder en visuell referens för operatören under konfigurationen av hårdvaruinställningen, vilket minskar operatörens mentala belastning och snabbar upp konfigurationsprocessen med upp till 11,5 sekunder per inställning i det avslutande användbarhetstestet.

Rapporten introducerar termen "fysisk UX" för att beskriva användarupplevelser som kopplas till människa-maskininteraktioner och avslutas med formuleringen av fem riktlinjer som är speciellt anpassade för området fysisk UX-design. Riktlinjerna slår fast att användbarheten bör beaktas tidigt i en designprocess och understryker vikten av konsekvent design.

Nyckelord: människa-maskininteraktion, användarupplevelse, användbarhet, användarcentrerad design, Double Diamond-metoden

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Acknowledgments

I would like to express my deepest appreciation to all those who aided me during the process of completing this thesis. Special thanks go to my supervisors, Johanna Persson and Emanuel Leufstadius, whose contributions in stimulating discussions and opinions helped moving the project forward and inspired me to explore avenues I had previously not considered.

Last but not least, I would like to acknowledge – and express my deepest appreciation for – the crucial role of Tetra Pak, who gave the permission to use all required equipment and the necessary materials to complete the user research, usability evaluation and usability testing. Without their help, this thesis would not have come to fruition.

Lund, October 2023

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List of acronyms and abbreviations

User experience	UX
Man-machinery interaction	MMI
Cardboard Packer 34	CBP34
Flat cardboard containers	flats

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1 Introduction

User experience (UX) design can not only be applied to digital product development, but also the development of physical products. This thesis aims to improve the physical UX of man-machine interactions in relation to a cardboard packer machine. The thesis consists of two parts: a usability evaluation and the development of a simple design solution.

1.1 Background

User experience (more commonly known as UX) is a well-known term within the field of product design development and is most commonly associated with human-computer interaction (HCI). UX design aims to create products that provide users a certain experience and is often applied in development of digital or semi-digital products such as computer software, phone applications and smartphones. However, the awareness of possible applications of UX design on physical machinery has increased in recent years, not least of all within the food distribution equipment industry.

The UX of analogue man-machinery interactions (MMI) carry implications for everything from machine safety and ergonomics to customer satisfaction. According to Kinnersley and Roelen [2] for example, about 50% of the accidents and incidents in the aircraft and nuclear industries are a result of poor design. There is nothing to suggest similar patterns would not be found in other industries.

Knowing good UX design can provide a distinct competitive advantage, the question is how Tetra Pak can improve the UX of their cardboard packer machines? Tetra Pak is a multinational food packaging and processing company that offers packaging, filling, and processing solutions for a wide range of beverages and foodstuffs. Included in Tetra Pak's product portfolio are also different types of cardboard packers – machines especially designed for packing sealed food packages before shipment to customers.

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One such example is Cardboard Packer 34 (CBP34), a robust and highly efficient piece of distribution equipment, see Figure 1.

Figure 1: View of the CBP34's pattern module (left) and tray module (right). [4]

Tetra Pak's customers typically expect a high degree of flexibility from the equipment, as the product dimensions might change between different production cycles. Each change in product dimensions require manual configuration and re-calibration of the hardware settings for each machine on the production line. This applies to CBP34 as well, but as of now, manually configuring the settings of the machine can prove a complicated and time-consuming task, resulting in longer downtimes and production loss as well as ergonomic strain on staff. The manual access to the hardware settings is not optimal, and the large number of settings require high degree of task accuracy. Improving the human-machine interaction during the hardware configuration process would have a positive impact on the usability in the eyes of the CBP34 operators, minimize the need for extra training, reduce the ergonomic strain and give Tetra Pak new insights on how to better design for positive human-machine interaction.

1.2 Project Goal

The aim of this thesis is to improve the machine operator's user experience during the process of manual hardware configurations by applying common UX design principles on the MMI. The thesis follows a strict user-centred approach to provide general UX recommendations and developing a simple solution to address some of the identified pain points. The project has two main components: a usability evaluation of the current situation, and a concept generation resulting in a final, high-fidelity prototype.

Part 1: Usability Evaluation
User experience provides a holistic perspective of a user's thoughts and feelings during product interaction, with a special focus on user satisfaction

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and product performance. The UX is subjective by nature but can be broken down into a series of objective components, such as usability.

Usability is a term that is used to describe the level of difficulty for a user who interacts with a certain product or service. The usability of a product can be measured using more or less objective metrics. This provides valuable tools for UX design and will therefore be the focus of this thesis.

In this thesis, the usability is evaluated in terms of efficiency, learnability, and user satisfaction.

Efficiency	The time required to complete the task, the number of errors.
Learnability	The user's ability to quickly learn how to interact with the product.
Satisfaction	User satisfaction when interatcing with the product.

The aim of the usability evaluation is to identify available design opportunities and challenges for usability improvements. The results will be used for the creation of a set of general UX design recommendations for the company. The evaluation will also provide valuable understanding and insights about the MMI, the users and their work environment. These insights are to be used as basis for developing a design solution during the second part of the thesis.

Part 2: Design Solution(s)
Based on the usability evaluation, the second part of the thesis concerns the development of 1 concept for improving the machine operator’s UX. The man-machine interaction of interest is the process of configuring the cardboard packer’s hardware settings. In order to narrow down the scope, the configuration is assumed to only occur between 2-3 standard cases. The product development process should have a distinctly user-centered focus and the design solution(s) shall be simple, robust and easily implemented in the current machine architecture. The final design should be presented using a high-fidelity prototype and its usability performance evaluated by user testing.

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The thesis hopes to not only improve the machine operator’s UX, but also provide some insights on how common UX design principles can be applied to the development and improvement of physical products.

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2 Methods and Theory

The thesis consists of two parts: a usability evaluation and the development of a design solution. The product development is modelled after the Double Diamond approach, and strived to incorporate a holistic, user-centered perspective throughout. Also in this chapter, we take a look at the different aspects that make up the user experience, and the functionality of the cardboard packer is explained in detail.

2.1 Double Diamond

A variety of methods were used throughout the design process to investigate, evaluate, and present solutions for improving the user experience during human-machine interaction. The design process was modelled after the so-called Double Diamond (DD) approach. The DD as defined by the Design Council [3] can roughly be divided into four phases: Discover, Define, Develop and Deliver (see Figure 2). This approach was chosen because it's an iterative process in which development is guided by the user's needs. This lines up well with the user centered theme of this thesis.

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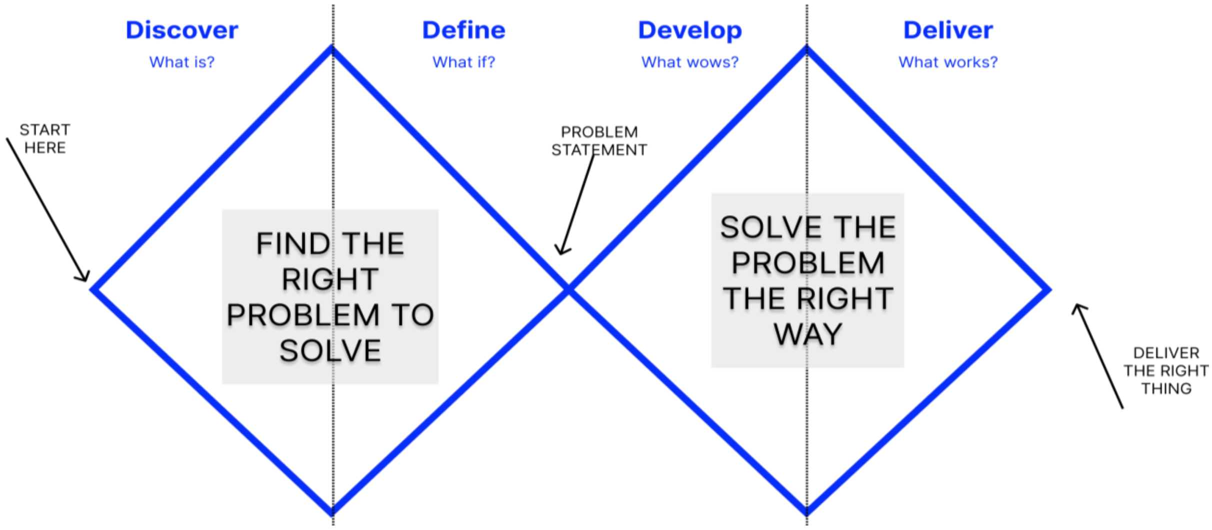

Figure 2: The Double Diamond design process. Note that the Discover and Develop phases are diverging phases that aim to gather a breadth of insights and ideas. The other two are converging phases that each aim to sort amongst and concretize the data from the previous phase. [5]

1. <u>Discover</u>
   The designer investigates the problem statement, users, and the intended product environment.
2. <u>Define</u>
   The designer analyses the information gathered during the previous phase.
3. <u>Develop</u>
   Based on the resulting analysis from the Define phase, the designer generates ideas that address the design challenge at hand.
4. <u>Deliver</u>
   The designer selects and refines the most promising concept(s), creating concrete solutions from abstract ideas.

Each phase leads to one or more so called decision points, for which user input is crucial in guiding the design process forward. It should be noted that in practice, the DD process is an iterative approach in which the designer can bounce back and forth between different phases as needed. A variety of techniques were used over the course of the project, see Figure 3.

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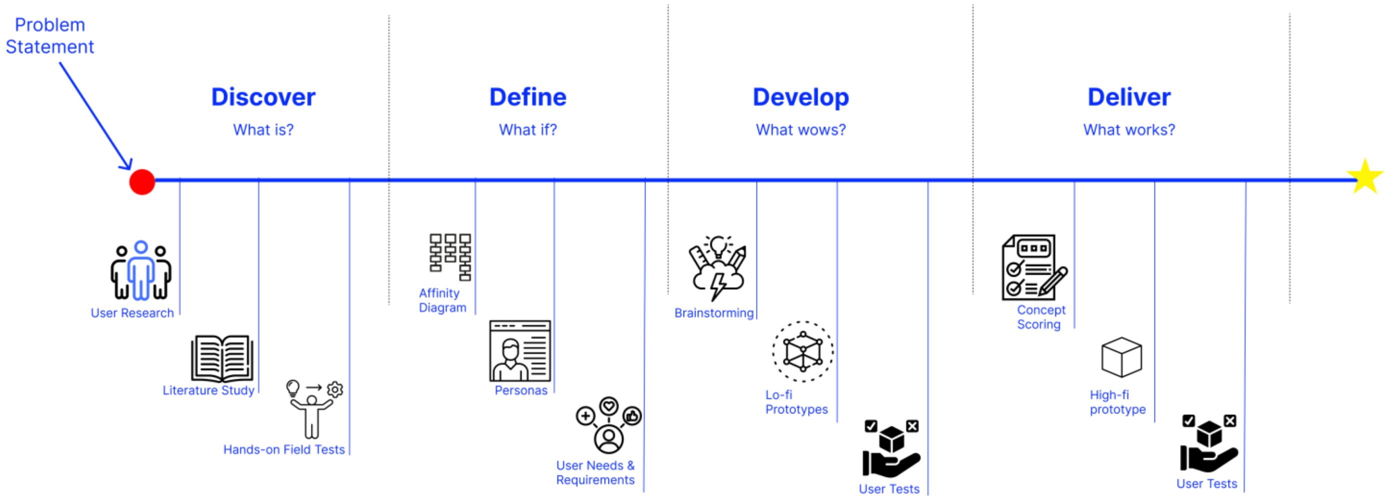

Figure 3: Overview of the techniques used in each DD design phase. While the project is illustrated as a linear process, considerable iteration occurred between different techniques in each phase as well as back and forth between different DD phases. [5]

A user centered approach was ensured by gathering continuous user input in every design phase. The reasoning behind adopting this approach, was to make sure the final product appropriately addresses an actual design challenge or need that is relevant to the users. If the product would fall short in this instance, the UX cannot be said to have been improved as a result of this design process. To avoid that trap, the work was structured in cycles of repeat iteration and evaluation, with as much user involvement as possible: by performing user tests, field observations, user surveys, and interviews. By involving different perspectives and striving for agreement in terms of framing, design decisions etc., the users and their needs were allowed to be the center of attention.

The goal of the Discover Phase was to gather qualitative data about the users, their needs, and their work environment. Since access to the end users (customers) was limited, I tried to gain an understanding of them through conducting a series of field observations and interviews with the super and expert users present at Tetra Pak. During these field observations, I got to try some of the activities myself. To corroborate the findings, I also reviewed some previous UX-studies performed at Tetra Pak. I also sought to understand the industry and competitors' solutions by conducting *competitor benchmarking*. Benchmarking was used to provide insights into the current design trends on the market and to learn about pre-existing solutions available to improve the UX for machine operators.

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The data gathered during the Discover Phase constitutes the usability evaluation which concludes Part 1 of this thesis.

Following the user research and usability evaluation conducted in the previous DD phase, the project moved onto the Define Phase. The methods used in the Define Phase were selected as ways to interpret large amounts of qualitative data and redefining it into actionable user needs and design requirements. The validity of the data was assessed by comparing data from different sources and trying to triangulate the data as much as possible. Preece et al. [6] defines *triangulation* as:

> *"[...] a term used to refer to the investigation of a phenomenon from (at least) two different perspectives".*

There are different types of triangulation techniques, but for the purposes of this thesis *methodological triangulation* was employed, meaning that the research conducting using different data techniques. During the Discover Phase, for example, data was collected by conducting field observations and user interviews, performing hands-on tests myself, as well as reviewing previous UX studies. The Define phase concluded in the creation of user personas and their corresponding user needs. The needs and requirements from different stakeholders were interpreted and summarized as a series of design requirements.

The personas and selected design requirements defined in the previous DD phase were used as the jumping off point for the Develop Phase. The Develop Phase aimed to generate a breadth of ideas and evaluate how well they fulfilled the design requirements. The Develop Phase can be said to consist of two parts: the conceptual and the concrete [6]. The conceptual part focuses on *the idea* of a design: how the product will function, look and feel. The concrete part focuses on *the details* such as specific features, mechanisms, feedback and graphics. The conceptual part included brainstorming and journey mapping techniques to generate ideas based on the design requirements, while low-fidelity prototyping and user tests were employed for the concrete part. This process is iterative by nature, as the prototyping and testing lead to new ideas and concept evolution. *Prototypes* are physical objects made to embody a conceptual idea, allowing users to interact with and evaluate the concept. *Low-fidelity prototyping* does not aim to capture the full likeness or functionality of a concept, but rather a simplified version that includes simulation of a few core features. The low-fidelity prototypes are quick and cheap to produce and modify, making

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them an ideal tool in the early stages of product development when the goal is to quickly explore a wide array of ideas.
In this project, the low-fidelity prototyping of the Develop Phase included journey mapping, sketching and simple cardboard prototypes.

The Deliver Phase focused on selecting and refining a final product based on the remaining design concepts. The concepts were evaluated based on user test data gained from the Develop Phase, and the concept that best fulfilled the design requirements was selected for refinement and a final usability test evaluation. Based on the refined concept, a high-fidelity prototype was created. *High-fidelity prototypes* are more detailed manifestations of the design concept that includes more advanced product functionality. The prototype is typically more realistic than low-fidelity prototypes regarding both look, feel and material choices. This means high-fidelity prototyping works well as a tool for refining and evaluating a final concept. In this project, the usability of the final concept was evaluated in a usability test using a high-fidelity prototype, during which target users were allowed to interact with the product prototype. The test results guided the final concept refinement, resulting in the presentation of a final product.

2.2 User Experience

The central theme of this thesis is the user experience (UX). UX is a broad term encompassing every aspect of a user's experience when interacting with a product or service, from the perceived ease of use to user engagement to visual appeal etc. The International Organization for Standardization (ISO) [7] defines UX as

> *"A person's perceptions and responses that result from the use or anticipated use of a product, system or service".*

UX design aims to affect both psychological and behavioral aspects of user interaction by designing products or services that evoke a specific experience to the user. Often, the stated design goal is to provide an interaction that is both useful and pleasurable. UX design can be applied to both digital and physical products, though it's commonly associated with the former.

It's important to note that the UX designers can't control the user's experience – i.e. their "perceptions and responses". This includes the user's

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emotions, senses, motions etc. The designer's goal should therefore be to design *for* an experience by controlling the products appearance, function etc. in such a manner that the user is invited to interact with the product in a certain way. Most importantly, the product should be designed as a direct response to certain user needs and/or challenges.

Since UX is such a broad field, it would be appropriate for designers to break it down into core aspects or subcategories. The Interaction Design Foundation [8] divides UX into three elements: Look, Feel and Usability.

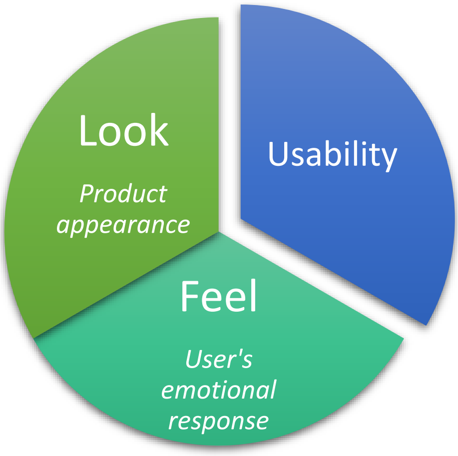

Figure 4: The 3 elements of UX design. The usability is the main focus of this project. [5]

Sometimes the terms UX and usability are used interchangeably, but this is not accurate in modern design practices. A product's usability specifically concerns the *ease of use* of a product. Usability is a big contributor to the overall user experience of a product but does not encompass the entire experience. In short, you could say that usability designers ask the question: "Is it easy to use?" while UX designers wonder: "Does it feel good?" However, it is fair to assume that improvements in usability, would also improve the user experience. Therefore, the focus of this thesis is to evaluate and – if possible – improve the usability of the CBP34.

2.2.1 **Usability**

The central aspect of this thesis is the concept of a system's usability: what affects it, how it can be improved and its impact on the user experience.

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Usability is most discussed in relation to human-computer interaction, but Szabó [9] provides a list of steps that can improve the usability of hardware equipment:

1. *Improvement and harmonization of accident investigation and reporting,*
2. *Usability tests should be applied and extended beyond normal operation, including emergency situations,*
3. *Understanding the specifics of various worker groups,*
4. *Improving user-friendliness systems,*
5. *Determination of the financial consequences of optimal HMI,*
6. *Developers, users, and suppliers must increase collaboration.*

The steps listed above put great emphasis on the importance of understanding the end users, their needs and work environment. In my project, steps number 2, 3, 4 and 6 were most applicable.
Nielsen [10] defines 5 usability components:

- *Learnability*: the user can quickly learn how to use the system.
- *Efficiency*: the user can achieve a high level of productivity when using the system.
- *Memorability*: it is easy for the user to recall how to use the system, after a certain period without interacting with the system.
- *Errors*: The user makes few errors in general, of which none are catastrophic, when interacting with the system. If an error occurs, it is easy to recover from it.
- *Satisfaction*: the user perceives the system as (subjectively) pleasant to interact with.

For a specific design project, each component should be defined in such a way that the system usability can be investigated, improved, and evaluated systematically, ideally by defining the usability component in terms of a measurable, quantifiable metric or goal. However, depending on the project, it’s not always possible to define objective metrics for comparison. If that is the case, the perceived usability should be evaluated according to the opinions or perceptions of test users. In this design process, all the previously mentioned usability components were considered in some capacity, but the focus was designing for efficiency, learnability, and user satisfaction, see Figure 5.

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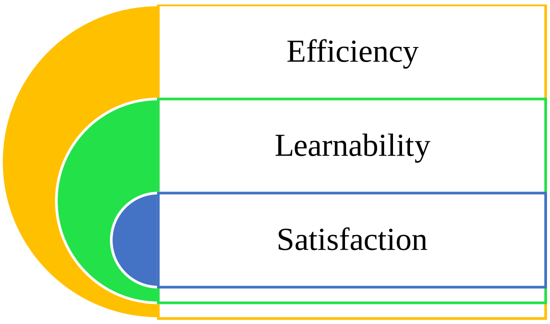

Figure 5: The selected usability components. [5]

The reasons for this choice are mainly attributed to the consideration of *usability metrics* i.e., the type of metrics used to measure each usability component.

In this case, learnability and user satisfaction were measured by gathering subjective user opinions, while the efficiency of the selected design concept was measured in terms of the time (s) it took to complete a task. The task completion time is a good way to measure efficiency, as keeping time is the key to minimize production losses in fast-paced industrial food distribution. Every second matters, as the machines handle thousands of packages per minute. Halts in production lead to lower product output and can result in large production losses, especially if the filling product consists of perishables like dairy that spoil quickly.

Since the evaluation of memorability ideally should be conducted over a longer time, it was tricky to complete within the project's relatively short time frame. The error component, while important, was considered inconsequential in relation to efficiency because fewer errors logically result in quicker task completion – and thus shorter time to complete each configuration task.

2.3 Cardboard Packer 34

Cardboard packers are a type of packaging machine typically placed at the end of the production line, when the product in question has been properly filled and sealed. The cardboard packer is used for producing cardboard boxes and packing them with finished products, readying the products for shipment to customers. The cardboard packer creates a packaging pattern (for example groups of 4x6 packages), places them on top of a flat box,

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tray, or wraparound unit (blanks) before folding the carton into the desired shape. CBP34, pictured in Figure 6, is one such cardboard packer, introduced to the market in December 2022. Currently, about 100 units have been sold to customers in Europe and elsewhere. [11]

Figure 6: View of the CBP34's pattern module (left) and tray module (right). [4]

The CBP34 is designed for relatively slow production speed and has a maximum capacity of 5 000-10 000 packages/hour (in commercial production).[4] The speed is dictated by the tray forming module, as the glue application requires a production stop for the glue to cool down and adhere the carton flaps together properly. This means the CBP34 is a so-called "index" machine, designed for constant short stops and acceleration.[11]

The CBP34 can handle a wide selection of packages with package volumes ranging from 80 ml to 2 000 ml [4], see Figure 7.

Figure 7: Package types that are compatible with the CBP34. [12]

The package dimensions and the shape of the packaging pattern determines the values for the internal hardware settings of the CBP34. This means that each time the dimensions change, the hardware settings must be adjusted accordingly. [11]

2.3.1 **Functionality**

The CBP34 is best studied by breaking the machine down into smaller modules sorted by function, see Figure 8. The machine can be said to consist of two main modules: the pattern module (pictured on the left in Figure 8) and the tray module (pictured on the right in Figure 8).

Figure 8: Overview of CBP34's main modules, split by function. [13]

The pattern module receives packages from the infeed conveyor, arranging them into groups of X by Z rows and columns. The box pusher then transfers the group onto a flat carton in the tray module.

In the tray module, the carton is folded into a tray, and the flaps glued securely around the grouped packages, a process which takes about 2.2 seconds per tray. From there, the closed package tray is discharged, ready for shipment. When operating at top speed, the CBP34 produces about 1 800 trays per hour.[11] For a schematic overview of this process, see Figure 9 below.

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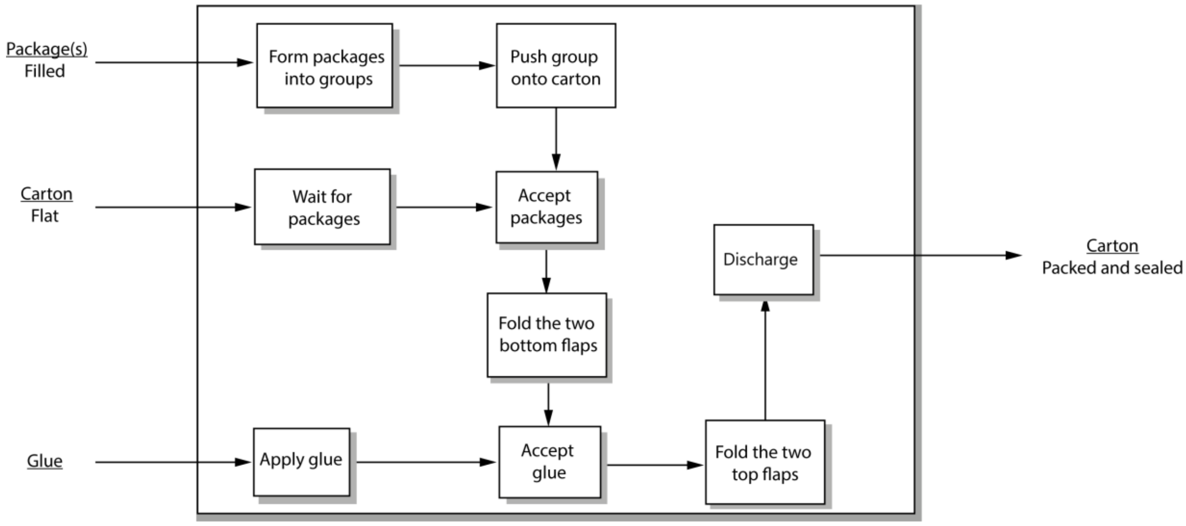

Figure 9: Functional diagram depicting the principal functions of CBP34.[5]

The machine is generally overseen by one operator per shift. The operator is responsible for performing maintenance and changeover tasks, loading blanks, overseeing production and responding to package jams. The operator is expected to be fairly independent and solve any issues quickly, as halts in production can lead to large production losses in a short time.[11]

To illustrate the great responsibility resting upon the operator's shoulders, consider the loading of blanks: The operator is in charge of keeping track of the amount of blanks (i.e. flat cartons) loaded onto the carton infeed (Figure 10), since this is not an automated feature.

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Figure 10: The Cardboard packer's tray module. The number (1) indicates the location of the carton infeed. [5]

The operator has to make sure the blanks are loaded with the right side up, as the CBP34 is not designed to handle an incorrect blanks placement. The machine itself won't raise any alarms in response to an incorrect blanks placement, but quite soon problems will arise due to the blanks not folding/gluing correctly, potentially damaging the internal equipment and/or cause package jams. [11]

This example goes to show, that the CBP34 functionality depends heavily on the human operators. This means there is a non-negligible risk of the human factor inherent in the machine design.

2.3.2 **Changeovers**

As mentioned previously, changeovers – i.e. the manual configuration of hardware settings – are a common task for CBP34 operators. For the purposes of this report, the term changeover refers only to the configuration of the internal hardware settings detailed in Figure 20 on page 35.
In CBP34, settings are typically adjusted either on a sliding scale or cranks, see Figure 11.

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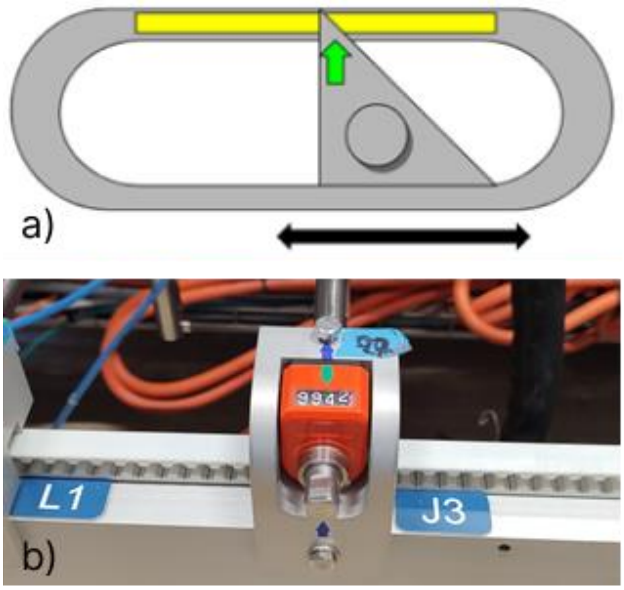

Figure 11: Depiction of common setting's mechanisms. a) Sliding mechanism. [5] b) Crank mechanism. [14]

About 50% of the total 55 hardware settings in the machine are slider-based. Both mechanisms are flexible in terms of the adjustment range.

Changeovers are primarily required as a response to changed package dimensions. These changes in dimensions can happen due to many different reasons, as illustrated in Figure 12.

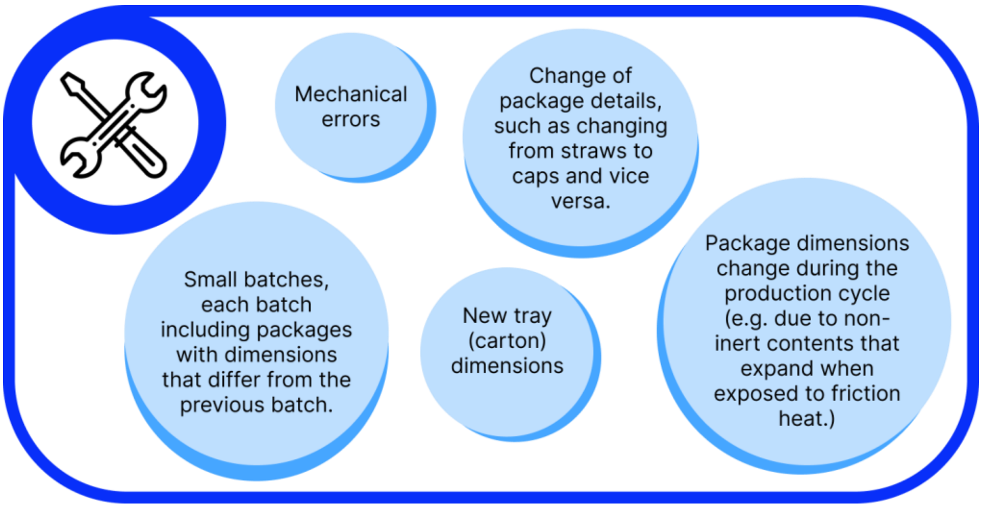

Figure 12: Some common causes of dimension changes. [5]

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As the majority of the changeover tasks are done manually, the machine architecture has a big impact on the operator's work and user experience. Knowing this, Tetra Pak designed the CBP34 to be considerably less compact than its predecessor, giving the operators easier access to internal components. Generally, the mean time of failure recovery is estimated to be less than 1h 30 minutes, which is better than for the predecessor.[11] Still, changeovers typically take up a substantial amount of resources in terms of staff, time and productivity:

> *"Changeovers can happen 1-2 times per 24 hours. Each changeover takes 30-60 minutes depending on the operator's experience."* - *Table 26*

While the machine flexibility allows for a wide range of setting's values, changeovers are commonly made only between 2-3 different values. In this report, I've chosen to refer to these settings as "standard settings" or "standard cases", and the values as "standard values".

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Discover Phase

The Discover Phase aims to create a good understanding of the cardboard packer machine, the users, and their work environment. To be able to triangulate the data and validate the insights gained, the data was gathered using several different methods. The gathered data is the basis for the usability evaluation and the defining of user needs and project requirements in the Define Phase.

2.4 User Research

The user research consisted of field observations, informal interviews, competitor benchmarking and reviews of previous internal user studies.

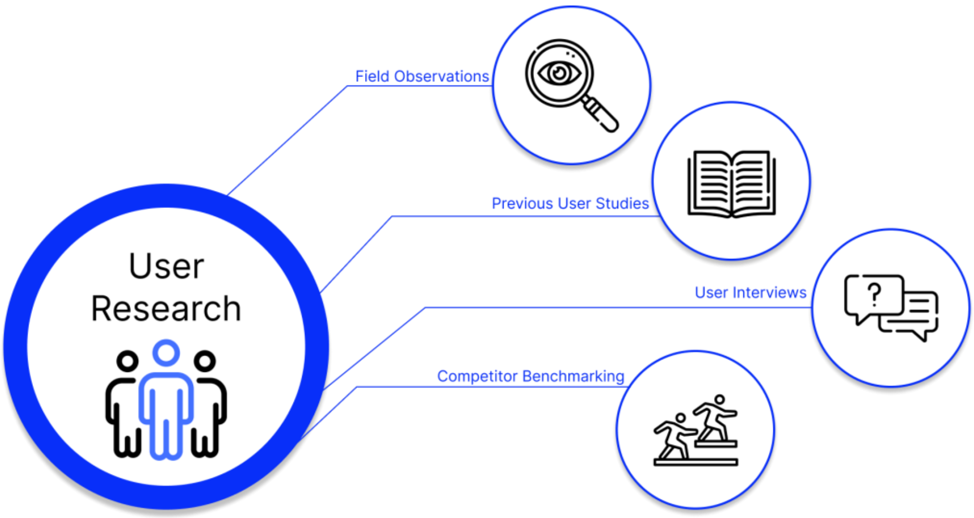

Figure 13: User research methods. [5]

Gathering information from different sources was done in the hope of being able to triangulate the data and get as accurate an understanding of the situation and available design opportunities as possible.

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2.4.1 **Field Observations**

The field observation consisted of two sessions (1-1,5 hours each) of direct observation during which the users were allowed to perform their tasks unhindered. The researcher took notes and asked questions for clarification or insight into their thought process throughout each session. The users observed were part of a team of technicians (1 super user and 2 expert users) at Tetra Pak's R&D site in Lund. The first observation took place during the final stages of a complete re-assembly of CBP34 after performing major maintenance. The second observation session took place during the final stages of CBP34's motor and control systems' calibration.

2.4.1.1 Changeover Calibrations

Configuring each changeover setting is usually an iterative process, as depicted in Figure 14. This is because the high measurement accuracy necessary requires repeated setting calibrations.

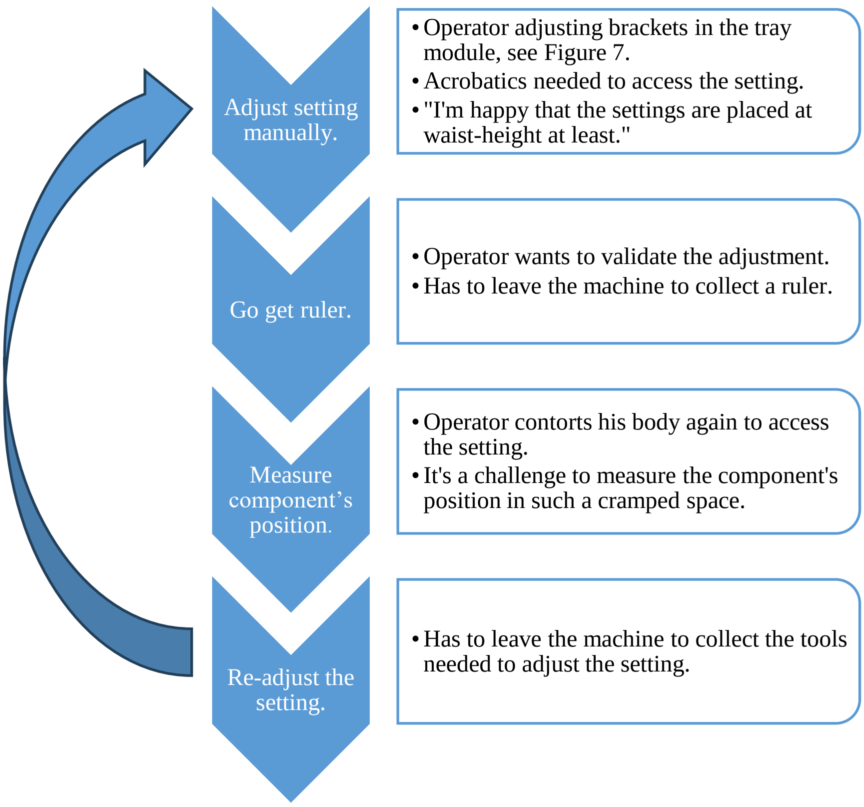

Figure 14: Action sequence of a typical configuration scenario. [5]

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As stated previously, hardware configurations are typically made between 2-3 standard cases. The configurations are performed due to a variety of reasons, as the superuser stated [11]:

> *"We have to configure the CBP34 in response to changed package or tray dimensions, or depending on the filling product."*

Water contents, for example, act like inert fluids, i.e., their material properties (viscosity, volume) are not affected by external conditions. Thus, heat or friction doesn't affect the package dimensions. However, juices and dairy products such as chocolate milk might swell during exposure to friction heat generated during conveyor transport, thus changing the package dimensions. To counter swelling the package can be left partially unfilled, but this can introduce new problems because the top centimeters of air volume make the packages behave differently. [11]

The changes in dimensions due to material properties are miniscule, but even a setting's error of a millimeter can have great consequences for production [15], as detailed in Figure 15.

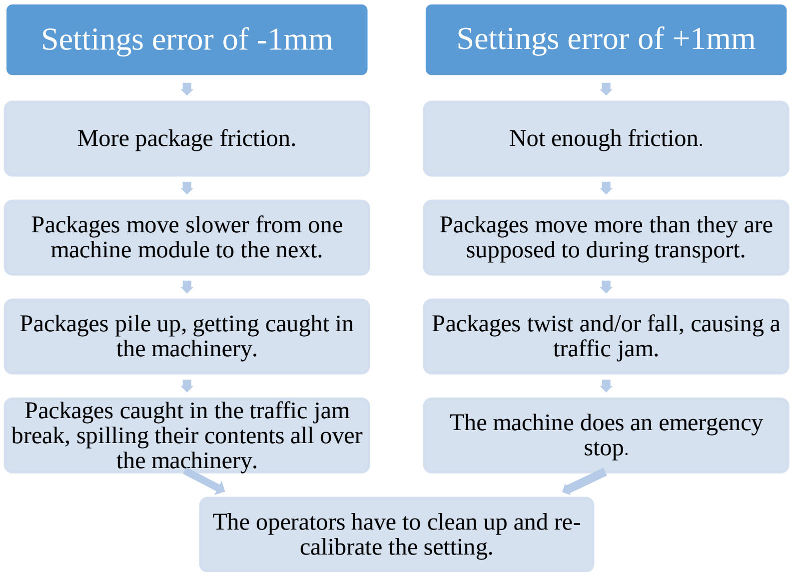

Figure 15: Setting's error scenarios.[5]

The operator states [11]:

> *"Water is not harmful, but milk, juice etc. can damage the machinery and must be cleaned up right away. Liquids get into every little crook and cranny; it can take forever to clean it all up and restart the production line."*

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The importance of accurate settings is clear, but the task is complicated by the design of the adjustment mechanism itself. On one hand, the sliding scale allows for great flexibility in terms of parameter range, which affords the customer more freedom to choose from a wide range of package types and dimensions. On the other hand, the flexibility slows the operators down due to the increased need for extensive calibrations to guarantee setting's accuracy.

While most of the relevant settings are located above thigh-height, the ergonomics are not always optimal, see Figure 16. The space is relatively cramped and the operators have to reach the settings from strange angles and at inconvenient depths. [15]

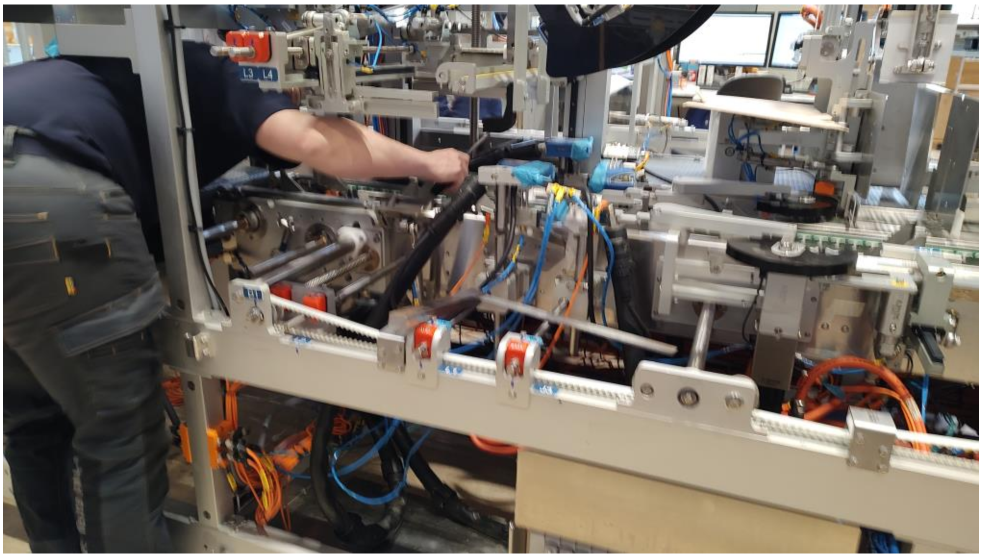

Figure 16: Staff member checking the alignment of a metal bracket. [14]

2.4.1.2 Signs and Icons

The CBP34 contains a large number of components that are hard to keep track of even for seasoned operators and technicians [11]:

> *"It's hard to identify/locate every single component. We put extra stickers on with their component ID".*

As navigation support, a set of signs and labels have been implemented to indicate the location of crucial interaction points for settings configuration. The set consists of a blue ID tag (format: letter-character), a blue arrow indicating the intended interaction point when locking/unlocking the

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setting, and a green arrow indicating where to read the current position on a scale, see Figure 17.

Figure 17: Example of interaction point C7.[14]

The icons and other signifiers used for navigation in CBP34 is listed in Table 1.

Table 1: Navigation icons and other signifiers in CBP34.[15]

Name	***Signifies***	***Visual description***
ID Label	Depicts the component ID number.	Blue square with white text.
Interaction Arrow	Indicates the setting’s lock/unlock feature.	Blue arrow pointing to the interaction point.
Read Arrow	Indicates where the setting’s value is read from.	Green arrow pointing to the setting’s scale.
Setting’s Scale		Yellow measurement scale.

Worth noting is, that neither the shape nor size of the arrow icons are consistent. Furthermore, identical icons can mean different things in different machines on the same production line [11].

One example are the blue and green arrows previously depicted in Figure 17. The arrow icons look very similar but indicate different actions. As stated by Nielsen [10], the most effective types of icons are those that depict both the concrete object and the abstract representation:

> *“The best icons show both the concrete object being operated upon (for example a sheet of paper) and an abstract representation of the operation (for example an arrow). Icons with only one these elements are harder to understand, as are icons with even more information.”*

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Overall, the visible signage in CBP34 is rather abstract i.e., consists mainly of labels and icons that lack clear symbolic connections to the surrounding components. Some of the cardboard packer's icons afford user action with a responsive visual outcome, such as the crank-based settings. Application of the abstract arrows work better in these cases because the users don't have to guess the icon's meaning when user input prompts immediate output. In other places such as for the A6 setting in Figure 18, user interaction results in a nonvisual outcome.

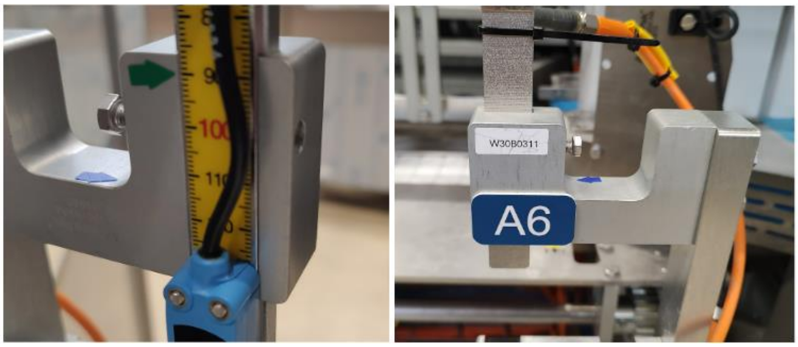

Figure 18: Signage by the A6 setting. Front from the user's point of view (right). [14]

The labels and icons are placed all around the setting; for the inexperienced user, it's hard to tell where the arrows are located.

In an effort to make the work more convenient, some settings have been adorned with mm-scales. This gives some clearer visual outcome in response to user interaction but is not implemented consistently and not always in ways that benefit the user. The placement of the yellow scale in Figure 18 makes it hard to adjust the setting and read the value on the scale at the same time because the scale is placed *behind* the component.

Sometimes, it's not immediately obvious which point of the component is supposed to be aligned with the numbers on the scale. At other times, the icon placement makes it unclear which set of arrows belong to which ID label.

To complete their tasks more efficiently, the operators require access to additional information regarding machine parts and machine functionality. The information is distributed in different forms depending on the level of detail, as summarized in Figure 19 below.

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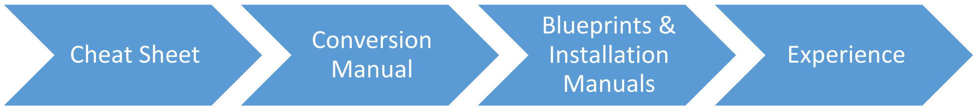

Figure 19: The databank levels, ordered by level of complexity from least to most. [5]

The simplest databank is the so called “Cheat Sheet”, which functions as a quick reference guide during changeover between a handful of standard use cases, see Figure 20. The Cheat Sheet was developed in response to customer complaints, as stated by the super user [11]:

> *“We created a cheat sheet and a conversion manual that list each step in the configuration process with short descriptions on how to do them. The customers complained that there are so many components and steps involved that it’s hard to remember.”*

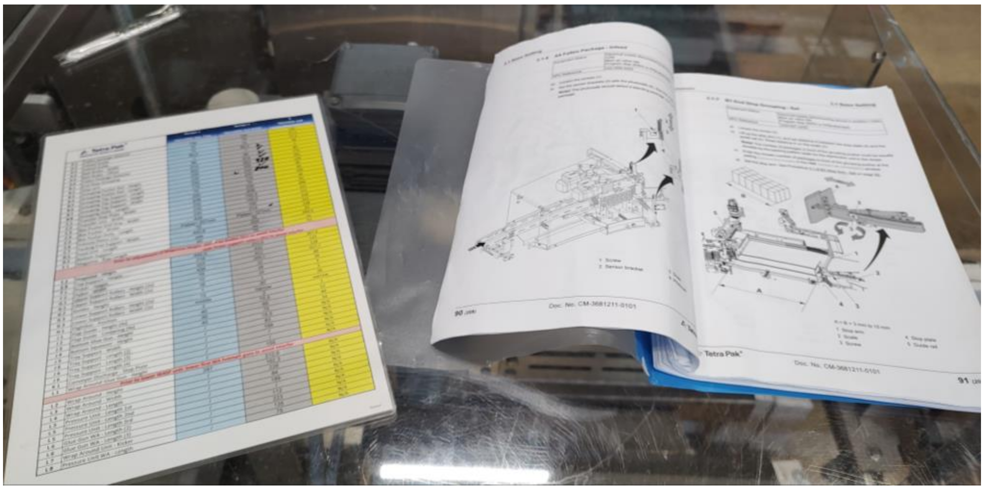

Figure 20: The Cheat Sheet (left) and Conversion Manual (right) of CBP34.[14]

The cheat sheet consists of four main columns: the changeover settings listed in task order, and each settings’ recipe parameter for three standard cases. Next databank level is the so called “Conversion Manual”, which provides a more detailed description of each changeover step.

2.4.2 **Previous Studies**

To gain further insight into the user experience of Tetra Pak’s customers, previous user studies [16] performed internally at the company were reviewed. The studies were mainly used to corroborate the researcher’s own insights obtained from the field studies previously described in section

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2.4.1. However, due to these studies being considered trade secrets most of the details had to be redacted from this report.

The studies were based on interviews with staff employed by two customers located in Europe, aiming to gain further insight into the users' perceptions of working with Tetra Pak machine systems. For the purposes of the thesis, the main focus was on the study material concerning the people interacting physically with the machine on a daily basis, i.e. the operators and maintenance technicians. None of the interviewees in the studies reported working with the CBP34 specifically, but their experiences are valuable for supplemental information about the users and the operator's role, and for comparisons of the CBP34 operators' user experiences.

It's clear that the operators and the maintenance technicians share some struggles regarding the tasks related to the Tetra Pak machines, chief among them accessibility and workflow inefficiencies. It's worth noting that the operators are especially affected by issues relating to physical strain, frequent changes of machine settings as well as safety issues. The maintenance technicians are heavily affected by the inconvenient safety system task flow and troubleshooting issues.

As previously noted in section 2.4.1, the operator's role is to ensure smooth production. The operators prepare, run and monitor production, ensuring the machines on the production line run smoothly, for example by making sure that production materials are refilled, cleaning the machinery and conducting weekly maintenance. The operators also act as first responders to any production related errors or emergencies that occur during their shift.

The operator spends the entirety of his or her time on shift working directly with Tetra Pak machines on the production floor. The operator rarely moves to other areas to the factory, but rather calls for assistance from the maintenance technicians stationed elsewhere in the factory if necessary.

Most of their shift revolves around tasks such as

- Operating the machines
- Documenting and reporting progress
- Conducting quality checks
- Performing relatively non-complex technical improvements.

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The previous UX studies[16] support these conclusions, and further emphasize the importance of the operator's independence: The operators are required to be able to work independently and not hesitate to take the initiative if the situation calls for it, as issues in the production line might arise suddenly and have to be solved quickly to avoid major losses due to production shut-down. The operators generally like their independence and the variety of tasks but dislike the complicated cleaning procedures and production stops.

The maintenance technician's role is to ensure that the machines on the production line are functional and in good condition. This requires technical expertise and hands-on machine experience, as well as the ability to solve problems in the moment.

The maintenance technicians spend a lot of their time on shift visiting the warehouse and the production floor, responding to urgent technical issues, and conducting planned maintenance. Therefore, the maintenance technician frequently comes into close contact with Tetra Pak machines. Each maintenance technician is responsible for several machines. The environment is intense due to the challenges arising from monitoring highly efficient industrial production and adhering to food safety regulations. As a result, the technician might be flooded with a lot of urgent tasks to complete within a short time frame – it's not surprising that the maintenance technician reports disliking stress.

2.5 External Benchmarking

After a review of the main competitors on the market for food processing and distribution equipment, a few trends regarding usability design emerge. Design solutions for:

- Decreasing changeover time.
- Improved ergonomics.
- Improved task workflow.

2.5.1 **Competitors**

Agents within the food and processing industry are interested in decreasing the changeover time. Some common solutions are the implementation of

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settings accelerators, pre-configured parts, quick release settings and designs to maximize easy component access for operators, see Figure 21.

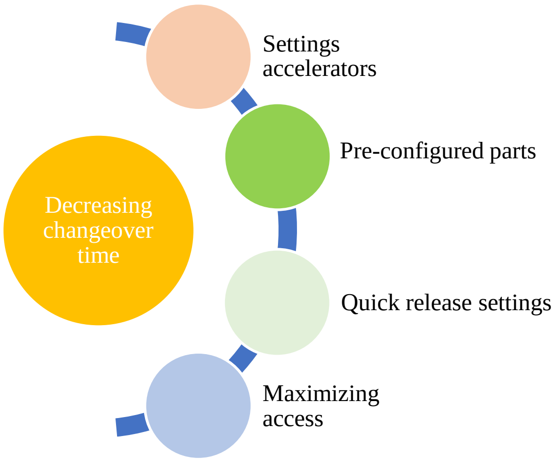

Figure 21: Design trends for decreasing changeover time. [5]

Starting from top to bottom, settings accelerators are design solutions intended to streamline and speed up the manual configuration process of settings during changeover. Some common settings accelerators are described in Figure 22.

Figure 22: Some settings accelerator solutions. [13][17]

Another way to increase the changeover, is exemplified by Somic Packaging's Changeover Guide, see Figure 23.

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"During operation, the panel shows all relevant information. In the event of a stop, the cause and steps for error correction are displayed in a clear and easy understandable fashion, this minimizes downtime."

Figure 23: Somic Operation screen. [18]

The step-by-step changeover guide is available in both printed and digital form, supported by clearly visible signage that helps the operator complete changeover tasks easily and quickly.

A notable example of pre-configured parts, is the plug-and-play concept developed by Schubert, see the image to the left Figure 24. Pre-configured components for each standard setting allows for quick and easy change of components with minimal additional tweaking of the settings after changeover.

Figure 24: An example of plug-and-play solutions (left). [17] Somic Quick Change Technology (right). [18]

Quick-release of hardware settings is another interesting design trend. Settings that can be unlocked, adjusted and locked again quickly, with a minimal number of interaction steps, decreases the total changeover time significantly. One such example is the Quick Change Technology promoted by Somic Packaging, see the image to the right in Figure 24.

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Maximizing easy component access for the operators is another focus for many competitors. Some common solutions are pictured in Figure 25.

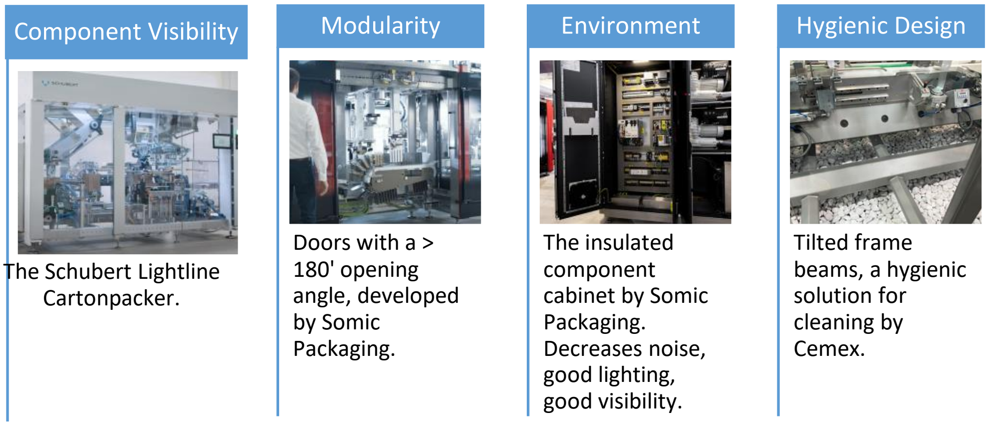

Figure 25: Common solutions for improved component access. [19], [17], [17], [13]

2.5.2 **Other Solutions**

Quick, reliable settings changes is not a need unique to the food distribution industry. Briefly scouring the solutions applied to solve similar challenges, generated new insights from agents active in the car industry, the metal and the woodworking industries.

Car seat displacement (slide rail) mechanisms are typically used to adjust the horizontal position of a common car seat is a type of slide rail with position anchor points distributed in discreet increments, see Figure 26. The adjustment distance is generally 0-100 mm.

Figure 26: Car seat adjustment mechanism. [20]

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Another interesting product is Woodpeckers' Super track flip stop, which enables the users to accurately stop a wood cut where needed, see Figure 27. When motion is necessary, the stop can be flipped out of the way.

Figure 27: Woodpecker's super track flip stop. [21]

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3 Define Phase

During the Define Phase I sought to analyze the gathered data during the Discovery Phase. The resulting usability evaluation concludes part 1 of this thesis. Based on the previous research, several insights relating to the users and their work environment were gained. These insights were used to define the target users and their needs, and to identify available design opportunities. The resulting project requirements are the basis for the Development Phase.

3.1 Usability Evaluation

The user experience of a product is subjective, but can be broken down into objective attributes, such as the usability components depicted in Figure 28. The usability of a product affects many aspects of the man-machinery interaction (MMI) like safety, ergonomics, and satisfaction.

Figure 28: The five usability components. [5]

The goal of the usability evaluation was to gain a deeper understanding of the MMI and the operator's work environment. The usability must be evaluated from the user's point of view i.e., the level of usability depends on the selected target user!

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3.1.1 **Target Users**

The target users of the cardboard packer are the machine operators interacting with the machine daily. The operators are a diverse group of people, both in terms of age, sex, nationality and level of experience. To better represent of the personalities and needs of the target group, the operators were reinterpreted as two personas, see Figure 29.

The personas, M and S, each represent a subset of the target user group. The main feature separating the two is the difference in user expertise. M is a novice user with limited cardboard packer experience, while S can be considered an expert user.

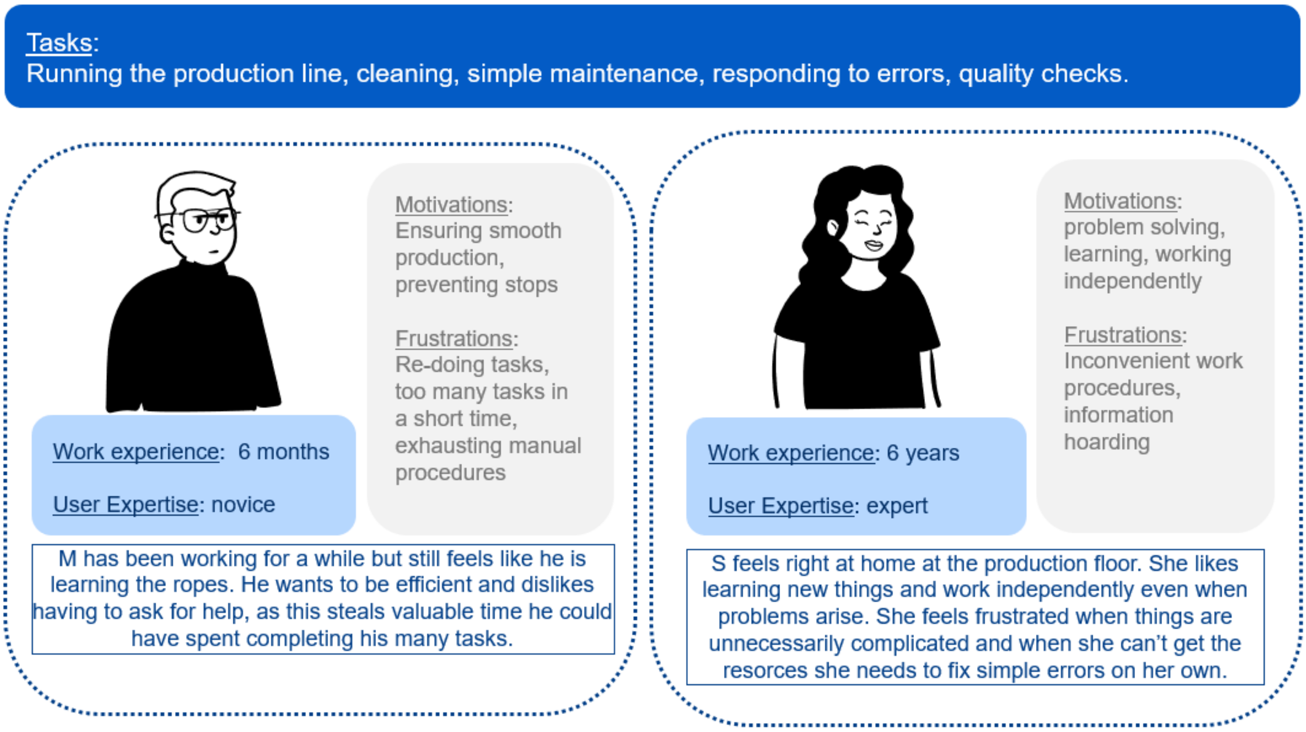

Figure 29: User personas based on insights from the user research. M and S have the same work tasks, but have different levels of work experience, motivations and frustrations. [5]

Their assignment is to run the production line, ensuring smooth production with minimal interruptions. Usually, there is only one operator working each shift. Since they are under pressure to make sure there are no – or at least very *short* – interruptions in production, the operators are highly motivated to solve any issues on their own.

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The operators have limited access to detailed technical information about the cardboard packer and are often dependent on maintenance technicians or more experienced colleagues to solve any problems that occur. However, technicians or experienced colleagues are not always available, which creates a lot of stress and means that the operator's own experience and abilities are very important in order to succeed at their job.

The operator's work environment is intense, with many tasks to be done in a short timespan on a fast-paced industrial floor. The operator's day consists of a lot of repetitive tasks that require intense physical labor, especially during changeovers. This process is complicated by the complex workflow and limited range of movement in the machine. The current workflow is oftentimes perceived to be unnecessarily complex and unintuitive. Each task consists of numerous steps that are hard to remember in order. Communication is mainly verbal, which means the operators must remember a lot of information, for example regarding task order, setting's values etc.

The key points based on the analysis of the target users can be seen in Figure 30.

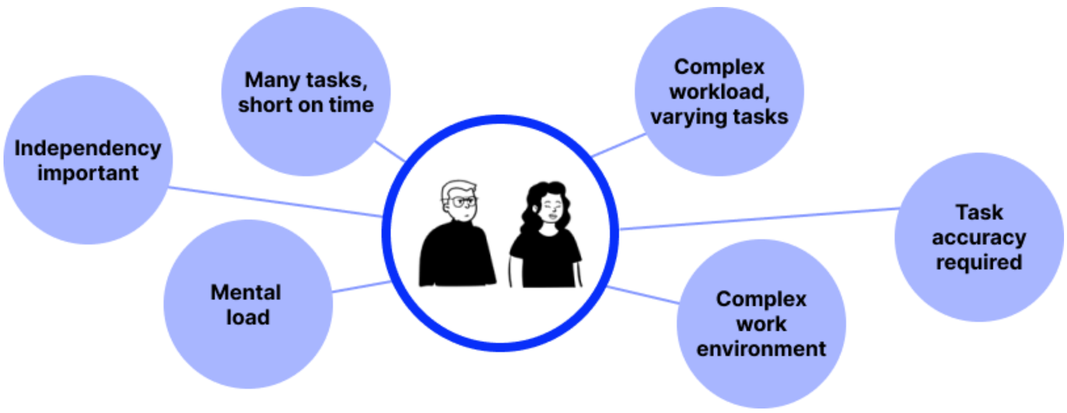

Figure 30: Key points from the target user analysis. [5]

3.1.2 **Evaluation**

Having defined the target users in the previous section, the cardboard packer's usability could be evaluated. The cardboard packer is designed to be a "one size fits all" machine that offers maximum flexibility in order to meet the demands of a diverse customer base. Some customers run short

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product cycles with different package dimensions that require a lot of hardware configurations, while other customers hardly use different packages at all. The range of compatible package dimensions is wide as well.

The “one size fits all”-approach provides a lot of flexibility, but flexibility can be a double-edged sword. It’s clear that a lot of customers find the cardboard packer *too* flexible and wish for more customization options regarding hardware and user manuals. The anecdotal tales of users “hacking” the machine themselves are many: unauthorized disassembly of undesirable modules/components, disconnection of security measures for convenience’s sake etc. Maximum flexibility restricts accessibility when the staff is unable to take shortcuts for routine tasks such as cleaning and maintenance. High levels of flexibility also impact machine navigation, creating a flood of information that the operators must wade through when performing even the simplest tasks.

Another challenge is the operators’ varying degrees of experience. The cardboard packer is intended to be operated by people who are highly trained but depending on the customer and the location, it’s not unheard of that operators are put on the production line after only a short introduction. (This isn’t necessarily a problem for Tetra Pak, but it could be argued that it’s in the company’s interest to make the operation as easy and intuitive as possible.)

Considering all this, it’s arguably evident that the full range of human-machine interactions have not been fully considered during the design of the cardboard packer. This includes MMIs during “normal operation” as well as MMIs during more “extreme” events. The “extremes” range from benign errors like damaged packages to more serious events like package jams and emergency cleaning. The negative impact on the user experience can be summed up in four general areas of improvement opportunities, see Figure 31.

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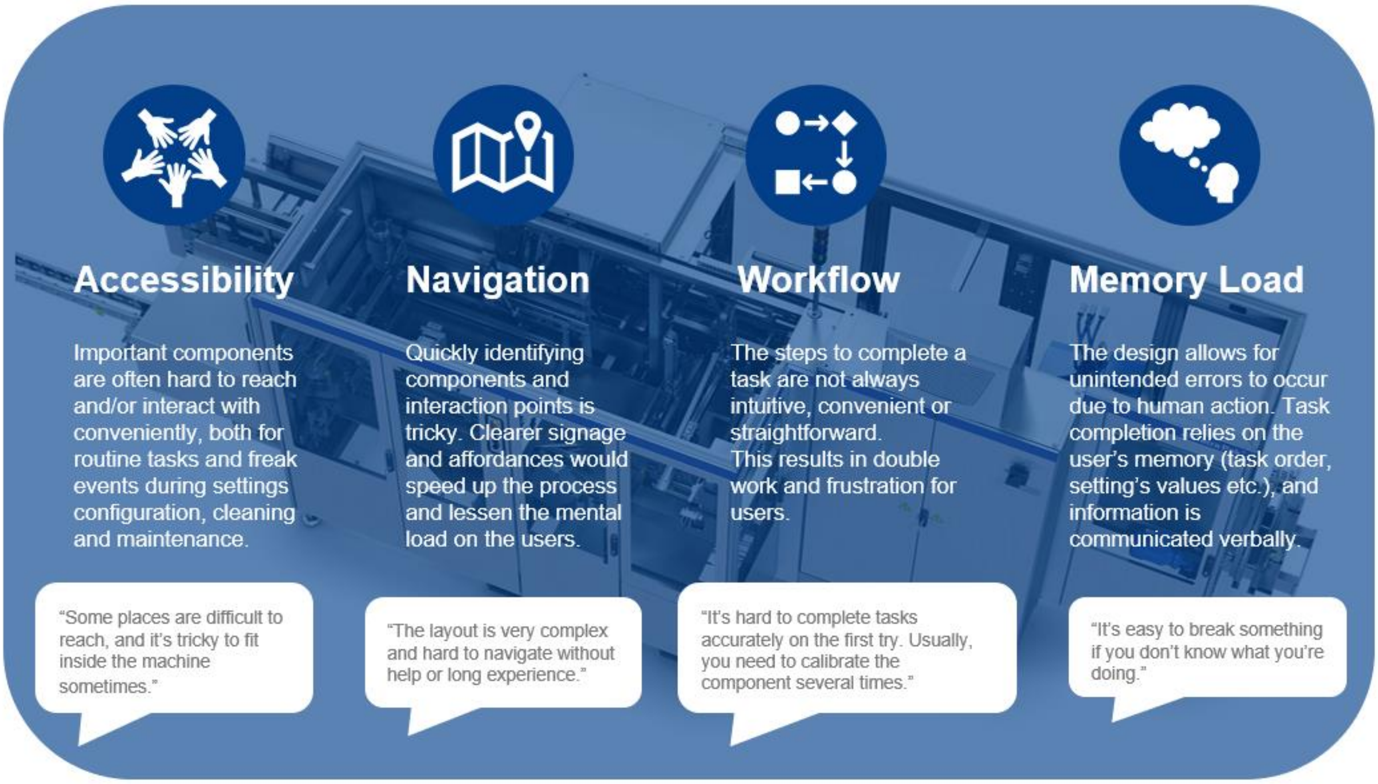

Figure 31: Main themes of the identified pain points. The themes emerged as a result from an affinity diagram of the user research input. [5]

A deeper dive into each area is available in the sections *Memory Load*, *Accessibility*, *Navigation* and *Workflow* below. For a detailed summary of the input and corresponding insights, see Table 26 in Appendix.

How do these areas impact the cardboard packer's usability? Overall, there are opportunities to improve all five aspects of usability regarding changeovers, see Table 2.

Table 2: A general evaluation of the cardboard packer's usability during changeovers in terms of learnability, efficiency, memorability, errors and satisfaction.

Learnability	*Efficiency*	*Memorability*	*Errors*	*Satisfaction*
The learnability is relatively low, since the target users are required to attend special training to be able to operate the cardboard packer.	The changeover procedure is quicker for the CBP34 than its predecessor, but complete changeover still require substantial amounts of time.	The memorability is relatively low. The navigation and task order is complex, with users asking for more detailed changeover manuals.	The margin of error is small, and the settings' flexibility negatively impacts the ability to complete accurate configurations on the first try.	The users perceive the cardboard packer as frustrating and unintuitive to interact with. Unauthorized "hacking" of the hardware is common.

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3.1.2.1 Memory Load

The cardboard packer is an advanced machine that is difficult to operate for the uninitiated, with complex changeover procedures:

> *"Operating CBP34 requires a high level of skill (above average). [...] Operator training is often done by TP staff while they install the machine at the customer's site. This means there is not a lot of time to teach the customer how to configure CBP34, especially if the customer's staff are not already highly trained."* – Table 26

Therefore, the overarching design goal should be to facilitate operators to be able to understand how to handle the CBP34 without a lot of special training.

Clearly, the operators have an incredibly important role in making sure the CBP34 runs smoothly. In general, the customer's operators have minimal technical support available if problems arise on the field. The time pressure and lack of continuous support mean that the operators have to do a lot of quick problem solving on their own, as any halts in production might lead to production losses. However, the machine allowances and information available could be better designed to support the operators in these tasks. Overreliance on the operators' own memory creates an unnecessarily large error risk due to the human factor, especially considering the high level of task accuracy required for successful changeovers:

> *"The margin of error is small, increasing the necessity of calibrations. Even 1 mm out of alignment can stop production."* – Table 26

On first sight, the full extent of the memory load resting upon the operators might seem elusive, but a closer inspection shows there are several things the operators need to keep in mind, see Figure 32.

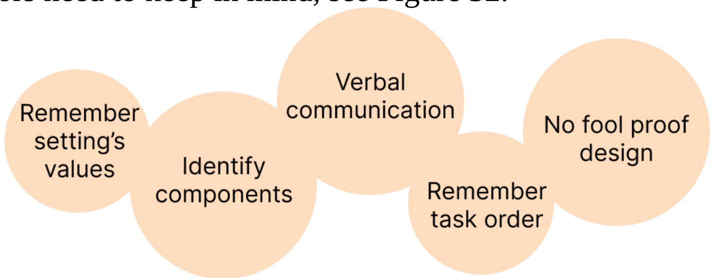

Figure 32: Areas contributing to the operator's memory load.[5]

Mistakes happen when recipe parameters must be calculated/measured manually by staff, and information is passed on verbally. Lack of simple, standardized procedures and reliance on verbal communication can cause confusion, leading to mistakes during changeover.

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3.1.2.2 Accessibility

The completion of changeover tasks is affected by accessibility limitations. Changeover tasks are physically demanding, due to both environmental and design factors, see Figure 33.

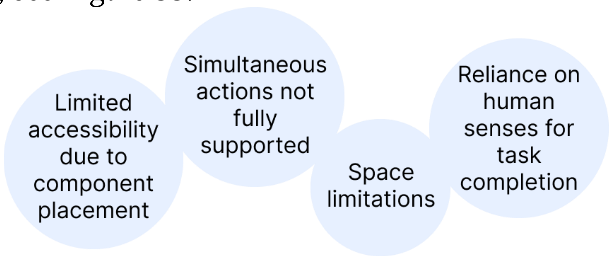

Figure 33: Insights related to ergonomics.[5]

The operators and maintenance technicians all explained that their tasks often require them to interact closely with the machine. However, they felt the accessibility was limiting their success:

> *"Some places are* ***difficult to reach*** *when changing the product sizes."* – Table 26

Based on these statements, it can be surmised that there are several instances of systems not having been designed with the users' experiences in mind.

The space to work is cramped and full of awkward angles, resulting in strain and slower work. This increases the importance of a smart component layout, which the machine designers seem to have taken to heart:

- Most settings are placed above thigh height.
- Most of the wiring, motors etc. are placed below thigh height, in a protected compartment.
- Good component visibility (good lighting, generous windows).
- The main machine architecture is split into two modules, see Figure 6. The modules are accessed on the opposite hand side from each other. The split architecture aids navigation and gives easy access.

Further internal modularity would be helpful but would require extensive modifications of the current machine architecture. Designing for improved modularity should be implemented early in machine development.

However, the layout is not fully adapted to facilitating efficient completion of changeover tasks: Despite thoughtful component placement in the vertical direction, the horizontal placement and the operator's limited range of motion have not been fully taken in consideration. This has a negative

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impact on the component accessibility, resulting in settings that are hard to reach.

The accessibility is further impacted when task completion requires the operators to perform multiple simultaneous actions, such as checking the component alignment by eyesight while also bending over to manhandle the component(s) in question. When inconvenienced by machinery not optimized for their daily tasks, the maintenance technicians are inclined to find their own solutions. "Hacking" the hardware by removing or disconnecting certain features is professed to be common, something that was also noted during the researcher's own field interviews. In short, the machine system is not designed to be foolproof nor customizable to accurately meet the customer's unique requirements.

3.1.2.3 Navigation

The navigation is another important area which mainly concerns signage system and availability of machine documentation, see Figure 34.

The technicians wish for the Tetra Pak equipment to be designed to work "universally" [16], mainly in terms of software. It can be argued that the same should be said for the hardware as well – the staff working with different brands of machines must learn how to operate them all intimately. Ensuring good learnability and memorability in the hardware structure will benefit the overall workflow and work environment.

The access to detailed machine related information is another point of contention. Currently, the operators' ability to navigate the machine layout requires access to additional information, as some components lack identifying features:

> *"Identifying the components can be tricky. We run back and forth between manuals, blueprints, and the machine. "*– Table 26

However, often the operators must rely on their own memory and experience to complete the changeover, since the cheat sheet and other manuals do not always reflect reality. For example, the order of configuration steps listed on the cheat sheet can differ from reality.

> *"You learn eventually when the order has to be changed. […] It's easy to break something if you don't know what you're doing."* – Table 26

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Clearly, signage is instrumental for supporting users during changeover. Its importance is further emphasized considering that the users have reported having troubles navigating the machine layout, as exemplified by the user statement:

> *"In response to customer complaints, we've added labels to help identifying interaction points."* – Table 26

The internal environment in CBP34 is largely monochrome and consists of many components, making it hard to get a good overview of the layout. Properly applied signage is therefore key to lessen the mental load on the human operators. To stand out in such an environment, good signage visibility should be a key concern for the machine designers. Currently, a preliminary signage system has been implemented in CBP34, as exemplified below:

> *"In response to customer complaints, we've added measurement scales to make it easier to adjust each component properly."* – Table 26

The implemented signage allows users to complete changeover tasks more efficiently. This is a good step when facilitating human-machine interactions (and thus improving the user experience) and should be embraced more fully.

However, the shape, color and placement of the signs is not consistent. This causes some unnecessary confusion, as the operators are forced to remember the significance of all sign variants. The placement of the signs in places where the settings are close together is not always clear, which sometimes makes it difficult to discern which sign belongs to which setting. Furthermore, the signage system is not consistent across different Tetra Pak machines either. The best option would be to standardize the signage across the entire production line. The next best option is to make sure the signage is as simple and clear as possible, which is the focus selected for this project.

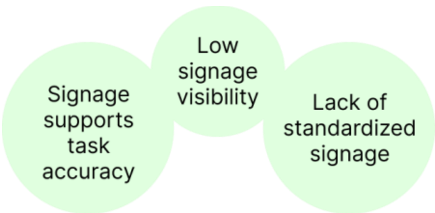

Figure 34: Insights related to signage.[5]

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3.1.2.4 Workflow

It is apparent that the operators perceive the work environment as fast-paced and stressful, with many tasks to complete in a short amount of time:

> *"Often we have **many small batches** with different products; therefore, there are **a lot of different small aspects and settings** that can cause issues (e.g., different ingredients, packaging materials, temperature parameters)."* – Table 26

Changeovers are time consuming due to the large number of steps involved. If multiple actions are required to configure one setting, it increases the work input required when multiplied across the entire machine. The perceived inefficiency inherent in the workflow, leads to a lot of user frustration as pictured in Figure 35.

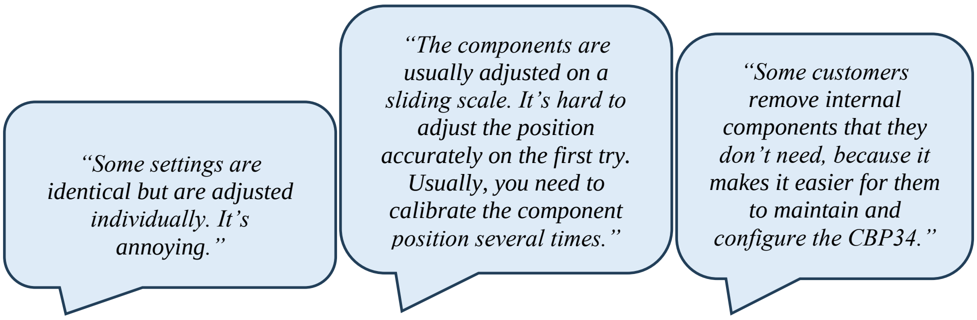

Figure 35: Common sources of user frustration.[11]

The frustrations can be summarized into five insights, see Figure 36. In some instances, identical settings must be manually adjusted individually. Another issue is that the component design negatively impacts the operators' ability to configure the component on the first try.

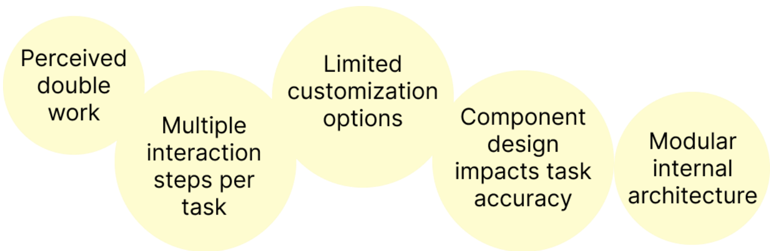

Figure 36: Insights related to workflow.[5]

In short, the users find certain aspects of the machine layout unnecessarily complicated, as exemplified by the last statement in Figure 35. This leads users to feel compelled to simplify the layout to make their work easier.

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> *"You can just take away two screws and then you do not get the door alarm. Sometimes an easy fix like that could allow for continuing the work faster."* – Table 26

It can be argued that the issue is not that the users *modify* the machine architecture on their own, but that they *feel compelled to*.

3.2 Clarifying the Problem

The general usability evaluation in section 3.1 provides a broad understanding of the level of usability of the cardboard packer. For the second part of the thesis – the development of solutions to improve the cardboard packer's usability – the scope of the thesis had to be narrowed down. The new scope must contain a description of the problem at hand and define what will be developed.

To do this, the problem space and the target users were explored in more depth. The pain points identified in the usability evaluation were sorted into an affinity diagram, see Figure 37. The pain points represent important aspects of the man-machinery interactions (MMI:s) from the point of view of the operator personas described in section 3.1.1.

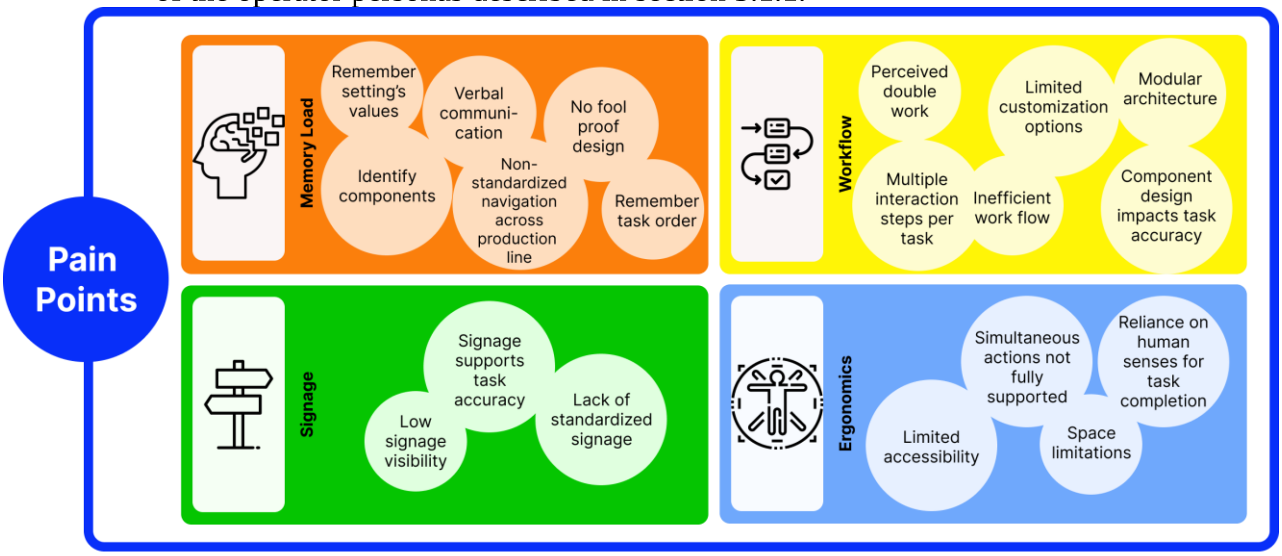


Figure 37: Affinity diagram of the pain points identified during the usability evaluation. The pain points concern the operator's memory load, workflow and ergonomics as well as the non-standardized machine signage.[5]

General

Some of the pain points occur as a result of human limitations, while others are connected to the machinery itself.

The usability evaluation (and the resulting pain points presented in Figure 37) were based on a more general understanding of the changeover process. To gain a deeper understanding of the user's workflow, the task of configuring a single setting was analyzed, see Figure 38. The task analysis investigated the *triggers* that incite changeover, the *desired outcome* (i.e. how/when the operators know that the task is complete), the *base knowledge* that the operators need to complete the task, the *required knowledge* that the operators need before starting the task and what types of *artifacts* (tools) that are required to complete the task.

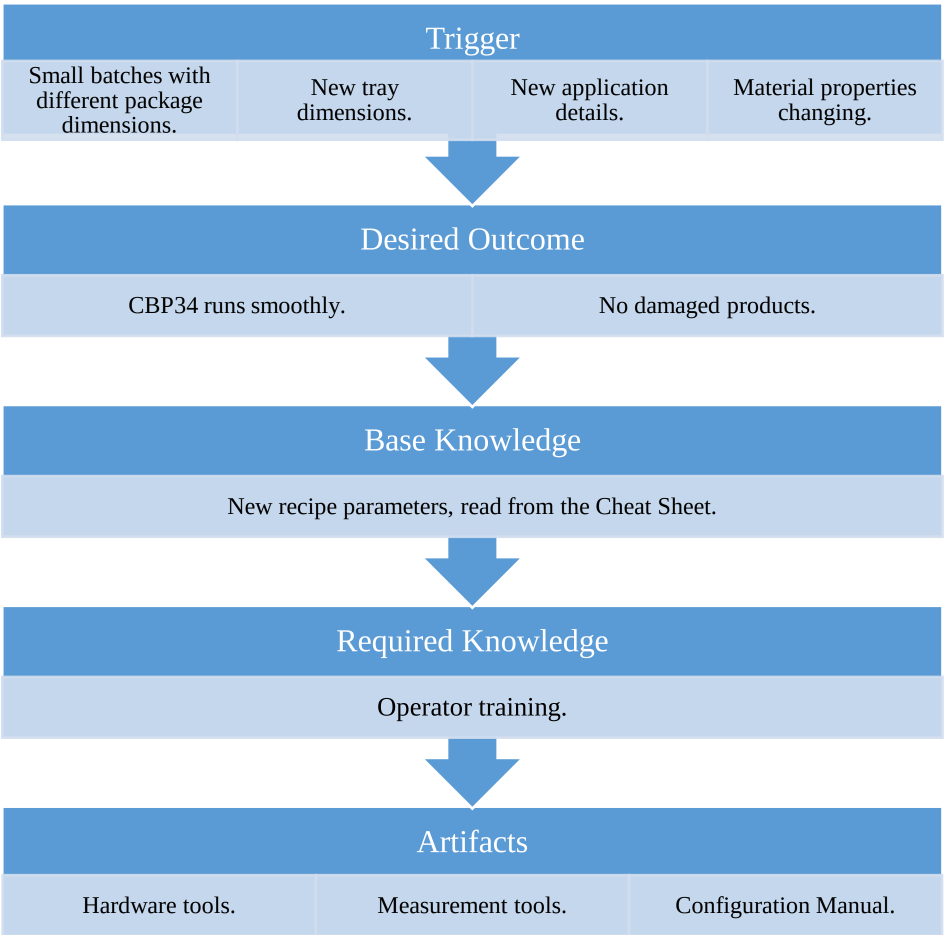


Figure 38: Task analysis diagram.[5]

General

Changeovers – i.e., the manual configuration of hardware settings – are typically triggered by a change in package or tray dimensions. The goal is to complete the changeovers as quickly as possible, to minimize production losses. Quick changeovers are especially critical when using dairy filling, which are perishable goods.

The users know that the changeover has been successfully completed when:

- The cardboard packer runs smoothly without package jams.
- No packages are damaged during the process.

Note that this is sometimes hard to tell right away, as the machine moves too fast for human eyes to accurately catch everything that's happening. When starting the changeover, the users must know the new recipe parameters. The users must also know the proper task order. For standard changeovers the recipe values are listed in intended task order on the pre-printed Configuration Cheat Sheet.

To be able to initiate and complete changeover, the user must have undergone the proper operator training. Untrained operators risk making mistakes that cause irreparable damage on the equipment. The users also need access to several tools, such as:

- Hardware tools such as wrenches, spanners etc.
- Measurement tools such as rulers, tape measures etc.
- Configuration manual, cheat sheet.

The insights from the identified pain points and subsequent task analysis can be summarized as a SWOT-analysis , which is a tool used identify strengths, weaknesses, opportunities, and threats for a project, see Figure 39.

Strengths	Weaknesses	Opportunities	Threats
• Robust design • Broad parameter range	• Low task accuracy • Inefficient workflow • Mental load • Small margin of error • Number of interaction steps	• Accessibility improvements • Improve task accuracy • Quick settings	• Modular design • Automated changeover technology • Plug-and-play

Figure 39: SWOT analysis of the CBP34 changeover procedure.[5]

General

3.2.1 **User Needs**

To make the users' goals and requirements more concrete, a series of user needs were identified based on the user research data presented in section 2.4. The user needs listed in Table 3 reflect the users wants related to the cardboard packer's hardware configuration process. Each user need was rated as either Necessary (N), Desirable (D) or Optional (O). The rating makes it easier for the design team to prioritize what needs to focus on during the Develop Phase.

Table 3: User Needs interpreted based on data from the Discover phase. The user needs are listed next to the user statements or field observations that inspired them.

User Statements	*User Needs*	*Need (No.)*	*Rating*
"The CBP34 is very expensive as-is."	The product should be cheap to produce and implement.	1	N
"The CBP34 is a complex machine with little possibility of revamping the architecture without affecting the functionality."	The product should be easy to implement.	2	D
	The implementation and use of the product should not affect the surrounding components in a substantial way.	3	D
"Changeover halts production, leading to production losses."	The configuration procedure should be quick.	4	N
"The operators have minimal technical support available if problems arise."	The operators should be able to calibrate the machine without external support.	5	D
"Operators should be able do some maintenance tasks [themselves]."			
Sometimes multiple actions are required to configure one component.	Interaction should be completed in as few steps as possible.	6	D
The large number of steps required to complete changeover is time consuming.			
"The main problem is […] a lot of changes between the products at a high frequency."			
"Some components require identical settings but are adjusted individually. It's kind of annoying. "	Duplicate actions should be avoided as much as possible.	7	O
"The margin of error is small."	The configuration tasks should be easy to complete with a high degree of accuracy.	8	N
"It's annoying to configure each component as it requires adjusting, checking, re-adjusting etc. each component many times before the task is done properly."			

General

User Statements	*User Needs*	*Need (No.)*	*Rating*
"It's hard to adjust the position accurately on the first try. Usually, you need to calibrate the component position several times." "It's annoying to configure each component as it requires adjusting, checking, re-adjusting etc. each component many times before the task is done properly."	It should be easy to complete the configuration tasks on the first try.	9	N
Some components lack proper features to check alignment, position etc. in a convenient way. It can be hard to adjust the components and check the alignment at the same time, see Figure 16.	It should be easy to verify the alignment/position.	10	N
"There are so many components and steps involved that it's hard to remember." "The problem with this type of factory is that we have many small batches with different products; there are a lot of different small aspects and settings that can cause issues."	The configuration workflow should be intuitive and easy to recall.	11	D
Low visibility of stickers and labels in a busy environment. "Identifying the components can be tricky. We have to run back and forth between manuals, blueprints and the machine. "	It should be easy to visually identify each relevant component.	12	O
It can be hard to find all labels that belong together and to know which one belongs to which component.	It should be easy to understand how to interact with each relevant component.	13	O
"We print extra labels ourselves to be able to navigate the machine easier." "The component layout is very complex and hard to navigate."	It should be easy to navigate the machine layout with as little aid as possible.	14	D
It can be hard to find all labels that belong together and to know which one belongs to which component. "It's hard to find the root cause of several errors that occur at the same time. The full picture of a problem is needed."	It should be easy to get a good overview of key areas (location of errors, settings etc.)	15	D
Some components can be hard to reach, even though most components are placed above thigh height. The operators are often required to contort their bodies, bend over etc. to reach. "Physical strain in the left hand and shoulder when operating the machines."	Accessing the relevant components should put minimal physical strain upon the user.	16	D
"Some places are difficult to reach when changing the product sizes." "It can be tricky to fit inside the machine sometimes."	It should be easy for the users to get close to the relevant components.	17	D

General

User Statements	*User Needs*	*Need (No.)*	*Rating*
Components can be knocked out of alignment by mistake.	The machine design should be robust.	18	N
"It's easy to break something if you don't know what you're doing."	The product should be fool proof, i.e., minimize the possibilities for errors due to human interaction.	19	D
" […] it is so easy to cheat the system […] You can just take away two screws and then you do not get the door alarm."			
Mistakes happen when recipe parameters are calculated/measured manually by staff, and information is passed on verbally.			
"It's not uncommon for users to dissemble certain internal modules or components that don't suit their own needs […] They find it more convenient."	More customization according to the specific user's needs should be possible.	20	D
"I wish operation manuals and hardware were more customized to our (specific) needs."			
The product should require minimal maintenance.	The product should be durable.	21	N

3.2.2 **Project Requirements**

As stated by Preece et al. [6], usable designs are products that support the way people *actually* interact in their everyday and working lives. Loosing sight of the product's design requirements will result in products that do not accurately support and/or meet the user's needs. Therefore, defining and communicating the product's requirements is important to make sure that this doesn't happen.

The goal of defining general requirements, is to provide a framework for the product development. The requirements are guidelines, that the design team can use as a touchpoint when making design decisions. The general requirements listed in Table 4 are based on the previous research and defined user needs in Table 3.

Table 4: The general requirements. [2, chapter 10.3.1]

Requirements
Functional
The product will facilitate the configuration of hardware settings and improve the user experience during completion of changeover tasks. The product supports the user in performing these tasks.
Data

General

The product depends on the machine layout, component dimensions and information about the values (mm, angle, position data) of the hardware settings. It also requires knowledge about the task order as well as how recipe parameters change depending on production pattern/type.
Environmental
Physical
The product is to be implemented in an industrial environment where the noise level is high, there is lots of movement, bright lights, and cramped spaces.
Technical
The product is to be compatible with the CBP34 machine. It's also desirable that the product can be adapted to other similar equipment in the Tetra Pak product line.
User Characteristics
The users are trained operators with varying levels of experience, from novices to experts. The users are able to work and solve problems independently, without a lot of technical support.
Usability Goals
The machine should be easy to operate without additional training.

The functional requirements state, that the final product will support the user during the configuration of hardware settings. Furthermore, the final product should be compatible with the CBP34 machine i.e., the implementation and use of the product should not affect the surrounding components or machinery in any substantial way.

The project requirements can also be interpreted in terms of usability criteria:

- *Efficiency*: “The final product will facilitate the configuration of hardware settings during changeover. The product supports the user in performing these tasks.”
- *User satisfaction*: “The final product will improve the user experience [compared to before].”
- *Learnability*: “With the help of the final product, the cardboard packer machine should be easy to operate without additional training.”

How well the final product meets the usability criteria will be measured and evaluated using different metrics:

- *The efficiency* is measured in time (s), and the design team expects that implementation of the final product will yield a significant reduction in the time it takes to complete the configuration of 1 hardware setting.
- *The user satisfaction* is evaluated based on the subjective opinions of test users during the development and refinement of the final product. The users should perceive the final product as helpful and pleasant to interact with.

General

- *The learnability* is evaluated based on the subjective opinions of novice users. If the novice users find the final product intuitive, it indicates good learnability.

For the sake of streamlining the design process, the designers elected to focus on adressing the user experience of Novice Users, especially during the early stages of product development.

The novice user was previously described on page 43, and summarized as the operator persona “M” as pictured in Figure 40.

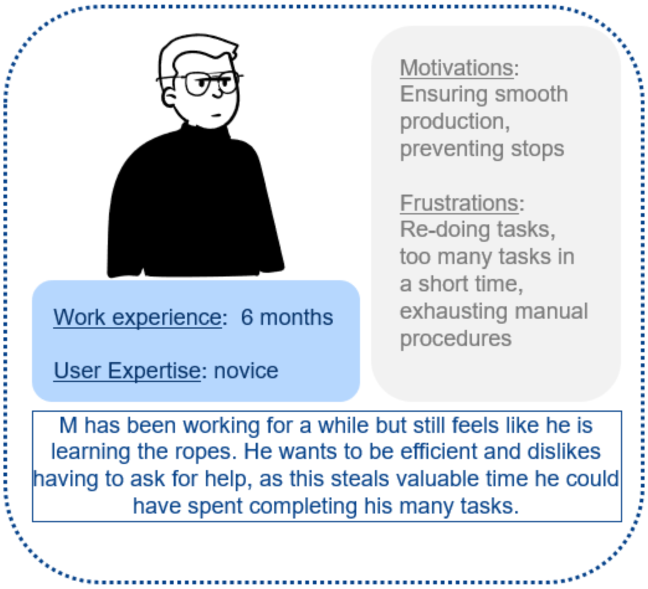


Figure 40: Novice user persona, “M”.[5]

During user testing, the participants would be selected based on their level of previous experience with operating the cardboard packer machine. There were a few reasons for this decision, not least of all that it was easier to get continuous access to novices than expert.

Any team is only as strong as their weakest link, and many Tetra Pak customers do not extensively train their operators. This made Novice Users an interesting “baseline” case. Any solutions that help Novice Users, would probably benefit the Expert Users as well. It was also reasoned, that Expert Users are more independent and more likely to come up with solutions on their own, which might skew the user test data.

General

From the wide range of user needs presented in Table 3, the ones marked "Necessary" (N) were selected for use as guidance for evaluating future design concepts. The selected needs can be found in Table 5.

Table 5: The selected design requirements and the user needs that inspired them.

Design Requirements	***Need (No.)***	***Rating***
The product should be easy and cheap to produce and implement.	1,2	N
The configuration procedure should be quick.	4	N
The configuration tasks should be easy to complete with a high degree of accuracy.	8	N
It should be easy to complete the configuration tasks on the first try.	9	N
It should be easy to verify the alignment/position.	10	N
The product should be durable.	21	N

Another project requirement concerns the setting's mechanism. As previously stated, the settings mechanisms are either of a slider or crank variety. Since the crank mechanism gives the user slightly better feedback, the selected to focus for this report was the improvement of the changeover procedure for settings based on a slider mechanism, which applies to about 50% of the hardware settings.

Lastly, it should be noted that the vast majority of CBP34 hardware configurations are changeovers between a handful of standard operating modes, or "standard cases". It's these standard changeovers that are the focus of this project.

3.2.2.1 How Might We Statement

Raw data is not always an optimal tool to explore the experiences and frustrations of users. To better capture these subjective facets of user interaction, the user research data was reinterpreted as a journey map. A small section of the journey map is displayed in Figure 41.

The primary goal of using a journey map is to communicate the status and changes in the relationship between a user and the product over time as they interact with one another. The aim for this project was to investigate how the user's expectations relate to their experiences, and subsequently find opportunities for improvement. The journey follows the novice operator,

General

M, as he initiates hardware changeover from standard case A to B. The journey was split action-by-action into 10 steps. For each step, M's thoughts and feelings were described, as well as any questions or design opportunities identified by the design team.

The main takeaways from the journey map were, that the operator is under a lot of pressure due to time pressure, information overload and inefficient workflow. To counter some of these frustrations, teamwork and access to experienced colleagues is key. This sparked some ideas for interesting design challenges, see Table 6.

Table 6: Design opportunities identified based on the journey map.

Design Opportunities
HMW make sure the relevant settings are easily identifiable?
Can we eliminate the need to consult with the checklist?
HMW make sure that the interactions points are easily identifiable? Placement, colors etc.
HMW create a system that provides more interaction feedback to the user? Haptic, visual etc.
HMW increase task accuracy?
Could the release sequence be simplified?
Can we make it easier for M to remember specific setting's values?
Can we eliminate the need for M to remember specific setting's values?
Can the system give more error feedback to users?

This led to the formulation the main design question to generate ideas around:

> *"How Might We… increase task accuracy?"*

The low accuracy when completing changeover tasks is a recurring sentiment. For the purpose if this project, "accuracy" refers to how easy it is for the operators to accurately configure the cardboard packer's hardware settings on the first try.

General

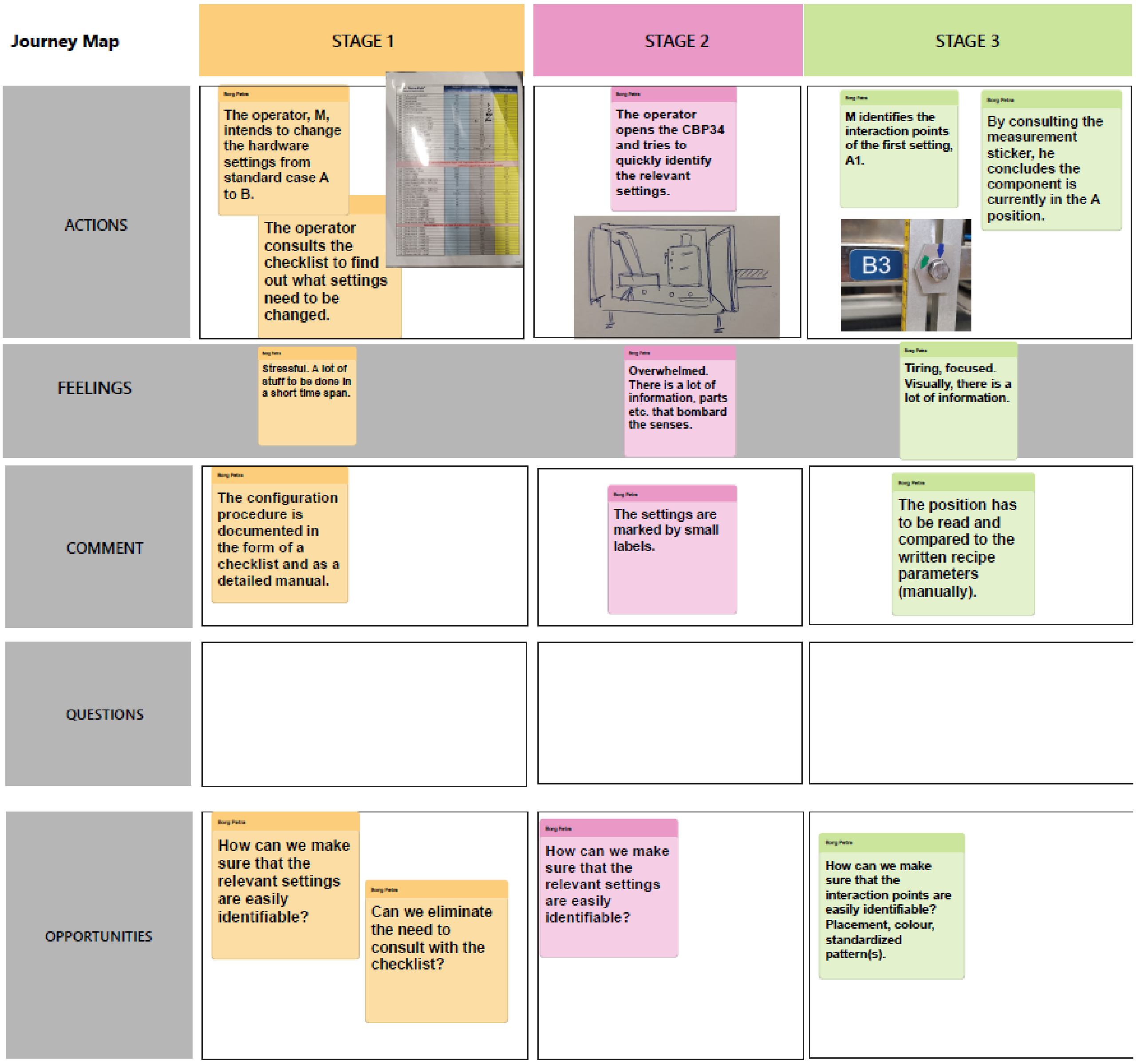


Figure 41: The first 3 stages of the journey map. Each stage describes a user action or event and includes five rows detailing the user's action(s), feelings, the researcher's comments and questions as well as any design opportunities inspired by that stage of the user's journey.[5]

4 Develop Phase

The concept development is handled as an iterative phase following a cycle of divergent idea generation, prototyping, user tests. The work is done in short sprints of 2 weeks, where the collected user input guides the concept development.

4.1 Idea Generation

The idea generation process consisted of brainstorming, concept screening and concept scoring, the creation of low-fidelity prototypes and user testing.

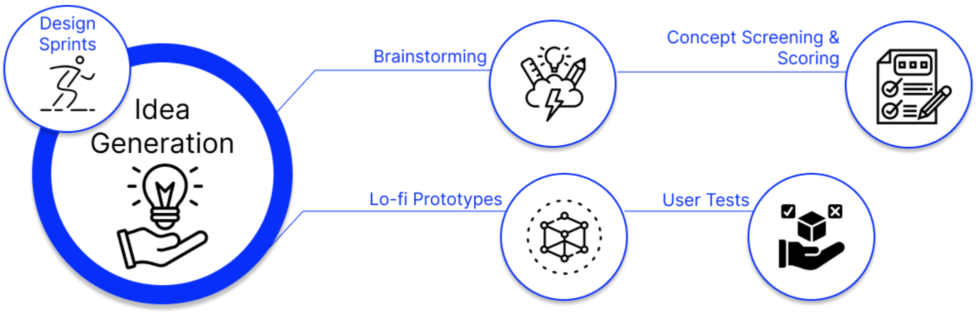


Figure 42: Techniques used for idea generation. The idea generation was conducted in short sprints.[5]

The overarching strategy was to work in short design sprints of about 2 weeks each. The first week of the sprint was spent analyzing the most recent user feedback and iterating the concepts accordingly. The second week of the sprint was spent creating prototypes and conducting user tests. The short deadlines was intended to help me keep up momentum, and to make sure that the design was continuously vetted and evaluated by users.

4.1.1 **Brainstorming**

In order to quickly generate a varied breadth of ideas, a series of short brainstorming sessions were carried out, both alone and in groups of 2-10 people. The focus of the sessions were not to design “for reality”, but a challenge to dare thinking of wild ideas. The participants were given about 10-60 minutes and a minimum quota of 10 ideas to come up with solutions to the question: “How Might We increase task accuracy?” Note that by “task” it’s the hardware configurations between a handful of standard operating modes that is addressed. A summary of imaginative ideas are displayed in Figure 43.

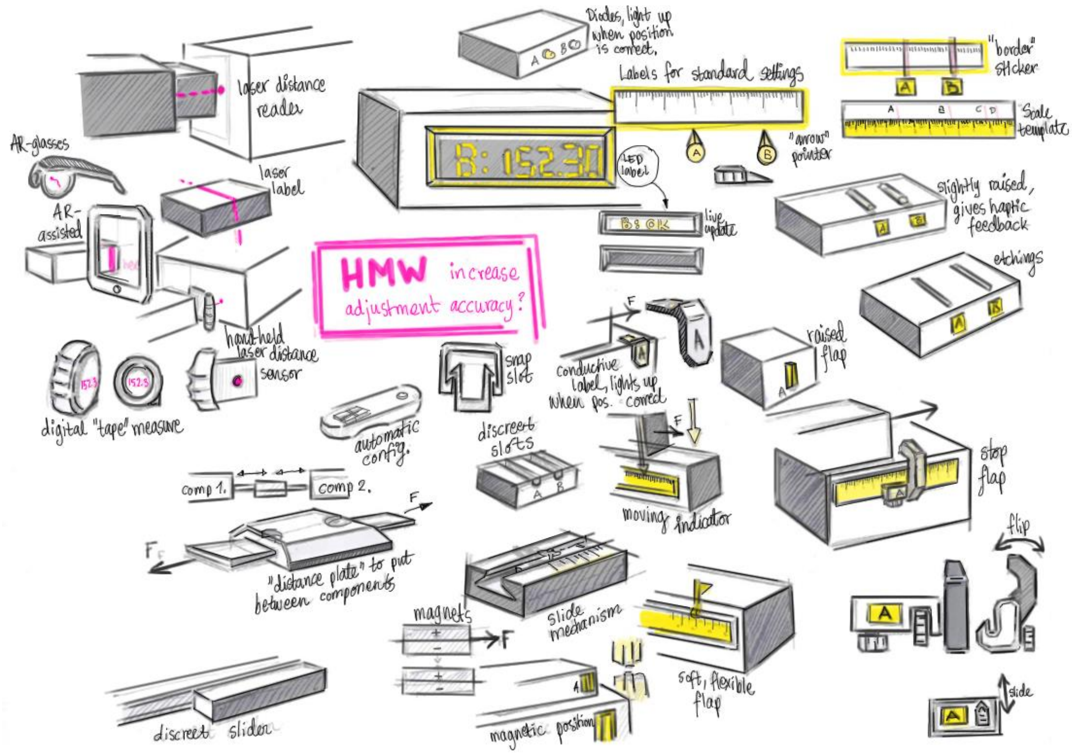


Figure 43: Ideas generated around “HMW increase adjustment accuracy?”. [5]

The design ideas could be sorted into three main categories similar to the design trends identified in section 2.5 External Benchmarking: Quick Adjustment Ideas, Easy Measurement Readings and Configuration Guide Ideas.

The first category, Quick Adjustments depicted in Figure 44, can be divided into two main groups: discreet and continuous adjustments, see Table 7. Solutions for discreet adjustments are based on pre-configured standard settings, while continuous adjustment solutions are designed for full flexibility in terms of placement. The advantage of continuous adjustment solutions are, that the product is fully customizable according to the user’s needs, even if the needs change over time.

Table 7: Quick adjustment solutions.

	Discreet adjustments	***Continuous adjustments***
Quick adjustments	Pre-configured slot feature.	Pre-configured flip stop.
	Pre-configured standard components (plug and play).	Magnetic position markers.
	Pre-configured template tool with standard settings.	Inductive/diode markers that indicate the standard position status as YES/NO.

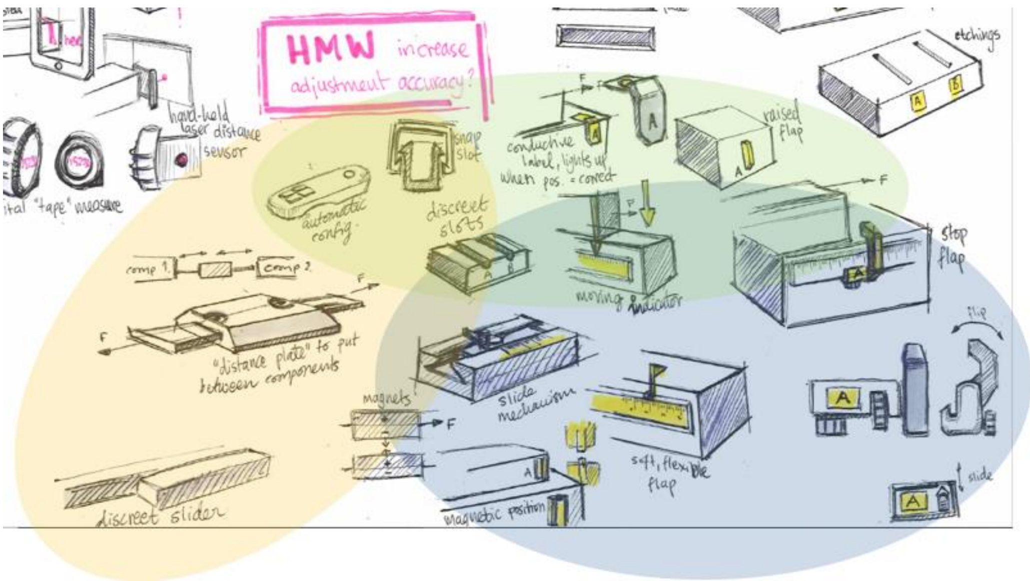


Figure 44: Concept category 1. [5]

The second category, Easy Measurement Readings in Figure 45, could also divided into two categories: static solutions and responsive solutions, see Table 8. The so-called static solutions are more fixed in nature, while the responsive solutions respond to user action/input.

Table 8: Solutions for easy measurement readings.

	Static	Responsive
Easy Measurement Readings	Standard settings markers.	Physical, moving position indicator.
	Scales with standard markers.	LED labels.
	Etchings.	Laser-based distance measurement tool.

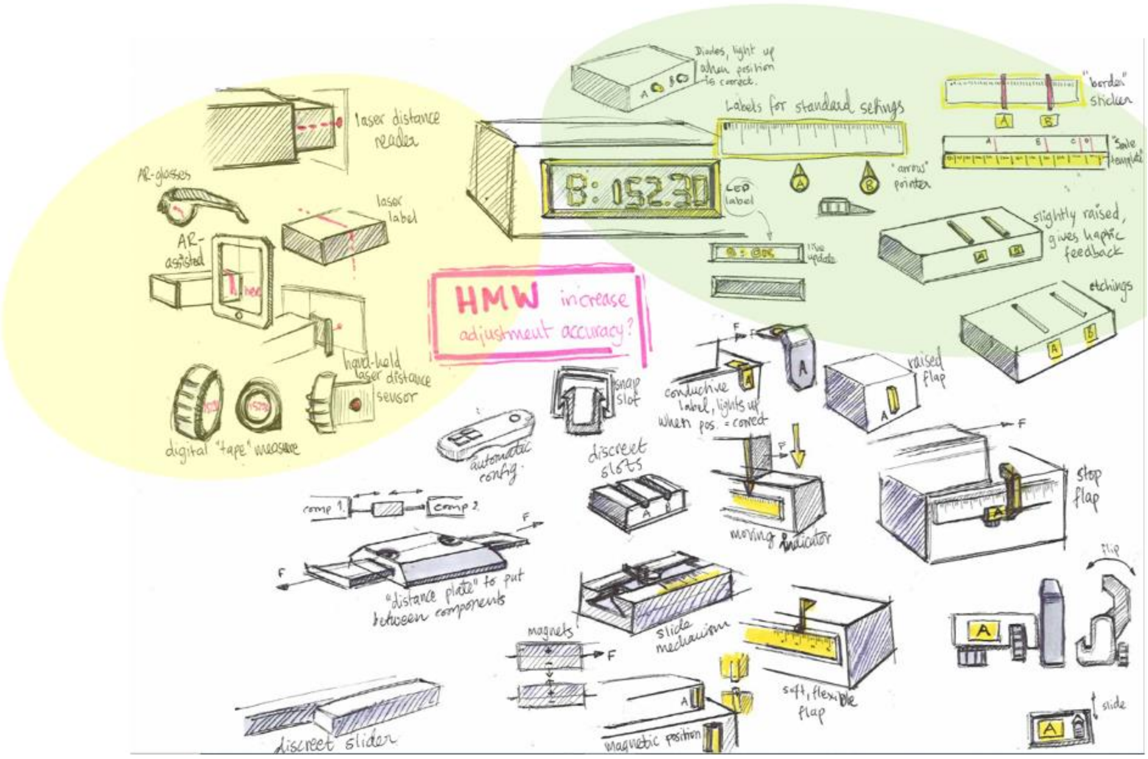


Figure 45: Concept category 2.[5]

The final concept category, Configuration Guide, could be divided into two groups: Digital and Physical solutions, see Table 9. As the name suggests, digital solutions depend on digital technology while the physical concepts depend on analogue solutions.

Table 9: Configuration guide solutions.

	Digital	Physical
Configuration Guide	AR guide	Trail
	Laser guide	Improved configuration manual
	Interactive HMI guide	Light system

4.2 Concept Selection

The generated concepts are very different from each other even though they aim to solve the same problem. Out of the vast array of generated ideas, eight interesting concepts were singled out, see Figure 46 below.

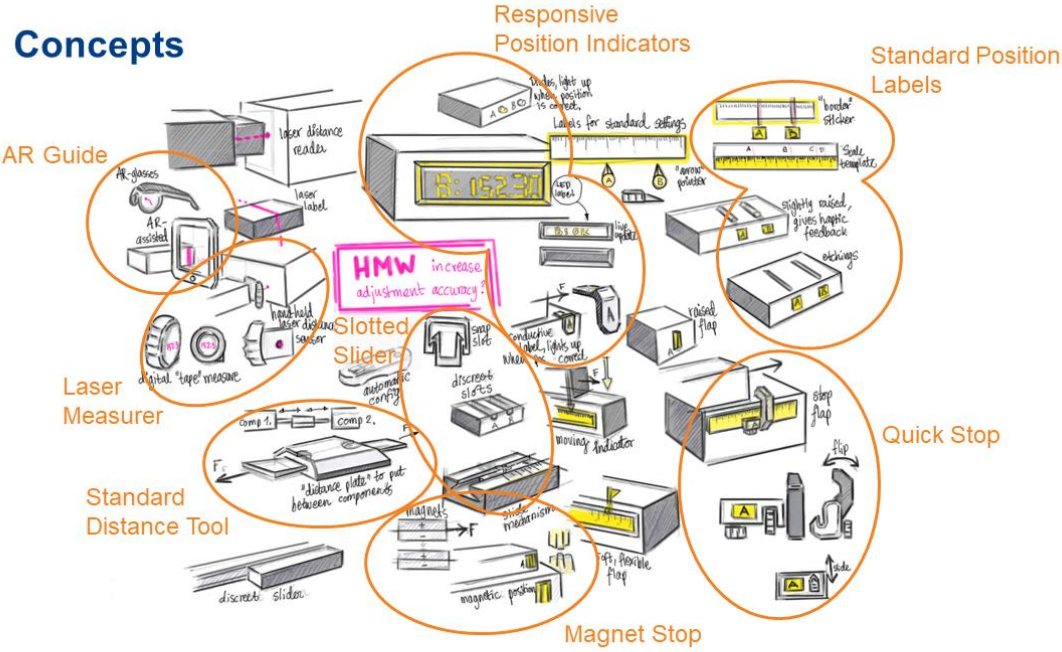


Figure 46: Selection of interesting concepts.[5]

A. Standard Position Labels

Concept A consists of position labels representing a set of standard use (e.g. A, B), see Figure 47. The labels are placed along the component's position scale by the customer, according to the customer's needs.

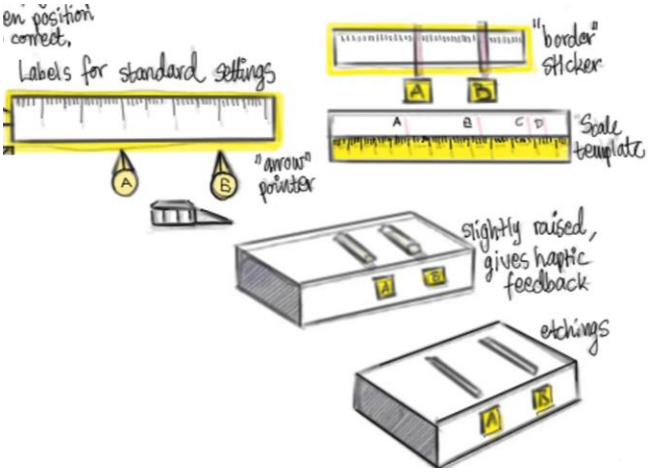


Figure 47: Standard positions labels concept.[5]

The labels serve as visual targets for the user when adjusting hardware settings. The normal use sequence, when the operator intends to change the hardware settings from standard case A to B, is detailed in Table 10 below.

Table 10: The action sequence when using the standard position labels.

Action Sequence
The operator identifies the relevant settings by checking for pre-configured A/B indicators (labels).
The operator releases (unlocks) the setting. The component is now free to move along the slider.
The operator shifts the component from position A to position B, as indicated by the standard position labels.
The operator locks the setting. The line is ready for production.

B. Magnet Stop

Concept B consists of 2 parts (magnets) as pictured in Figure 48. One part is placed on the component, the second is placed in the correct standard position (e.g. A or B) by the customer. The quick stop is left in place between configuration sessions.

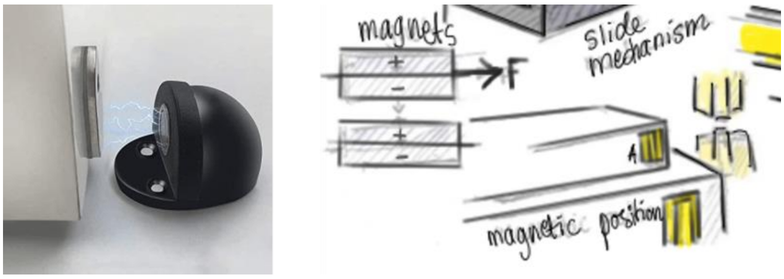


Figure 48: The Magnet Stop concept. [5]

The magnet stop provides a form of haptic feedback for the user when the two parts of the magnet align, signaling that the setting has reached a standard position. The normal use sequence, when the operator intends to change the hardware settings from standard case A to B, is detailed in Table 11 below.

Table 11: The action sequence when using the magnet stop.

Action Sequence
The operator identifies the relevant settings by checking for pre-configured A/B indicators (magnet stops**).**
The operator releases (unlocks) the setting. The component is now free to move along the slider.
With a slight application of force, the component is disengaged from the A magnet stop. The component is now in free motion.
The operator slides the component from position A to position B. When the component comes within range of the B magnet stop, the magnets attach to each other, signalling to the operator that the setting is properly adjusted.
The component is now in the standard B position.
The operator locks the setting. The line is ready for production.

C. *Quick Stop*

Concept C, pictured in Figure 49, is a stop device that is placed in the correct standard position (e.g. A or B) by the customer. The quick stop is left in place between configuration sessions.

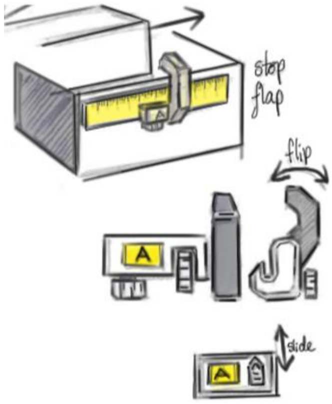


Figure 49: The Quick Stop concept.[5]

The quick stop provides a form of haptic feedback for the user when the component bumps into the quick stop, signaling that the setting has reached the selected standard position. The normal use sequence, when the operator intends to change the hardware settings from standard case A to B, is detailed in Table 12 and Figure 50 below.

Table 12: Action sequence when using the Quick Stop.

	Action Sequence
1	The operator identifies the relevant settings by checking for pre-configured A/B indicators (quick stops).
2	The operator releases (unlocks) the setting.
3	The operator disengages the A quick stop. The component is now free to move along the slider.
4	The operator engages the B flip stop.
5	The operator shifts the component from position A to position B. When the component comes into contact with the B flip stop, the operator knows the setting is properly adjusted.
6	The operator locks the setting. The line is ready for production.

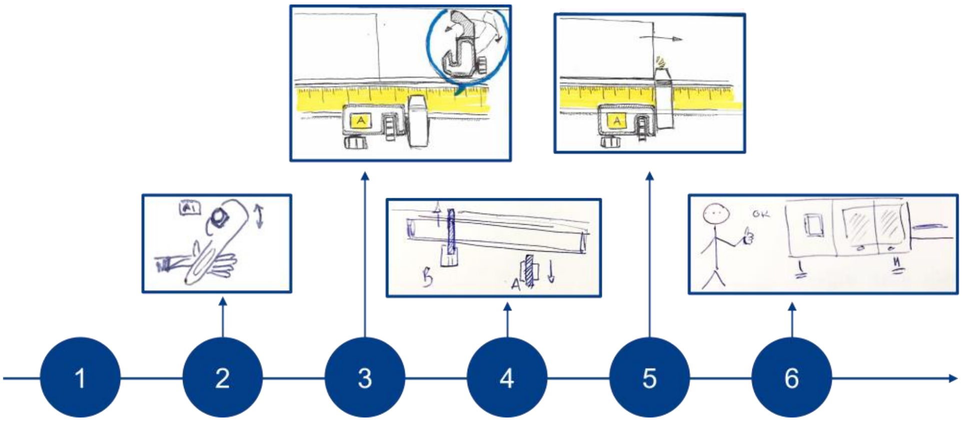
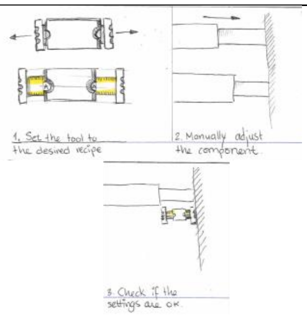
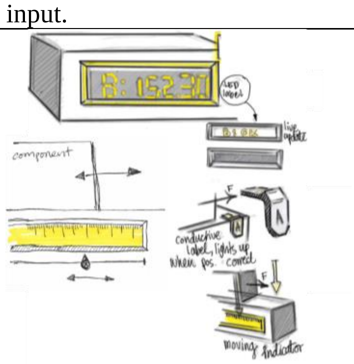
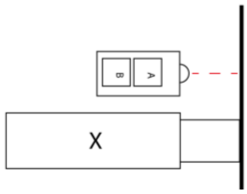


Figure 50: Action sequence when using the Quick Stop. [5]

Other concepts worth mentioning are concepts D, E and F, see . For detailed action sequences for these concepts, please refer to Table 27, Table 28 and Figure 85 in Appendix.

Table 13: Concepts D, E and F. [5]

D. Standard Distance Tool	*E. Responsive Position Indicators*	*F. Laser Measurer*
Concept D is a standard position key for quick comparisons of the component's position to the desired standard position, see Figure 51.	Concept E, pictured in Figure 52 consist of a position indicator calibrated according to the customer's needs. The marker indicates when a given component is in the correct position by providing feedback in response to user input.	Concept F consists of a handheld device that measures distance using a laser sensor. When the distance is correct, the corresponding case button lights up.
 **Figure 51: The Distance Tool concept.**	 **Figure 52: Concept E.**	 **Figure 53: Concept F.**

4.2.1 **Concept Screening**

The idea generation activities resulted in several interesting concepts and ideas. Each concepts had its own merits and had to be evaluated considering the stipulated user criteria and project resources. In order to get an overview of the generated concepts, the initial concepts were positioned in an affinity diagram according to two criteria, see Figure 54.

During the idea generation process, it became immediately clear that the generated concepts vary greatly in technical complexity. This was used as one metric for comparing the concepts. As stated in Table 3, the first user criteria is that "The product should be cheap to produce and implement." For the sake of the diagram, this was re-defined as "Broadly Applicable Solution" versus "Solution Requires Custom Tailoring".

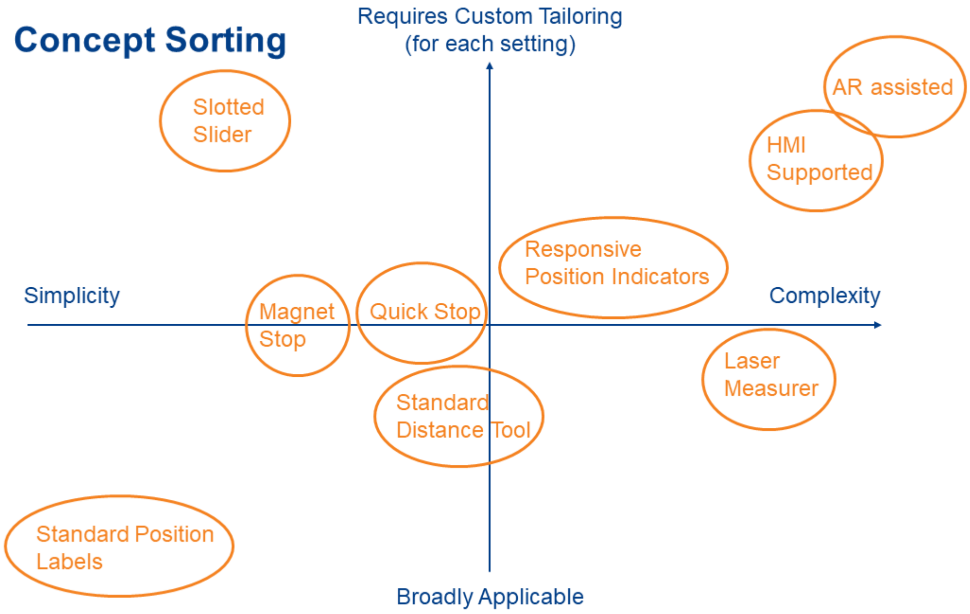


Figure 54: Concept Screening Diagram. [5]

In the top right corner of the diagram, the AR Assisted and HMI Supported concept solutions can be found. Both concepts were deemed complex to produce, use and implement, and require extensive custom tailoring to fit each hardware setting configuration procedure. The concept were therefore removed from the selection pool.

The Slotted Slider concept can be found in the top left corner of the diagram. The design is rather simple but would require an extensive hardware rehaul in order to be installed. The concept was therefore removed from the selection pool.

In the bottom left corner, the Position Label concept can be found. The solution is rather simple and should be easy to implement. This concept merits further consideration.

The rest of the concepts are clustered closely together and are hard to evaluate properly using this method. As such, they needed to be evaluated further.

4.2.2 **Concept Scoring**

The initial concept screening left 6 concepts to be evaluated further:

A. Position Label
B. Magnet Stop
C. Quick Stop
D. Distance Tool
E. Responsive Indicator
F. Laser Measurer

In order to evaluate and narrow down the remaining number of concepts, structured approach was modelled after the Pugh concept selection matrix, where each concept is evaluated according to a series of selected requirements and compared to a reference concept. Ulrich and Eppinger state that,

> "The reference is generally either an industry standard or a straightforward concept with which the team members are very familiar." [22]

For this, the concept deemed most simple and broadly applicable in the previous step was chosen: Concept A – Standard Position Labels.

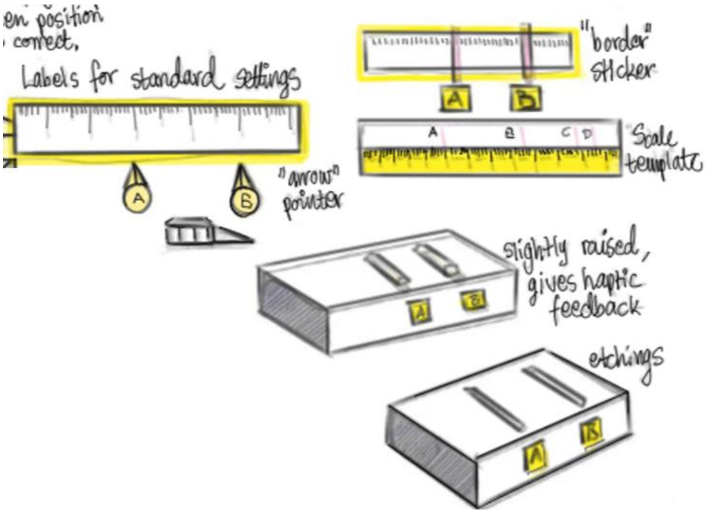


Figure 55: Concept A - Standard Labels. [5]

The selected concept scoring criteria are detailed in Table 14 below. Note that the criteria are identical to the design requirements in section 3.2.2.

Table 14: Selection Criteria for concept scoring.

Selection Criteria	***No***
The product should be cheap to produce and implement.	1
The configuration procedure should be quick.	4
The configuration tasks should be easy to complete with a high degree of accuracy.	8
It should be easy to complete the configuration tasks on the first try.	9
It should be easy to verify the alignment/position.	10
The product should be durable.	21

The concepts are scored using a simple rating system of (+), (0) and (-). A rating of (+) signifies that the concept fulfills the criteria better than the reference, a (-) that it does worse, and a (0) signifies that the concept and the reference are equal. The concepts were evaluated and scored by a 2-person team consisting of me and a stakeholder representative at Tetra Pak.

Based on the results presented in Table 15 below, the winning concepts (besides the refence, Concept A) are concepts B and C. Compared to Concept A, Concept B is more expensive to manufacture and implement due to more expensive materials and more parts. However, the concept affords better readability, ease of use and task completion, since the product provides multi-sensory feedback (sight and touch). One drawback is that the magnets' positions are not adjustable and hard to recalibrate if the user's needs change. This is a weak point that could be improved with future development. The team also noted that Concept B might be more easily scalable than Concept C, i.e. easier to apply in situations with more than two standard use cases.

Similarly, Concept C is also more expensive and complicated to produce and implement than Concept A due to material costs. However, the concept affords greater readability, ease of use and task completion due to better interaction feedback.

Table 15: Concept Scoring Matrix.

			Concepts		
Selection Criteria	***B Magnet Stop***	***C Quick Stop***	***D Distance Tool***	***E Responsive Indicator***	***F Laser Measurer***
Ease of manufacture	-	-	-	-	0
Ease of implementation	-	-	+	-	-
Ease of task completion	+	+	-	0	+
Readability of setting(s)	+	+	0	0	+
Ease of use	+	+	-	0	-
Durability	0	0	+	+	+
Sum: +	3	3	2	1	3
Sum: 0	1	1	2	3	1
Sum: -	2	2	3	2	2
Total Score	1	1	-1	-1	1
Rank	2	1	5	4	3
Continue?	Yes	Yes	No	No	No

Concept B and C are very similar, as they both use touch to provide more interaction feedback. The main differences between them are, that they are based on different mechanisms and that Concept B consists of two separate parts that have to be in sync, while Concept C consists of only one. This means Concept C is easier to install, as the customer only has to calibrate one part rather than two. Furthermore, the Quick Stop (C) has a clear advantage in that its lateral position is adjustable, allowing for easier re-calibration by the customer.

Concept D and E were eliminated from the selection pool due to their low scores. The low scores were mainly attributed to manufacturing and implementation costs. Concept D had some good qualities but is less intuitive to use. There were also some fears that the concept would require a lot of custom tailoring for each customer. Concept E was deemed too immature i.e., an idea that require significantly more development before market introduction. Considering that the goal is to implement the product in an existing machine, the concept is not mature enough to be worth pursuing further at this time. It would be more fitting to implement in machines that are still under development.

While Concept F got a high score, it was ultimately eliminated from the selection pool due to the team after some deliberation classifying it as immature compared to concepts A, B and C.

Moving forward, concepts B and C are grouped into one category: “Stop Block Concepts”. Concept A is renamed “Position Label Concept”.

4.3 Concept Iterations

Main concepts selected, each concept group was developed and evaluated further in an iterative process consisting of sketching, prototyping, and testing. For each iteration cycle, the prototypes became more and more realistic: from simple paper models to cardboard, clay and finally 3D printed plastic.

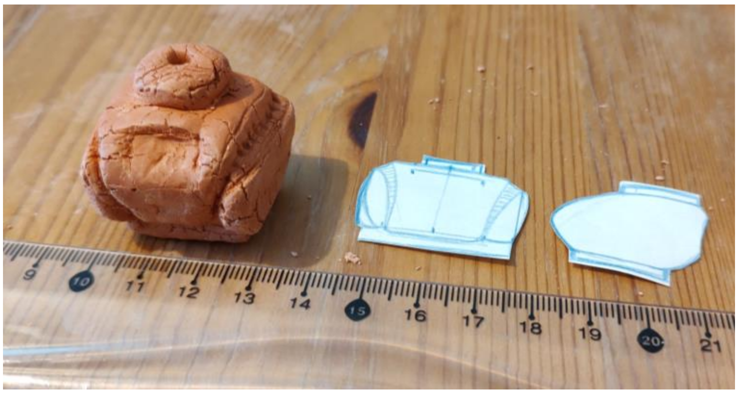


Figure 56: Clay model of the final stop block concept.[14]

With each new iteration, previous user feedback was used to guide development and improve the concepts step by step.

4.3.1 **Sketching**

4.3.1.1 Stop Block Concepts

The stop block concepts are presented in Figure 57. The idea is to help the operator to quickly adjust the setting by providing a stop block “end station” to aim for when adjusting the slider settings. The stop block provides both visual and sensory input. The stop block can be engaged and disengaged as needed. If the customer so desires, the stop block can easily be moved into a new position.

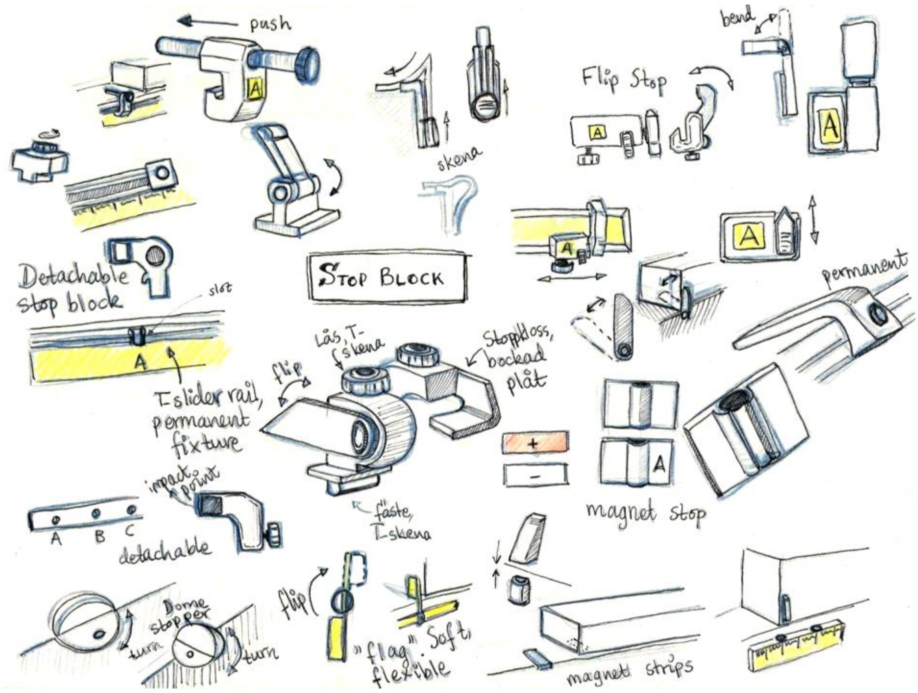
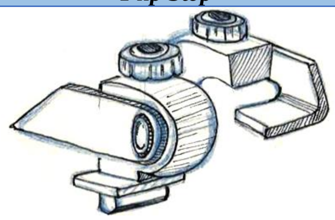
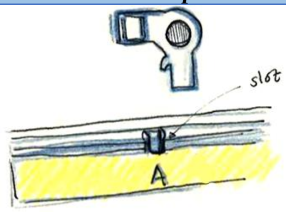
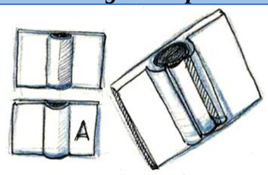
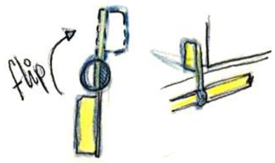


Figure 57: Stop Block Concepts. [5]

An initial evaluation was done by discussing the merits of each concept with the stakeholder company. Some features that were deemed most promising were sensory feedback, scalability (the concept is broadly applicable across the machine settings and allows for the inclusion of more than one standard case) and movability. An initial selection of three of the most interesting label concepts are summarized in Table 16.

Table 16: Initial evaluation of the stop block concepts. [5]

	Flip Stop	***Detachable Stop Block***	***Magnet Stop***	***Soft Stop***
				
	The flip stop is a stop block on a T-rail that runs along the setting's slider. Prior to use, the customer places the stop block in the correct standard position, fixing it in place with a screw.	The stop block is attached to a pre-configured slotted rail, with slots for each standard case. A slot rail is installed by each setting. When needed, the block is attached to the correct slot by the operator. Task accomplished; the block is removed to ensure no interference during run.	The magnet stop consists of two magnets, of which one is placed in the correct standard position on the setting's scale, and the other is placed on the moving setting's component.	The stop block is engaged at all times. Its softness ensures that the block does not interfere with machine functionality. The stop block flexes under force, providing sensory feedback. The flexibility of the stop block ensures that it moves back into its starting position when not pushed.
Pros	+ Provides haptic feedback. + Ease of Use + Easy installation + Adjustable	+ Provides haptic feedback. + Durable + Simple, no moving parts	+ Provides haptic feedback. + Durable + Ease of Use	+ Does not interfere with other equipment. + Provides responsive interaction feedback. + Durable
Cons	- Requires space - Several pieces, includes moving parts	- Must be retrieved and removed before/after each configuration session. - Not adjustable	- Not adjustable	- Only slight, if any, haptic feedback.

4.3.1.2 Position Label Concepts

The position label concepts are presented in Figure 58. The idea is to help the operator to quickly adjust the setting by aiming for the marker on the setting's scale. If the customer so desires, the marker can easily be moved into a new position.

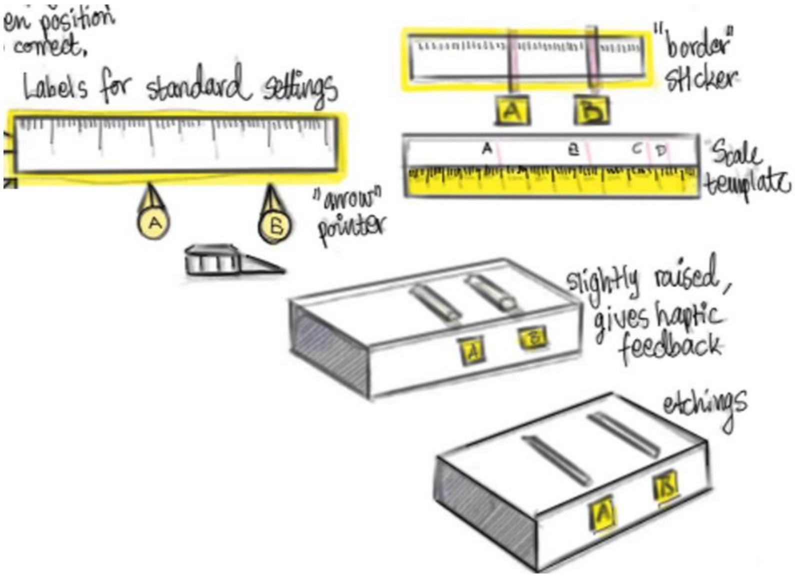
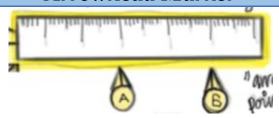
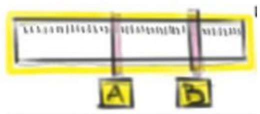
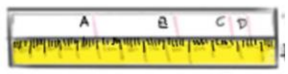


Figure 58: Position Label Concepts. [5]

An initial evaluation was done by discussing the merits of each concept with the stakeholder company. Some features that were deemed most promising were durability, scalability and movability. Another feature that was deemed worth investigating, was the varying levels of sensory feedback for each concept. An initial selection of three of the most interesting label concepts are summarized in Table 17.

Table 17: Initial evaluation of the position label concepts. [5]

	Arrowhead Marker	***Long Strip Marker***	***Scale Key***
			
	The marker is installed and calibrated in the desired position beside the scale. The marker is attached by magnetic force.	The strip marker is a long sticker that is placed across the scale by the customer. The operator can quickly adjust the setting by aiming for the sticker on the setting's scale.	The scale key is contains the markings for each standard case. The key is placed side by side the setting's scale.
Pros	+ The marker is movable and adjustable. + Does not interfere with other equipment. + Easily scalable.	+ Durable + Does not interfere with other equipment. + Easily scalable.	+ Durable + Does not interfere with other equipment.
Cons	- Does not provide multisensory feedback.	- Does not provide multisensory feedback. - Is not reusable/movable.	- Does not provide multisensory feedback. - Is not reusable or movable. - Is not easily scalable.

4.3.2 **Concept Tests**

As stated in the previous section, the concepts were split into two groups: the Label Concepts and the Stop Block Concepts. To further investigate them, user tests were conducted.

4.3.2.1 User Test 1

The purpose of the test was to – for each concept group – investigate:

a) Which concept(s) should be pursued further?
b) How can the concepts be improved?

A smaller sample size was favored for this test, since the aim was to gather qualitative user data. For this project, the user segment consists of both novice and expert users. As the test was costly in terms of time and resources, with limited access to expert users, a small group of novice users was selected for this user test.

The test was conducted as an explorative face-to-face, hands-on user test with the goal to observe the test subjects using the product while acting out a typical use scenario. The test consisted of 2 parts, one for each concept group. After each test section, the user was asked to choose the best concept of the concept group. The customer response was recorded in a written interview format. The users were also asked to rate two important aspects of their user experience, on a scale of 1-5, see Table 18.

Table 18: Example of the user response questionnaire used in User Test 1.

	1 ***Not at all***	***2*** ***Not really***	***3*** ***OK***	***4*** ***Good***	***5*** ***Very***
Intuitive				x	
Easy to use		x			

The *intuitiveness* of the product concept refers to the perceived ease of understanding of how to complete the task. *Ease of use* refers to the perceived ease of completing the task.

Each user was first introduced to the CBP34 and its functionality, with supporting pictures, see Figure 59. The user was then asked to act out a given scenario:

> *"You are working as an operator of CBP34. You learn that a new batch of packages is incoming. The new packages have different dimensions than the current batch, which means you have to configure the hardware settings.*
>
> *The component slides along a rail. Your task is to locate the placement along the rail that corresponds to "Case A". This is the most common setting."*

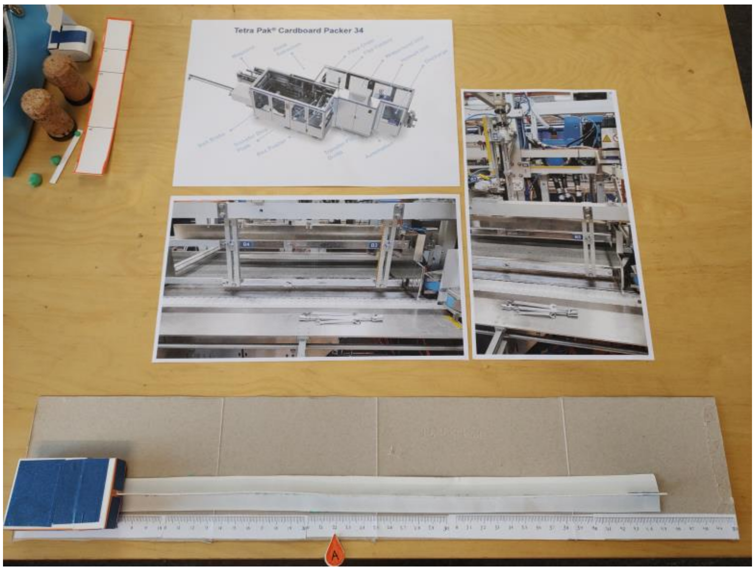


Figure 59: Equipment setup during User Test 1.[14]

4.3.2.1.1 Low-fidelity Prototypes

Low-fidelity prototypes representing each design concept were used as props for the users to interact with when acting out the test scenario. The label concept prototypes were created in cardboard, see Figure 60.

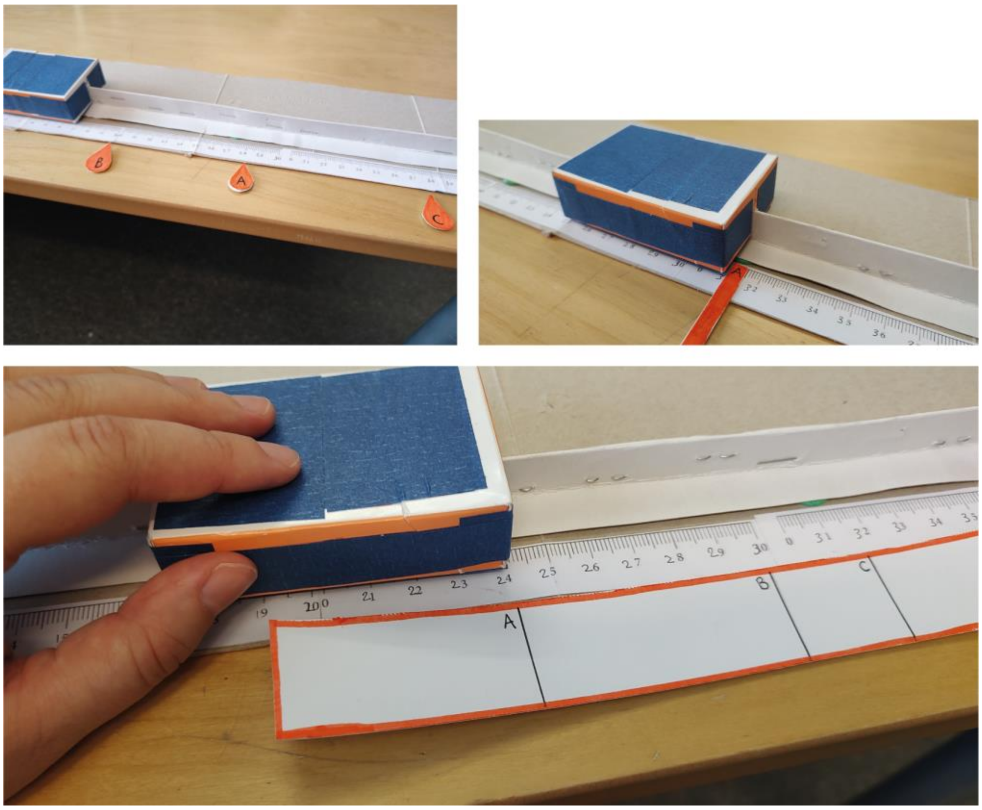


Figure 60: Label concept prototypes.[14]

The CBP34 hardware setting was greatly simplified for the purpose of this user test, consisting of a cube shaped cardboard “component” and a T-shaped rail. The underside of the “component” had a groove cut out lengthwise, enabling the “component” to slide along the T-rail. Next to the T-rail, a simple measurement scale had been attached, imitating the yellow scales typically mounted by each hardware setting in the original CBP34 machine.

The stop block concepts were also created in cardboard, see Figure 61.

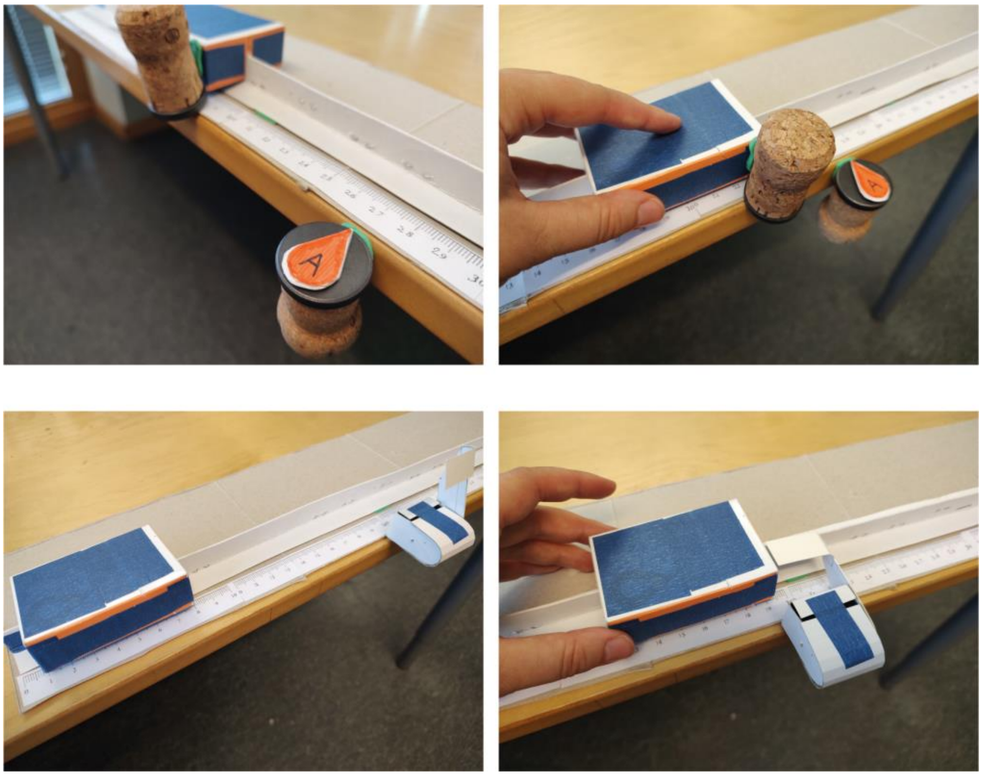


Figure 61: Stop block prototypes.[14]

The magnet stop prototype also included two flat magnets, each mounted on a separate corkscrew. One magnet was then mounted on the hardware stand, while the other was attached to the “component”.

The flip stop consisted of two cardboard parts: the rectangular body and the flip arm. The arm was attached to the body using pins, allowing the arm to rotate 360 degrees about the pin axis.

4.3.2.1.2 Results from User test 1

After the user (N = 4) scores for *intuitiveness* and *ease of use* had been combined, it became clear that the Label Concepts were slightly more popular than the Stop Block Concepts, see Figure 62.

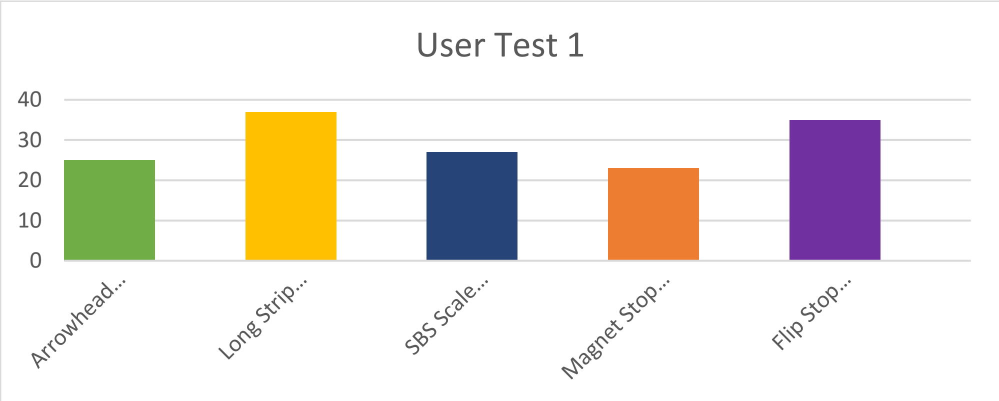
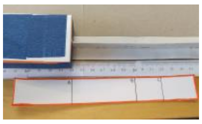
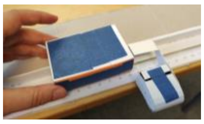


Figure 62: User response data from User Test 1. Not that "SBS Scale" refers to the Scale Key concept. [5]

The two most popular concepts, however, could be found in both groups. Based on the feedback displayed in Table 19, the most popular concepts were Concept 2 (Long Strip Label) with a combined score of 37, and Concept 5 (Flip Stop) with a combined score of 35.

User comments (see column 3 and 6 in Table 19) suggest that users appreciate clear *design barriers* i.e., design features that constrain the human-system interaction in such a way that the barriers guide the user through a preferred interaction sequence.

Table 19: Result from User Test 1.[14]

	Label Concepts			*Stop Block Concepts*	
	Concept 1	*Concept 2*	*Concept 3*	*Concept 4*	*Concept 5*
					
Score	25	37	27	23	35
Comments	"It's a little challenging to see exactly where the marker is pointing.." "The shape stands out and helps attract attention to the marker."	"I like that the marker provides a clear finish line that overlaps with the scale and the component's path." "The marker gives a good overview and is easy to adjust."	"The straight lines are easy to read." "The lines don't cross the scale. It's hard to read the setting's value." "The format feels confusing. The marker doesn't span the entire scale: I don't understand if I should aim for the A-line or the entire sticker."	"It's cool!" "Confusing, I don't see a marker anywhere and the haptic feedback is pretty weak." "Fine-tuning the position was hard, because the magnets want to force you into one specific position!"	"I don't have to watch the scale at all. The stop block tells me when I'm in the right position."

A breakdown of the user scores, presented in Table 20, gives a more nuanced insight into the user's experience: The Label Concepts were perceived as more intuitive than the stop blocks. However, the stop blocks were considered easier to use.

It's possible that the label concepts seem more familiar to the novice users than the stop blocks, which might skew the results (regarding the intuitiveness) in their favor. Despite this, Concept 5 (Flip Stop) was more intuitive than most of the label concepts. It also received a higher combined score than the label concepts.

Table 20: User scores.

	Arrowhead Concept		***Long Strip Concept***		***Scale Key Concept***		***Magnet Stop Concept***		***Flip Stop Concept***	
	Intuitive	***Ease of Use***	***Intuitive***	***Ease of Use***	***Intuitive***	***Ease of Use***	***Intuitive***	***Ease of Use***	***Intuitive***	***Ease of Use***
Score	11	14	18	19	13	14	8	15	16	19
Combined Score	25		37		27		23		35	

The users were also asked to "*Choose the concept that best helps you complete the task! Rate them in order of best to worst.*" Out of the label concepts, the users all preferred the Long Strip Concept, see Table 21.

Table 21: The user rankings of the Label Concepts.

User 1	Long Strip	Scale Key	Arrowhead
User 2	Long Strip	Scale Key	Arrowhead
User 3	Long Strip	Scale Key	Arrowhead
User 4	Long Strip	Arrowhead	Scale Key

The Arrowhead Concept was not as well received as one could have expected, which was due to its "odd" shape. The Long Strip Concept was liked by users because it afforded convenient navigation.

Out of the Stop Block concepts, the majority of the users preferred the Flip Stop Concept, see Table 22. The Magnet Stop was disliked by users because the magnets had a strong pull on each other, which affected the finetuning negatively.

Table 22: The user rankings of the Stop Block Concepts.

User 1	Flip Stop	Magnet Stop
User 2	Flip Stop	Magnet Stop
User 3	Magnet Stop	Flip Stop
User 4	Flip Stop	Magnet Stop

Based on this, the Long Strip and Flip Stop Concepts were selected to be pursued further. Insights gained from the first user test, sparked ideas for possible concept improvements: It seems like the novice users wanted to have a good overview of the components and interaction points. A good overview aids the navigation and lessen the mental load put upon the user. One example of this, is that some users noted that they appreciated the adjustment scale indicators but would have liked corresponding markers on the hardware equipment as well. The users felt this would help them when configuring the setting's position.

4.3.2.2 User Test 2

The purpose of the test was to – for each concept group – to find out:

a) Which level of feedback (flat, raised, block) do the users prefer and why? and
b) Which concept(s) should be pursued further? How can the concepts be improved?

There were three concepts to test, see Figure 63.

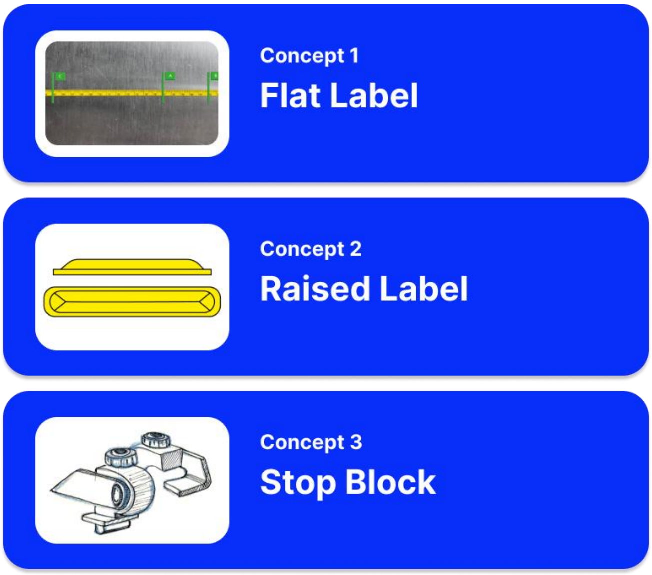


Figure 63: Concepts tested in User test 2.[5]

Since the goal was to gather qualitative data, a smaller sample size (N=5) was favored. To keep the data consistent with the previous test, novice users were favored. It was also assumed, that a product that serves novice users well, will also be helpful for expert users.

The tests were performed as hands-on user tests, during which users were observed while interacting with the prototypes. The users were then asked to digitally fill out a complementary survey designed to capture the user's experiences. To increase the users' motivation to participate, participants were rewarded with sweets after completion of the survey. The users were introduced to the CBP34 (Figure 64) and asked to act out the following scenario:

> *"You are working as an operator of CBP34. You learn that a new batch of packages is incoming. The new packages have different dimensions than the current batch, which means you have to configure the hardware settings.*
>
> *Task: The component, B7, slides along a rail.*
>
> 1. *You learn that the new batch of packages have dimensions that require a setting's value of 4.3 mm. Your task is to set the component to this value.*
> 2. *There are three different standard cases: A, B and C. These are the most common settings. Each standard case is marked with a label of some sort. You learn that the new batch of packages have A-dimensions. Your task is to set the component B7 to case A.*
> 3. *You learn that there is a new C-batch incoming. Your task is to set the component B7 to case C.*
> 4. *You learn that there is a new B-batch incoming. Your task is to set the component B7 to case B."*

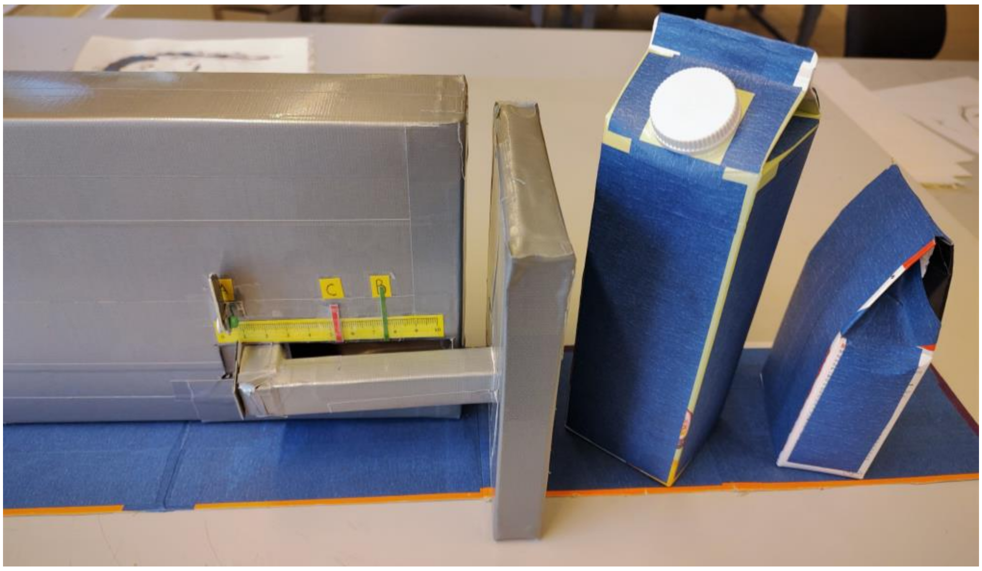


Figure 64: Test setup during User Test 2.[14]

The new, updated prototypes were made to resemble the CBP34 better. The prototype was still fairly simple cardboard models, wrapped in duct tape to mimic the metallic sheen of real metal, see Figure 65.

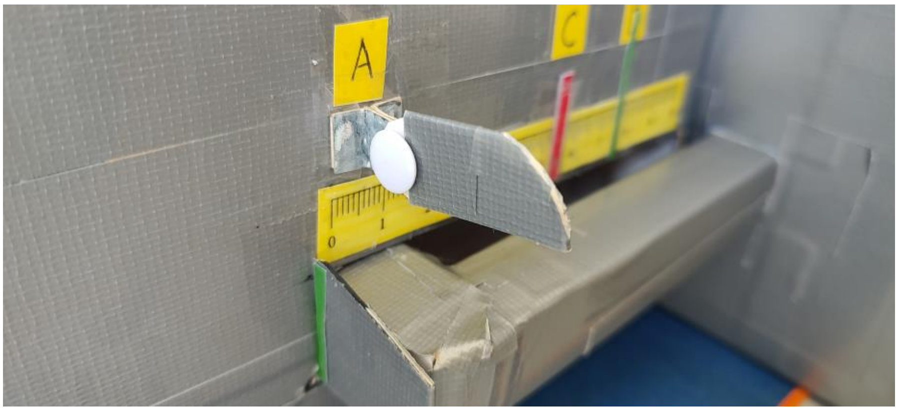


Figure 65: High-fidelity prototypes used in User Test 2.[14]

4.3.2.2.1 Results from User Test 2

The survey focused on capturing the user experience and consisted of a handful of questions requesting replies in the format of "*I agree completely – I do not agree at all*", where "Agree completely" garnered a score of 5 and "Do not agree" a score of 1. The total score of each concept was calculated by combining the score from each user:

$$Tot_{score} = n_{users} \times score\ 1 + n_{users} \times score\ 2 + n_{users} \times score\ 3 + n_{users} \times score\ 4 + n_{users} \times score\ 5$$

The intuitiveness of each concept was investigated by inquiring: *"I understood how to use the marker [concept] right away: Don't agree – Agree completely."*, see Figure 66.

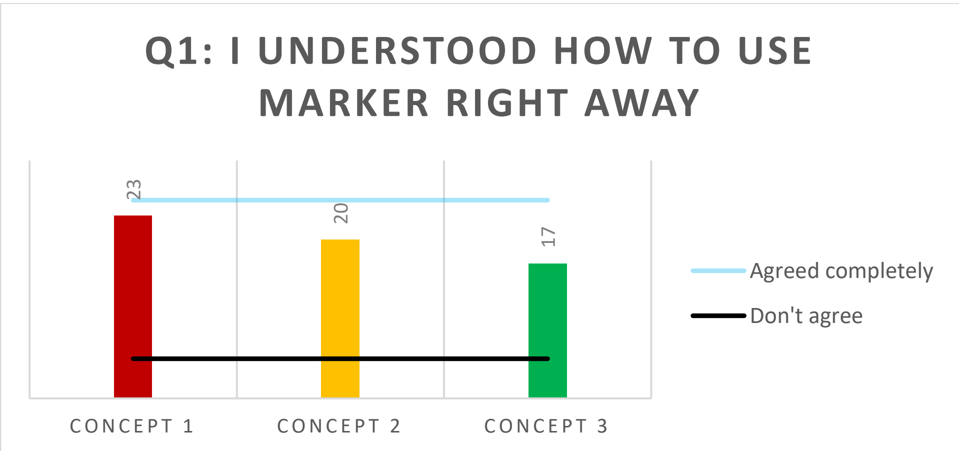


Figure 66: Concept scores based on the user responses to the question inquiring about the perceived intuitiveness for each concept.[5]

There is a clear divide in the users' perceptions of the intuitiveness for each concept: the label markers (Concept 1 and 2) are considered more intuitive than the stop block concept. This might be because the concept of using labels for position markers seems more familiar to users, as this type of signage is widely used in many everyday situations. Concept 3, however, might seem more complex at first sight. However, the users reported that they were able to quickly identify the important affordances provided by the stop block such as how to engage/disengage the stop block blade.

The "ease of use" of each concept was investigated by inquiring: *"The case marker [concept] was hard to use: Don't agree – Agree completely."*, see Figure 67. Because of the way this question is phrased, a low score indicates a positive perception of the ease of use of the concept.

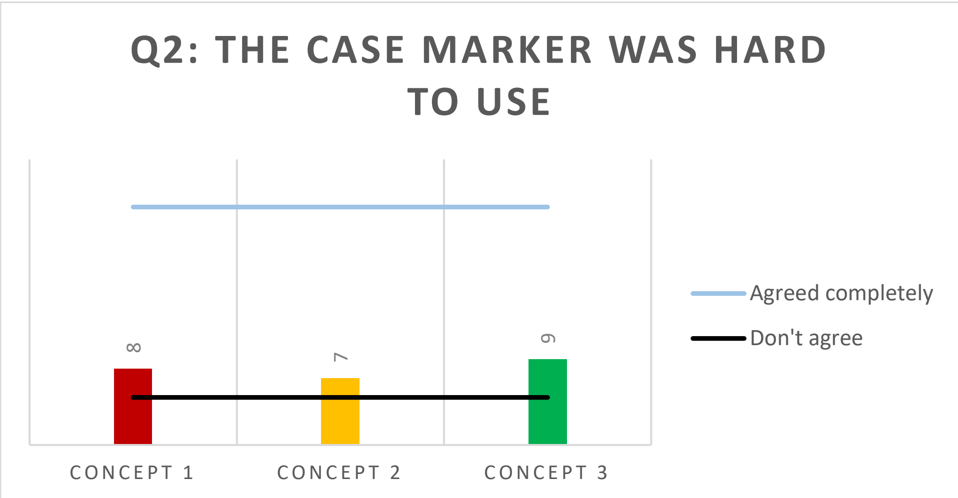


Figure 67: Concept scores based on the user responses to the question inquiring about the perceived "ease of use" of each concept.[5]

The differences in score for "ease of use" are pretty small, but Concept 2 comes out on top because of the combination of multisensory feedback and convenience it offers. "Convenience" refers to how likely the marker is to interfere with surrounding equipment during normal conditions. Concept 1 is also considered convenient but only offers visual feedback, while Concept 3 is less convenient than them both but offers the strongest feedback. Some users noted that concepts 2 and 3 would be more in cases with limited visibility due to the sensory feedback they provide.

Another factor to consider, is that the intuitiveness of each concept probably affects the perceived ease of use which could influence the score to the label concepts' advantage.

The user satisfaction regarding each concept was investigated by inquiring: *"The case marker [concept] made it easy to complete my task: Don't agree – Agree completely."*, see Figure 68.

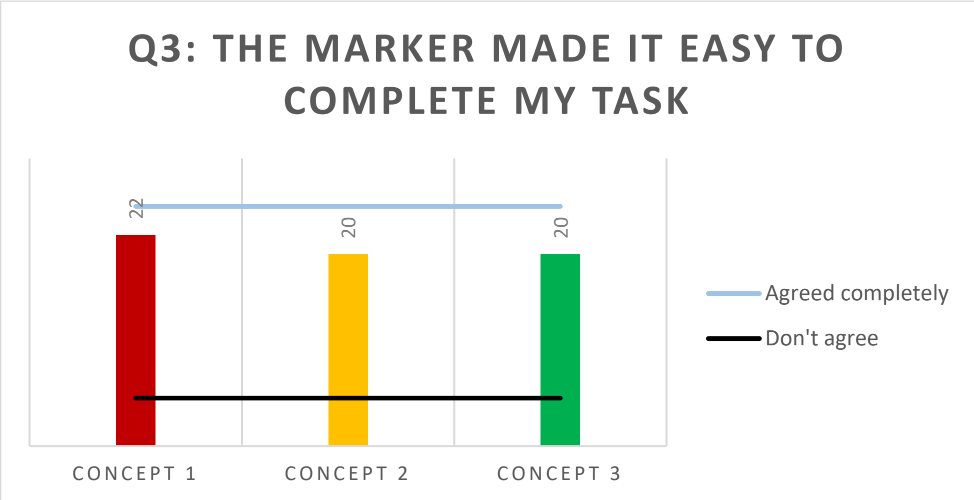


Figure 68: Concept scores based on the user responses to the question inquiring about the user's satisfaction regarding each concept.[5]

The differences in user score for satisfaction is very slight. The user satisfaction can be said to reflect the user's overall impression of product interaction, including the intuitiveness and ease of use. With that in mind, it makes sense that the flat label (Concept 1) garnered a slightly higher score than the others.

The users were also asked to rank the three concepts based on how helpful they found the concepts were for completing the user's tasks, see Figure 69.

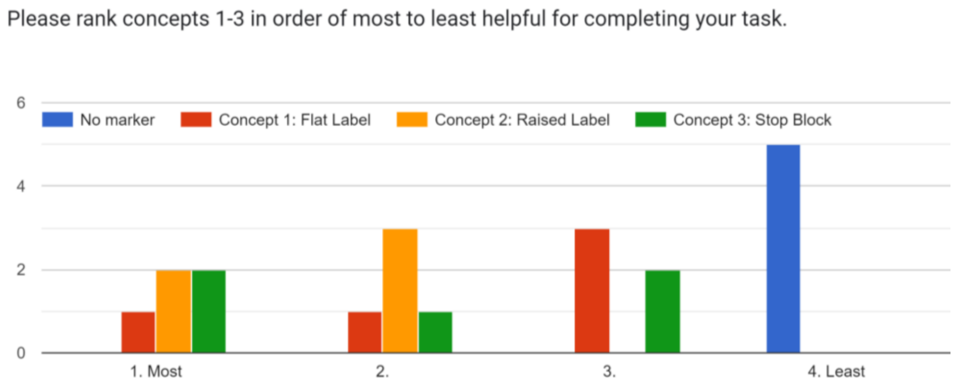


Figure 69: The users' rating of each concept, from most to least helpful. Note that any marker was preferrable to none at all.[5]

The result suggests that all three marker concepts performed better than using no marker at all. The label concepts, Concepts 1 & 2, were overall more popular, with Concept 2 never scoring bottom 3 even once. It's possible that this is because Concepts 1 & 2 are more familiar to the users than Concept 3.

However, according to user comments, Concept 3 gives better feedback and is less inconvenient (than Concept 2) since it can be disengaged when not used. Users also noted that Concepts 2 and 3 have a clear advantage over Concept 1 in cases of limited visibility, while Concept 2 has a clear advantage over Concept 3 in cases with limited space.

While the raised concept scored slightly higher than the flat concept, it did not meet design requirement 1 – "*The product should be easy […] to implement (in the current machine).*" – properly because it risks interfering with surrounding equipment. Another concern was that Concept 2 might interfere with moving components if a large portion of the component is in contact with the markers all the time. With this in mind, Concept 2 was not selected for further development.

4.4 Reflections

Some good concepts that did not make the cut were omitted from the report. This included ideas for features that required extensive overhauls of the machinery or were too futuristic to be realistic for this project. In other words, they failed the selection criteria from the get-go.

For all tests, the sample group consisted of novice users without any previous experience with CBP34. Since time was of essence and it was easier to come by novice users, which is why the sample size consisted exclusively of novice users.

Another aspect that encouraged focusing on novice users at this stage in the design process, was that the expert users were such proficient operators that they would be able to depend on their own experience to a greater extent. The expert users would therefore be less likely to depend on the design allowances to solve the task, meaning insights gained from expert user tests might not be as useful for the subsequent development process. Furthermore, it was thought that a product that serves novice users well, would also be helpful for expert users.

There was an odd number of concepts between the two concept groups: 3 label concepts and 2 stop block concepts in the first test, and 2 label and 1 flip stop concept in the second. This makes any statistical analysis less reliable. This, in combination with the small sample size, meant the user comments were given a lot of weight in the subsequent test result analysis. Proper test preparations are of utmost importance, as this helps the design team modify the tests to achieve reliable results. For example, a narrower rating scale (1-3) was used during pilot testing in preparation for the tests previously described in this chapter. This was later changed to a broader scale (1-5) to obtain more nuanced test results. During the pilot test, the user reported difficulties rating all concepts accurately because the rating scale was too narrow.

During the first test, the prototypes were purposely created to be simple and unrefined in order to encourage honest user critique. This strategy proved successful, as the users provided a lot of interesting feedback that sometimes went against the designer’s own opinion. For example, there was an expectation that the magnet stop and the arrowhead concepts would perform well, however they were not particularly favored by the users.

During the second test, the prototypes were more refined in order to create a more believable experience, as some users in the previous test had experienced some confusion due to difficulties grasping the context. This approach was quite successful, and the users found it easier to play along and focus on the tasks at hand.

The tests highlighted the importance of conducting continuous user tests, as the results were of great help in development. However, it’s clear that the use scenario has to be communicated clearly: what the context is, what you expect the user to do etc. The danger in unclear test instructions is a negative impact on the results because the users find the concepts less intuitive than they would if they understood the assignment.

5 Deliver Phase

The Deliver Phase sought to refine and evaluate the final product. Based on the user tests conducted in the previous phase, the label concept was selected final product, and refined based on user feedback from the same test. Finally, the usability metrics of the finished, high-fidelity prototype were tested and evaluated.

5.1 Final Concept Selection

After the previous user tests, the selection pool had narrowed to two viable concepts: the flat label concept (Concept 1) and the stop block (Concept 3).

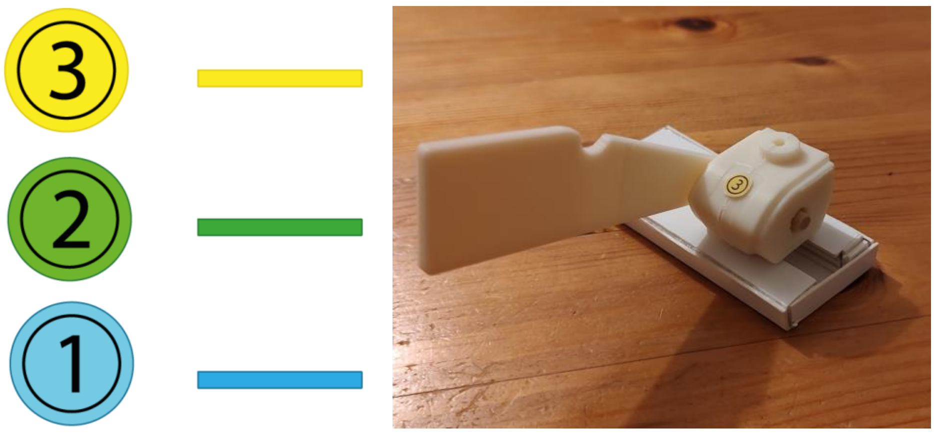


Figure 70: The last two remaining concepts, the flat label (left) and the stop block (right).[5],[14]

The aim of the second part of this thesis was to develop a final product that accurately meet the needs of its target users i.e., a *usable* product. Before entering the stage of final concept refinements, a last question remained: do both concepts fulfill the project requirements?

To answer this question, the two concepts were evaluated based on how well they fulfilled the design and usability requirements. In the Define Phase, five design requirements were formulated as follows:

1. *The product should be easy and cheap to produce and implement (in the current machine).*

Compared to Concept 3, Concept 1 seems easier and cheaper to both produce and implement in the current machine. However, had the stop block been designed for a machine in earlier stages of development, the production and resources required machine implementation would probably have been lower.

2. *The configuration procedure should be quick.*

Both concepts support quick configuration of the hardware settings. Due to the different types of user feedback the concepts provide (multisensory vs. visual), the stop block might be more suited in cases of poor visibility or of settings adjusted in the vertical direction. In these cases, the stop block might provide better support than the flat label.

3. *The configuration should be easy to complete with a high degree of task accuracy.*

Both concepts afford easy task completion with a high degree of accuracy since their positions are accurately calibrated during machine installation. However, the stop block might give more definitive feedback, thus performing a hair better than concept 1 in this arena.

4. *It should be easy to complete the configuration task on the first try.*

Both concepts provide some kind of clear feedback. However, the intuitiveness and ease of use of each concept can skew how well they meet this criterion. As previously noted in section 4.3.2.2.1, Concept 1 scored higher than Concept 3 regarding both intuitiveness and ease of use.

5. *The product should be durable.*

It stands to reason, that the stop block concept is more durable than Concept 1 due to being made out of more durable materials. However, due to its shape the flat label is less likely to be negatively affected by surrounding machine equipment, making it less susceptible to wear and tear than Concept 3. Furthermore, Concept 1 contains no moving parts, thus minimizing the need for maintenance compared to Concept 3. Should the label be damaged, it’s easier to replace it than it would be with the stop block.

The usability requirements could be evaluated based on the users' ratings of the concepts during the second user test. The ratings are pictured in Figure 71 below.

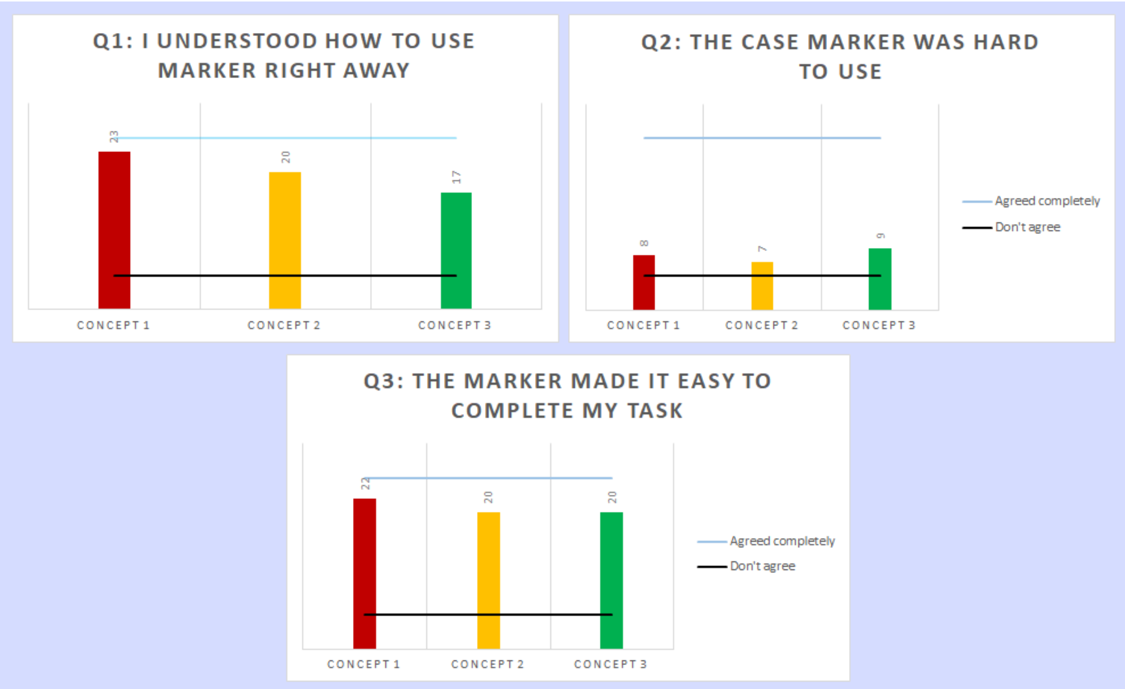


Figure 71: Resulting concept scores from user test 2. Q1 measures the concept's intuitiveness, Q2 the perceived ease of use and Q3 the overall user satisfaction.[5]

Based on the concept score results from User Test 2, the users found Concept 1 more useful than Concept 3 overall. Concept 1 scored very high for intuitiveness ($\frac{23}{25}$ points) and user satisfaction ($\frac{22}{25}$ points), while Concept 3 scored $\frac{17}{25}$ and $\frac{20}{25}$ respectively. The difference in intuitiveness might be because Concepts 1 seem more familiar to the users than Concept 3. The differences in the user satisfaction ratings (Q3: "*The marker made it easy to complete my task*") might be attributed to the fact that the stop block concept requires more user input during the interaction.

When asked to rate the perceived ease of use, the test participants awarded both concepts good scores, $\frac{8}{5}$ (Concept 1) and $\frac{9}{5}$ (Concept 3) respectively. Since Concept 3 provides multisensory feedback (haptic and visual), the users noted that Concept 3 gave better feedback than Concept 1, which only provides purely visual feedback. This can potentially be especially advantageous in cases of limited visibility.

With all these factors combined, the flat label concept, Concept 1, was selected for further development. Compared to Concept 3, the flat label is more scalable, and easier to produce and implement in the current cardboard packer machine. The flat label also appears more intuitive and easy to use than the stop block, meaning the chances of receiving high scores for the user satisfaction are higher. While Concept 3 was considered broadly applicable, it would require a lot more development to feasibly reach full functionality than the given timeframe would allow. Therefore, the concept was not developed further.

For convenience, the selected concept will be referred to as "CaseMarker" from now on.

5.2 Concept Refinement

Based on user comments during User Test 2, there are some CaseMarker features that could be improved:

- As the marker relies on sight alone, the design needs to be very clear in order to guide the users properly, for example in terms of width, color and text elements.
- The design should communicate with its surroundings, with proper affordances in place that help users understand how the product should be interacted with.

When designing products that provide a good user experience, maintaining internal and external consistency is of great importance. Since the target users are so diverse, the product should to be easy to use no matter the user's experience level i.e., require minimal user effort. Consistent product design makes it easy for the user to adopt and incorporate the product in their workflow. The UX Magazine [23] describes design consistency as:

> *"[…] repeating UI components as required and ensuring constant behavior throughout the product. […] The [features] need to be consistent with the product's main UI design so the users don't perceive them as interruptions. Also, keep consistency when designing UI patterns for different purposes."*

This highlighted the importance of also evaluating the cheat sheet during the refinement of the label concept. The cheat sheet is one of the most important changeover tools, as shown in the task analysis in section 3.2, and should as such be used in tandem with the Case Marker. Therefore, the designs both have to incorporate signifiers that communicate to the users that the products are part of the same navigation system. This invites less confusion and increases the usability of the label concept.

During refinement of the Case Marker, two use cases were considered:

1. The customer has three recipes, each with unique setting's parameters, that they regularly change between.
2. The customer has three recipes, of which two recipes often share the same recipe values.

The Case Marker can be applied in cases with a maximum of 3 recipes. However, should the user have fewer standard recipes, the Case Marker can still be used.

5.2.1.1 Label Refinement

The concept refinement process mainly consisted of experiments with label thickness, shape and color. In the interest of keeping the label narrow, an accompanying recipe number marker was created to be put beside the setting's scale and act as easy reference for each of the colored labels. The recipes were assigned the colors blue, green and yellow, i.e. distinctly different colors to help distinguish them from each other, see Figure 72.

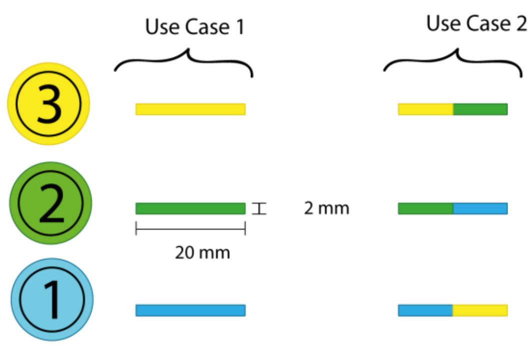


Figure 72: Refined version of the Case Marker labels.[5]

Red was not considered simply because of its association with important signs or emergency situations within an industry environment.

5.2.1.2 Cheat Sheet Refinement

The goal of the cheat sheet refinements was to improve its readability by smart application of color and layout design. The original cheat sheet is loaded with information, making difficult to get a good overview and prioritize the tasks, see Figure 73.

Tetra Pak		Recipe 1 TBA1000E 3x6 Tray	Recipe 2 TBA1000E 2x3 WASF	3 TBA200SL 3x8 straw 5 mm open tray
A1	Fallen package detector	130	130	130
A2	Infeed guide	75	75	57.3
A3	Infeed guide	75	75	57.3
A4	Belt brake – width	69,5	69,5	38
A5	Belt brake - offset	-1	-1	2
A6	Fallen package detector	90	90	80
B1	End stop grouping	914	914	773
B2	Stop arm	922	922	781
B3	Grouping Pusher Rail - Height	200	200	120
B4	Grouping Pusher Rail - Length	230	230	85
B5	Grouping top support – Length	230	230	85
B6	Grouping top support – Height	175	175	105
B7	Grouping top support – Width	70	70	44

Figure 73: The original cheat sheet, displaying information about each hardware setting and the corresponding recipe parameters for three standard recipes.[14]

Each column has a different color, which helps to visually separate the three recipes. On the other hand, it's harder to visually separate the rows. This results in mistakes when the operators try to quickly compare the recipe parameters of each setting.

In an attempt to improve the readability of each row, the recipe parameters that differ between each other were highlighted, see Figure 74. The column colors were selected to match those of the Case Marker. Each unique parameter on each row was highlighted using a red dot.

However, the red highlights seemed to increase the information overload because of the large number of unique recipe parameters. The large number of red highlights made the unique recipe parameters less visible, thus defeating the purpose of the red highlights. This made the highlights seem redundant.

CBP34		Recipe 1 TBA1000E 3x6 Tray	Recipe 2 TBA1000E 2x3 WASF	Recipe 3 TBA200SL 3x8 Straw 5 mm. Open tray
A1	Fallen Package Detector	130	130	130
A2	Infeed Guide	75	75	57,3
A3	Infeed Guide	75	75	57,3
A4	Belt Brake – width	69,5	69,5	38
A5	Belt Brake - offset	-1	-1	2
A6	Fallen Package Detector	90	90	80
B1	End Stop Grouping	914	914	773
B2	Stop Arm	922	922	781
B3	Grouping Pusher Rail - Height	200	200	120
B4	Grouping Pusher Rail - Length	230	230	85
B5	Grouping top support – Length	230	230	85
B6	Grouping top support – Height	175	175	105
B7	Grouping top support – Width	70	70	44

Figure 74: The first iteration of the cheat sheet. [14]

Instead, the row readability was enhanced by alternating the row colors, see Figure 75. The intention was to make it easier to visually distinguish the parameters belonging to each hardware setting, while still provide clear, visual separation of each standard recipe.

CBP34		Recipe 1 TBA1000E 3x6 Tray	Recipe 2 TBA1000E 2x3 WASF	Recipe 3 TBA200SL 3x8 Straw 5 mm. Open tray
A1	Fallen Package Detector	130	130	130
A2	Infeed Guide	75	75	57,3
A3	Infeed Guide	75	75	57,3
A4	Belt Brake – width	69,5	69,5	38
A5	Belt Brake - offset	-1	-1	2
A6	Fallen Package Detector	90	90	80
B1	End Stop Grouping	914	914	773
B2	Stop Arm	922	922	781
B3	Grouping Pusher Rail - Height	200	200	120
B4	Grouping Pusher Rail - Length	230	230	85
B5	Grouping top support – Length	230	230	85
B6	Grouping top support – Height	175	175	105
B7	Grouping top support – Width	70	70	44

Figure 75: The final version of the cheat sheet. [14]

5.3 Usability Testing

To determine whether the Case Marker fulfilled the design requirements, usability testing was performed on-site at Tetra Pak.
The test setup consisted of two settings, B6 and B7. The B6 scale was marked with Case Markers, while B7 was kept as-is, see Figure 76. The

users (N = 3) each had different levels of experience: novice, intermediate and expert.

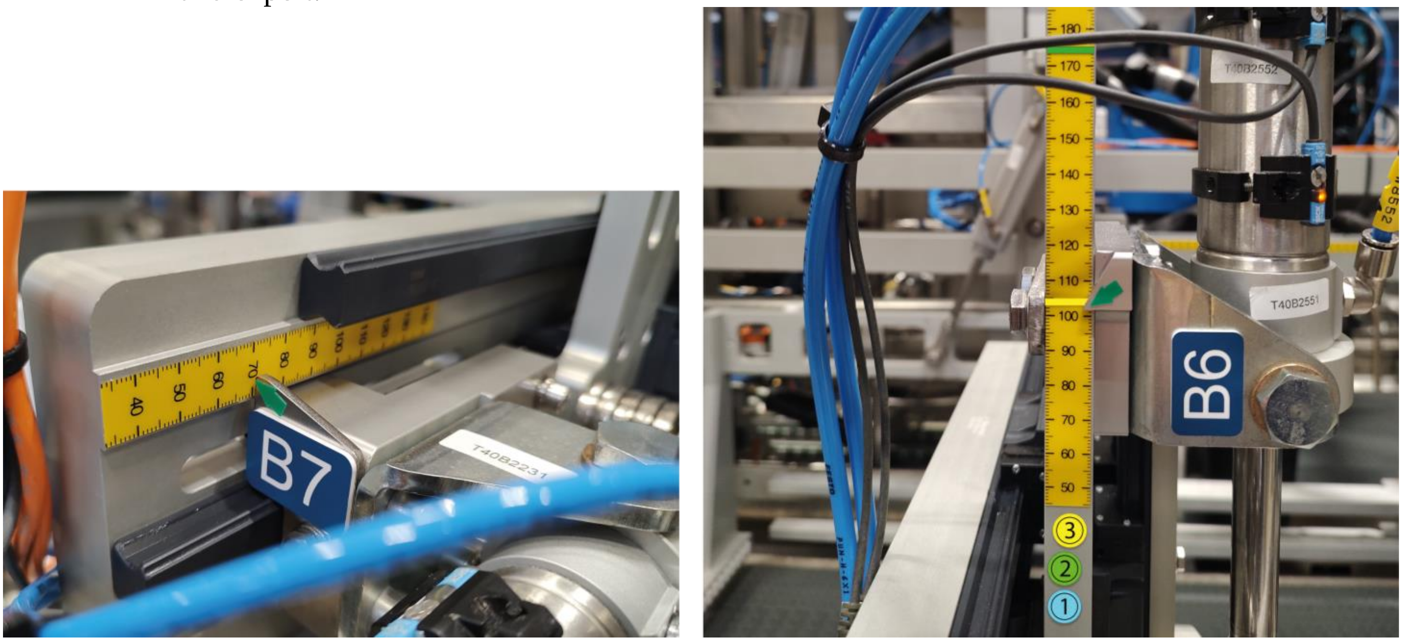


Figure 76: Test setup during the final usability test. [14]

The test was conducted in two steps:

1. The user adjusts the B7 setting using the original cheat sheet and an unmarked setting's scale.
2. The user adjusts the B6 setting using the updated cheat sheet and a labelled setting's scale.

Lastly, the test users and other observing participants were asked to fill out a satisfaction survey. The users' attempts to complete the configuration of each setting were timed, and the time differences compared, t_0-t_1 = Δt. The test results can be found in Table 23.

Table 23: Usability test data.

	Experience Level	***No Case Marker Time, t_0 (s)***	***Case Marker Time, t_1 (s)***	***Time Difference, Δt (s)***	***Comments***
User 1	Novice	37.71	26.21	-11.50	"Aiming for a label requires less effort!"
User 2	Intermediate	17.23	20.05	+2.82	"I like that the label numbers are included, as a reference."
User 3	Expert	19.79	14.95	-4.84	"It's a little unclear which edge of the label I am aiming for."

Though the sample group is small (N = 3), there is a marked time difference between the two settings, especially for the less experienced user (User 1) who completed the task 11.50s faster with aid of the Case Marker.
For User 2, however, the time to complete the task increased, $\Delta t = +2.82s$. The reason for this could be that the B6 setting is moved vertically, not horizontally like B7. While User 1 adjusted B6 downwards, User 2 adjusted B6 upwards, which was more complicated as he had to work against the gravitation. Pushing and judging the setting's value simultaneously meant that the difficulty level for User 2 was slightly higher than for User 1, not least because he actually dropped the component once during his attempt.
User 3 (expert user) completed the test with a resulting time difference of t = -4.84s. While User 3 completed the B7 task quickly, he made a mistake when reading the setting's scale, adjusting B7 to a position = 36 cm rather than position = 44 cm. This is interesting from a task accuracy perspective, as it further proves the point of low task accuracy inherent in the current changeover procedure.

Though a difference of only seconds might seem insignificant, the impact is massive when multiplied across all hardware settings of the cardboard packer. Thus, the time difference can be said to definitively indicate, that the Case Marker provides a marked improvement in both efficiency and task accuracy. The test users all agreed that the presence of Case Markers lowered their mental load and meant they could work without double and triple checking the cheat sheet.

It's possible that the participants completed task the configuration of setting B7 faster than that of B6 due to getting some practice from the first configuration. To mitigate the possible impact of observing other users, the less experienced users were asked to complete the test first. The "learning effect" should affect the less experienced users more and thus contribute to better results for the first two users, either as a result from getting practice or observing previous test participants completing the tasks. This might contribute somewhat to the time reduction, though it could be argued that this does not have a major impact on the validity of the results, since the expert user also showed a significant reduction in time.

The test results would be more reliable if the sample group was bigger, and the test settings were both adjusted in the horizontal direction. For optimal evaluation a full usability test of the entire changeover sequence for all 50+

settings would be beneficial. However, the test results should arguably be enough to prove the validity of the Case Marker.

5.4 Final Product

During the usability test described in section 5.3, the users reported that they wished the Case Marker included some feature to tell them which edge of the sticker to aim for. This could be done decreasing the marker thickness, include an icon or alter the shape, see Figure 77. Each option has certain pros and cons.

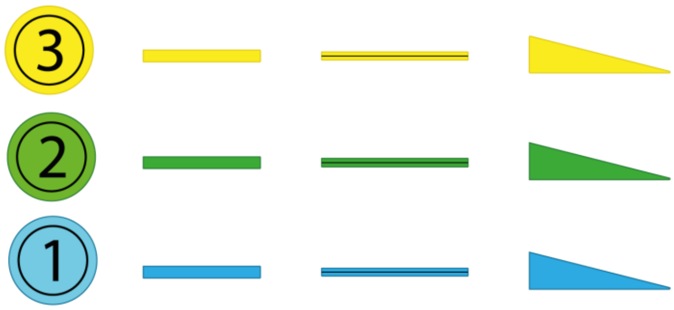


Figure 77: Possible refinements following the usability testing.[5]

While narrower labels could easily indicate the edge to aim for, there is a risk they would not provide the desired navigation overview from a distance. A marker with a bisecting black line would provide a target and also tie the label and number marker designs together. Triangular labels would also provide an easy target and tie the design together with the triangular setting's plates. However, it might be harder to visually communicate when several parameters overlap. Another comment was that yellow markers blend into the yellow of the setting's scale, making them hard to see properly.

The Case Marker colors are a challenging aspect:

1. The colors have to stand out and not blend into the background.
2. The colors should not have other pre-established connotations, such as emergencies.
3. The colors should be easy to differentiate from each other.

After some deliberations, the final Case Marker colors selected were blue, green and orange, see Figure 78. Each marker is bisected by a black line, similar to the thin black line encircling the number on each recipe marker.

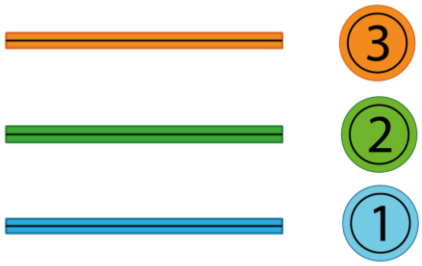


Figure 78: Final CaseMarker improvements.[5]

5.4.1 **CaseMarker**

The final CaseMarker is a product meant to improve the user experience during configurations of slider-based hardware settings in the cardboard packer machine. The CaseMarker consists of two parts: a set of color-coded label decals and an accompanying setting's cheat sheet, see Figure 79.

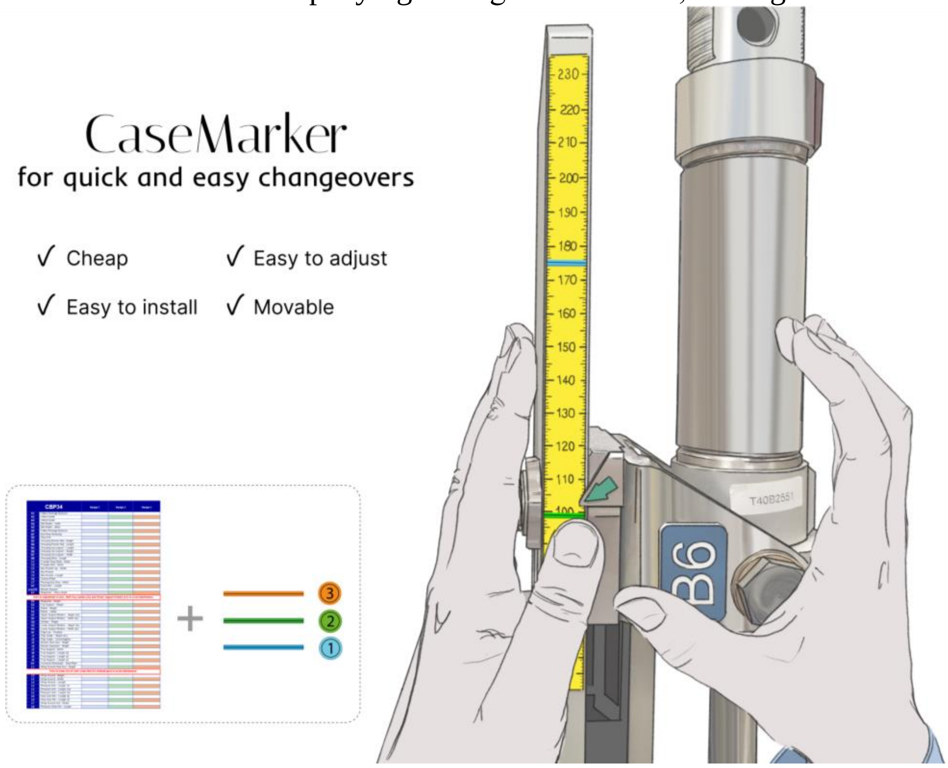


Figure 79: The CaseMarker. [5]

The decals are made from a color-fast vinyl substrate. The unprinted side is coated in pressure-sensitive adhesive that attaches securely to a range of materials such as metal, glass, and plastic. The decals are resistant to dust, heat, and liquids, making them ideal for application in the food distribution industry.

The accompanying cheat sheet is a printed sheet of paper displaying a list of the hardware settings and their corresponding values for up to three different standard recipes. The standard recipes are color-coded to match the color scheme of the CaseMarker decals. The cheat sheet is distributed as a pre-configured template, allowing customers to easily configure the recipe parameters according to their own needs.

The CaseMarker system is designed to be flexible and easy to adjust to every customer's needs, whether permanent or temporary. Upon arrival to the customer, the operator can easily install the label in the machine, in a position that marks the desired recipe value for each hardware setting. See Figure 80 for a step-by-step guide.

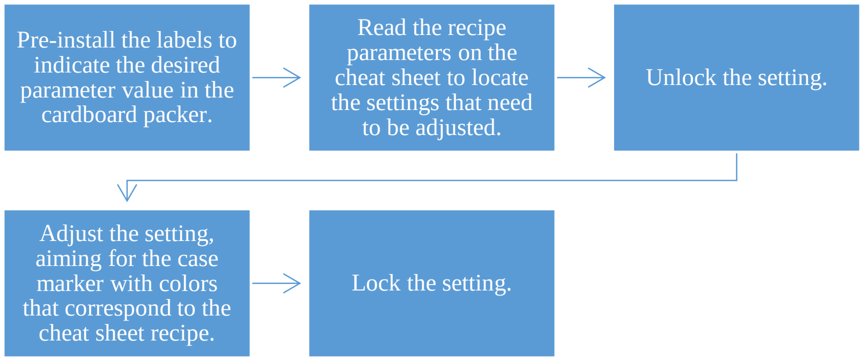


Figure 80: A step-by-step guide for how to use the CaseMarker.[5]

Minor or major position changes – for example in response to new package dimensions – are easily done because of the decals' design. Should the hardware setting need to be re-calibrated in response to temporary dimension changes, the decals can be easily ignored since they don't interfere with the range of movement for surrounding equipment.

5.4.2 Final Product Evaluation

One of the goals of this thesis was to develop a solution that improved the user experience during configuration of the cardboard packer's hardware settings from the operator's point of view. It was also determined that one way to achieve this goal, was by improving 3 of the 5 usability components. In chapter 2 section 2.2.1, the selected usability components were defined as:

- *Learnability*: the user can quickly learn how to use the system.
- *Efficiency*: the user can achieve a high level of productivity when using the system.
- *Satisfaction*: the user perceives the system as (subjectively) pleasant to interact with.

Based on the results from the usability testing conducted in section 5.3 of this report, none of the test users reported any difficulties learning how to use the Case Marker, which means the learnability requirement can be considered fulfilled. As the test results in Table 23 show, the Case Marker provided a marked improvement in task efficiency compared to the norm. Lastly, all users expressed an appreciation for the Case Marker, as it lessened their mental load and was perceived as a helpful tool.

With all this in mind, the Case Marker can be said to have fulfilled the selected usability criteria, see Table 24.

Table 24: Usability evaluation of the final product.

Usability Requirement	***Fulfilled?***
Learnability	Yes
Efficiency	Yes
Satisfaction	Yes

In order to be considered successful, the solution also had to fulfill the design criteria that had been defined based on stakeholder input and user research, see Table 25.

Table 25: Evaluation of whether the solution fulfill the stipulated design criteria.

No	*Requirement*	*Fulfilled?*
1	The product should be easy and cheap to produce and implement (in the current machine).	Yes
2	The configuration procedure should be quick.	Yes
3	The configuration should be easy to complete with a high degree of task accuracy.	Yes
4	It should be easy to complete the configuration task on the first try.	Yes
5	The product should be durable.	Yes

The first criterion states, that the product should be easy and cheap to produce and implement in the current cardboard packer machine. The final product consists of a cheat sheet and CaseMarker labels that are produced from cheap materials, using cheap production methods. The labels are easy to implement in the current machine, as they don't interact with surrounding equipment and are fixed in place by sticker glue. Therefore, the product can be considered to be both "easy" and "cheap".
The second criterion states, that the configuration procedure using the final product should be quick. As the time results from the usability testing in section 5.3 show, the CaseMarker meets this criterion.

The third criterion states, that the final product should support task completion with a high degree of accuracy, something that is also apparent from the test results. The tasks were completed quickly and accurately. The users also reported that having a marker to relate the setting to, lessened their mental load and helped them aim for the accurate setting's value for each hardware setting.

The fourth criterion state, that it should be easy to complete the task on the first try. During the usability testing, no mistakes were made using the new CaseMarker, but that could not be said for the original setting setup! The users reported that it was remarkably easy to complete the task in one try when they had a marker to "aim" for.

The fifth criterion states that the final product should be durable. Sticker/decals are not extremely durable due to the materials they are typically made of, however they are not as susceptible to wear and tear as other concepts previously explored in this report, since flat stickers typically don't interfere with surrounding equipment. The sticker is also easy to clean in cases of splatter of product waste for example. If the sticker is damaged beyond use, it is also easy and cheap to replace with a new one.

With this in mind, I’d argue that the final product can be considered durable.

With all this in mind, the final product can be said to provide a positive UX for the cardboard packer operators. The CaseMarker improves their work situation by providing a simple and cheap way to increase task accuracy and lessen the operator’s mental load.

6 Discussion

In this chapter I discuss the applications of UX design on physical products and MMIs. The chapter also provides a summary of the results from Part 1 and 2 of this thesis, and reflections on the design process. Finally, suggestions for future work is provided.

6.1 A Word on User Experience Design

When researching for this thesis, it quickly became apparent just how neglected user experience in relation to hardware components are in the scientific field. Most of the literature and studies published the past few decades about the subject mainly concerns UX design in digital environments. For example, most of the studies included in the *Design, User Experience, and Usability* from the Third International HCI Conference 2014 focus on the UX in relation to computer software, smartphone applications and VR/AR technology. [24][25][26]

The same trend could be seen in the product development industry, where the main focus is either designing digital services, or pure hardware functionality with very little attention paid the interactions where humans and the physical world intersect. In instances where the MMIs are considered, it's primarily in relation to a handful of aspects such as ergonomic design, but there is little thought to the big picture.

By definition, UX design encompasses more than that, as stated in section 2.2 of this report. I'd like to argue that the scientific and product development community seem to have become blind to this aspect of UX design, even though we all primarily live in the physical world.
If I were to speculate on the reasons why so little attention is paid to physical UX, I'd say it's two-fold:

1. *Lack of Incentives*: designing physical products is generally more expensive than digital ones. The development process includes

several iterations of prototyping and testing, and the costs involved in creating a series of for example foam prototypes versus wireframe mockups differ, as does the challenges involved in conducting tests with users in person rather than digitally.
These factors are further compounded for industries with long product life cycles, or where only a few agents dominate the market. Slow sale cycles and/or little competition create an environment with low incentives to improve and evolve.

2. *The Cool Factor*: The future is digital, a sentiment that has been the general consensus in the Western world for decades already. With our daily lives increasingly spent interacting with the digital or semi-digital world, it's no wonder Human-Computer interaction design has risen to the forefront of product development and related scientific fields. Advances in Human-Computer interaction generate bigger headlines than similar advancements in Human-Machine interaction.

Nevertheless, it seems the need for good physical UX is ever-present in people's lives. In the internal UX study[16], for example, the end users of Tetra Pak equipment repeatedly expressed wishes for different types of UX accommodations such as improved user access and customized user manuals. Similar sentiments surfaced in my own research, with stories of users "hacking" the hardware of their own volution simply because it would simplify their own workflow. The wishes for an introduction of a preliminary signage system is another example.

This should tell us, that users are still very much affected (and inconvenienced) by physical products and services. And judging by the reception of the design solution presented in section 5.3, users are very appreciative of even minor improvements.

6.2 Project Summary

The user experience (UX) of man-machinery interactions (MMI) carry implications for everything from machine safety and ergonomics to the subjective sense of customer satisfaction. Thus, there is great potential for gaining a competitive advantage with thoughtful UX design.

Knowing this, the goal of this thesis was to investigate and improve the UX of Tetra Pak's cardboard packer machine. The MMI in focus was the process of changeover between 2-3 standard recipes, and more specifically the configuration of slider-based hardware settings. To do this, the thesis was split into two main parts: a usability evaluation and the development of a design solution.

6.2.1 **Part 1: Usability Evaluation**

UX is a subjective term that encompasses the entire range of an MMI, including the product's usability. For this thesis, a special focus on the usability aspect was selected because it offers possibilities to evaluate a subjective concept in terms of more objective parameters. Nielsen writes, that the usability of a product, system or service is always relative to specific users and specific tasks.[10] Thus, the usability evaluation presented in part 1 of this report can only be said to apply with certainty specifically to the operators of the CBP34, during hardware configurations. However, many of the usability insights can be applied to other Tetra Pak machines and users and be used to make more informed design choices during product development.

One example is the creation of user personas to gain a more intimate understanding of their needs and work conditions. In this thesis, the operators were distilled in two personas, see Figure 81.

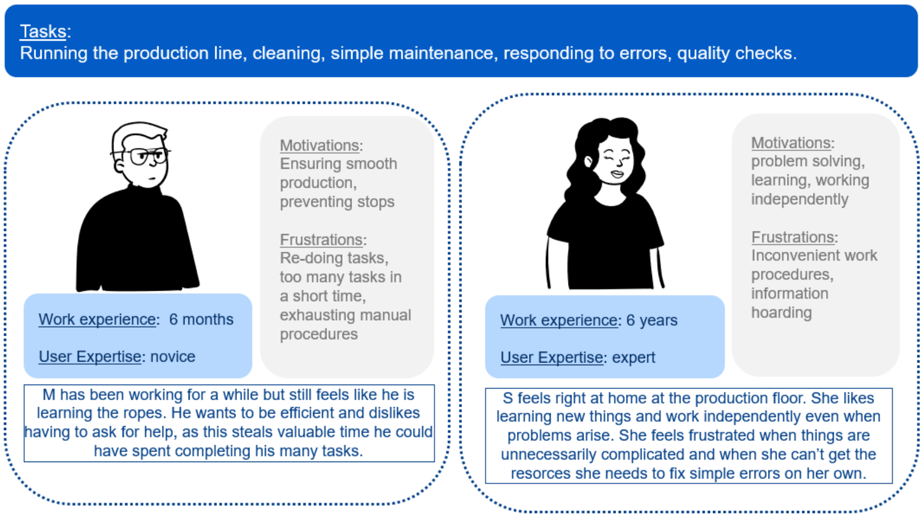


Figure 81: User personas modelled after the cardboard packer's operators. M and S have the same work tasks, but have different levels of work experience, motivations and frustrations.[5]

Design is – at its core – an exercise in empathy. If the designers loose touch with the end user, they risk designing products that solve irrelevant problems or meet the wrong needs. In *The Design of Everyday Things*, Norman writes,

> *"Engineers are trained to think logically. As a result, they come to think all people must think this way, and they design their machines accordingly. [...]*
>
> *'Why are people having problems?' they wonder.*
>
> *'You are being too logical,' I say. 'You are designing for people the way you would like them to be, not for the way they really are.'"* [27]

In short, designers and product developers who get too stuck in their own heads and neglect seeking out the perspectives of others create elegant solutions that are not adapted to the way an average person would interact with them.

For the purpose of this thesis, the operators' personas were a valuable tool to understand the users and their needs, but also served as important reminders throughout the design process of *who* the design is meant to serve. I would argue that this is especially important in cases where the designers have limited access to the target users themselves.

Using the personas M and S as lenses, the strengths and challenges of the cardboard packer's MMI became more clear and easier to identify. A good illustration of this are the insights depicted in Figure 82 below:

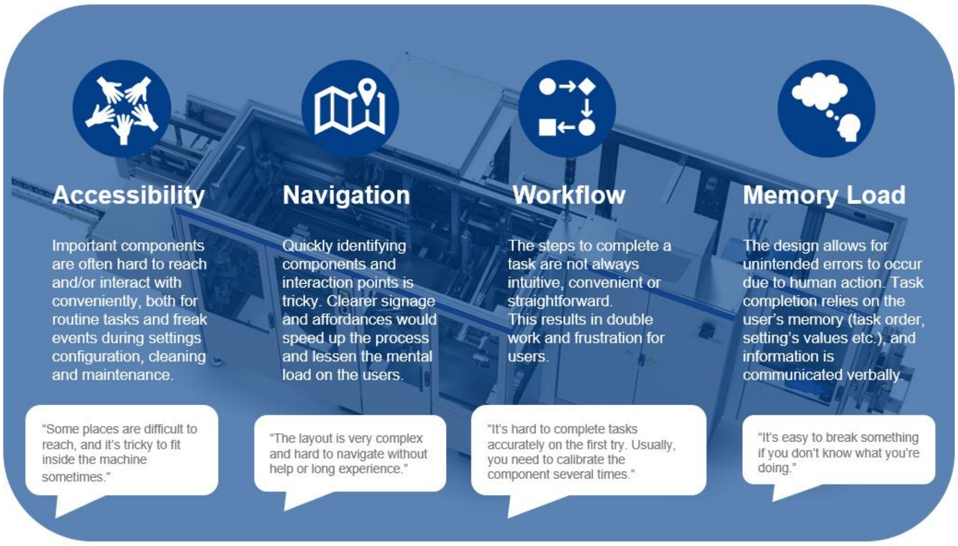


Figure 82: Summary of the usability evaluation.[5]

While the focus of the usability evaluation was on the changeover MMIs, I found that it is hard to isolate only a few aspects of the MMI, since the usability of one aspect is so interconnected and affected by other components and processes. This observation is echoed by Nielsen:

> *"Usability applies to all aspects of a system with which a human might interact, including installation and maintenance procedures." [10]*

Therefore, I'd like to argue that those who wish to evaluate a system's usability, should always consider the entire system. In Tetra Pak's case, this would mean that the usability of any machine component should be considered not only in relation to surrounding equipment but the entire machine, its MMIs and production line. Similarly, the design should not only be optimized for a single task but adapted to both normal and extreme operating conditions. For the cardboard packer, a striking example is the accessibility challenges during normal cleaning vs emergency cleaning. Emergency cleaning due to dairy waste from damaged packages can in many ways be said to require *better* machine access than planned cleaning. The time pressure is higher, and the operators are more likely to need access to machine components not normally intended to be accessed.

What use is a usability evaluation of such a complex machine as CBP34? While some the evaluation uncovered some easy fixes to improve the usability that can be applied on the current machine, usability design is generally most effective when applied early on in product development.

Usability considerations are easier, faster and cheaper to implement and accommodate for early on in a design process, than as an afterthought. This is exemplified by the effect on the result due to limitations imposed upon this thesis project because I was working on a pre-existing machine. As a result of these limitations, several promising design ideas had to be scrapped!

6.2.2 **Part 2: Design Solutions**

The second part of thesis revolved around the development of a design solution to address some of the usability challenges identified during the usability evaluation.

The design concepts presented in this thesis came to mainly revolve around different types of feedback, which ranged from purely visual to multisensory touch feedback. Norman defines feedback as some way that the system communicates the result of an action, to let the user *"know that the system is working on [their] request"*. Feedback can be communicated in numerous ways, including visually, audibly, by touch, or by influencing our vestibular and proprioceptive senses.

For optimal MMI, the feedback must be immediate. A delay in feedback that is even a tenth of a second too long will make the user start to doubt the interaction. [27]

The feedback must also be informative. Tetra Pak machines use red lightbulbs to signal when an error has occurred, but the flashing red light does not inform the users of *what* has gone wrong, or *where*. This is both annoying and stressful for the operators trying to get the machine up and running as quickly as possible. This example tells us, that the system's feedback must be carefully designed, because poor feedback can be worse than no feedback. The purpose of feedback is to confirm an action, but in a manner that is informative and unobtrusive.

In my assessment of the original hardware setup, it became evident that the operators did not receive adequate system feedback. Feedback can be a valuable tool to support the users during MMIs. In this case, the lack of proper system feedback meant that the users' mental load increased as they were increasingly forced to divide their attention between the task at hand and their environment.

Some interesting concepts could be found on the “high feedback” end of the scale. I think concepts such as the Stop Block, Slot Mechanism and similar were very promising in terms of usability, but were ultimately not found applicable in this project due to the late stage of product development the cardboard packer machine is in. As it was, those concepts did not fulfill enough usability and design requirements, since they were harder to integrate seamlessly into a pre-existing machine architecture without altering the surrounding equipment/components. Had this thesis been made in relation to a machine in earlier stages of development, the concepts would have been very promising indeed. Thus, I would strongly suggest that the company considers some of these discarded concepts when developing their next generation’s cardboard packer.

On the “low feedback” end of the scale, the chosen CaseMarker concept can be found. This concept fulfilled both the usability and design requirement criteria. Among the main advantages from the stakeholders’ point of view was that the marker is both usable and cheap to produce and install. Based on this, the CaseMarker was selected for the final product.

For this thesis, the selection of multisensory touch feedback versus purely visual feedback was not clear-cut. Firstly, there is a range of other types of feedback and ways of designing touch/visual feedback that was not explored in depth in this thesis, but that could potentially be applied to similar projects or products. Secondly, different types of feedback are more suitable to certain environments than others. In our case, visual feedback (such as provided by the CaseMarker) is more suitable for well-lit environments where it’s easy to get a look at the marker from straight above or straight ahead. Looking at the marker from an angle, skews the perspective and might negatively affect the ability to set an accurate parameter value on the first try. Multisensory feedback like that provided by the Stop Block (i.e., touch + visual) is more suited to poorly lit environments and odd angles. In short, the merits of different types of feedback depend on the situation and the information the system is must communicate.

6.3 The Design Process

The lack of publications about the UX of “physical products” did initially pose a bit of a challenge when planning this thesis. To overcome this problem, I went back to review some of the foundational literature concerning the disciplines of user experience and interaction design. Based on this, I formulated some general UX guidelines that could be applied to a hardware UX design,

1. *Understanding the User*: Designers can’t design *experiences*, only products that *invite* to a certain experience. By gaining an intimate understanding of the end user and their needs, designers can create features that are attractive to users.
2. *Usability First*: the usability of a product must be the primary concern of hardware design, as it’s one of the key elements of UX. Good usability will draw little attention, but poor usability will always be noticed by the end user. The usability should not only be considered in terms of the most common interaction scenarios, but also take the extremes into account.
3. *Design for the Weakest Link*: all target groups are more or less diverse, with a unique set of strengths and challenges. Identifying the weakest features of the current design can provide valuable information on how to move forward. Similarly, identifying the type of support (affordances, signifiers etc.) needed to provide the least proficient users with a good user experience, will create designs that also benefit experienced users.
4. *Only Necessary Features*: as a designer it’s easy to get carried away, but adding an abundance of neat features can quickly transform great design to cluttered design. Information and option overload makes for an overwhelming user experience.
5. *Internal and External Consistency*: maintaining consistency across products and systems makes for a smooth user experience. Consistency supports the components of usability such as learnability, memorability and efficiency.

The basic hardware design guidelines proved to be useful tools during my design process. Following guidelines 1 and 2 proved challenging at first, since my access to end users (customers) was limited. Besides interviews with and field observations of super and expert users present at Tetra Pak, I supplemented my user research with try-it-yourself sessions during which I interacted with the CBP34 as a stand-in for the end user. This certainly provided a lot of valuable insights, though the efficacy of this data can be discussed, since I lacked proper operator training. However, I was able to also review interview material from UX studies[16] performed at Tetra Pak in 2021. This data became a valuable point for comparison when evaluating my own user data. Since the study premise differed, it would have been preferrable to get direct access to the end users, but I still found that the data largely coincided with my own observations.

6.3.1 **Methods**

Several methods and techniques were used throughout this project, but the overall workflow was primarily modelled after the Double Diamond (DD) process which consists of the phases: Discover, Define, Develop and Deliver. [1]

The DD was selected because it’s an iterative process that lends itself well to be combined with a user-centered approach, wherein design concepts were continuously refined and evaluated through user testing.

The majority of the iterations occurred during the Develop Phase, but a few times the iterations moved back several phases. Working iteratively was a good way to keep up momentum and ensured the insights and input from each iteration was incorporated in the new design cycle. This meant that the user input could continuously inform the development after each iteration.

6.3.1.1 The User-Centered Approach

The goal with striving for a user-centered approach, was to make sure the proposed design provides a solution for *the right* problem. This was done by working iteratively in design cycles with repeated evaluations, along with maximum user involvement. The aim with such iterative processes are to gather as many external (i.e. non-designer) perspectives as possible and try to find a good middle-ground in cases of conflicting interests and needs.

This approach served the overall design process well and provided much needed guidance in pivotal design choices. However, direct access to the end users (i.e. the operators employed by Tetra Pak’s customers) was very limited, which complicated the design process. Instead, the majority of the initial user input came from second-hand accounts of customer feedback and visits. These accounts were given by in-house technicians and super users at Tetra Pak, as well as the design engineers closest connected to the cardboard packer machine. To mitigate the risk of missing important user pain points, I tried to triangulate the data as much as possible and look for commonalities between the insights gained from different sources.

Another factor that complicated the user-centered approach, was the timing of this report. The majority of the work was conducted during late spring and the summer months, when most Swedish companies are very busy in preparation for the summer holidays or running at minimal capacity when staff are on summer holiday. This resulted in limited access to potential test users, which slowed down the development process considerably during certain periods.

To work around this issue, different techniques were employed. For example, the user personas became an important tool for not losing sight of the target users and their needs. The lack of direct access to end users also meant that the importance of continuous user tests increased. In the early stages of development, the majority of the user input came from external novice users who had never been in contact with the cardboard packer before. The imbalance of novice input vis-à-vis expert input brought certain risks of developing solutions that were so simple they alienated more experienced users. This made the input from the experienced users in the usability test in section 4.3.2.2 important data for the subsequent final usability evaluation.

In similar projects in the future, it would be wise to thoroughly plan how and when to interact with users. This also includes careful selection of who to involve as users during research and prototype tests: A pool of participants that is too small risks skewing the design in the wrong direction, and high demands in terms of the users' time increase the risks of users dropping out. You also have to factor in the increase in experience as the users get more and more practice as they test several iterations of prototypes. If the usability is tested in terms of learnability, for example, this might impact the test results negatively.

6.3.1.2 The Project Requirements

The usability of a product is, as stated in section 6.1.1 of this report, is relative to specific users and specific tasks:

> *"The usability of a product, system or service is always relative to certain users and certain tasks. Since usability is typically measured and evaluated by having a number*

of test users, the selection of users and the design of the test are important factors that greatly affect the results." [10]

As a consequence, the results of any usability evaluation or usability design process also depend on the requirements selected for a certain project.

In this thesis, there were three different sets of project requirements: the general requirements, the design requirements and the usability requirements. The different requirements constitute the framework for different aspects of the product development:

- The general requirements define the general technical, social and environmental conditions for this project. In short, they define the context of the design.
- The design requirements define the most important criteria that the proposed design solution should meet. These requirements were – along with the input from the user tests – the most important touchpoint during the development stages of the design process.
- The usability requirements define the bar against which the successfulness of the design concept(s) was evaluated. Should the final product fail these requirements the design solution could not be considered to have improved the operator's UX, which was one of the main goals of this thesis.

The evaluation of how well the concepts fulfilled the different requirements was heavily impacted by the design of the tests, the identity of the selected test users, and the techniques used to interpret the data. In the end, this was the most challenging aspect of this thesis.

The way you value each requirement compared to the others also matters. One example is the concept evaluation based on results from User Test 2. During this test the raised label (Concept 2) received the most positive reviews in the ranking (*"Please rank concepts 1-3 in order of most to least helpful in completing your task"*) but failed some of the stipulated design requirements. If the user reviews had been given more weight than the requirements, the concept would not have been discontinued.

As a result of inconsistencies in the conduction of the tests, the resulting data is not always statistically reliable. These inconsistencies concern things like slightly differing test scenarios or some users receiving more detailed instructions than others for example. More rigorous pilot testing could have alleviated this.

In hindsight, the usability especially could have been measured better. For example, there was no target value selected for the usability measurements such as “The time to complete the task should decrease by a minimum of 5 seconds”. This can be seen as a weakness, but since only 1 concept was tested during the final Usability Testing this type of target value was not necessary. Target values are more important when comparing the usability of several products. However, it would have been a good idea to measure the original usability metrics early on in the project, rather than testing both the original setup and the new setup at the same time towards the end of the project. This would have made it easier to identify target values and new pain points. But due to the scope changing several times throughout the project it was very hard to know what metrics to measure from the start.

In the end, I think this shows the importance of detailed planning, foresight, and the conducting multiple pilot tests.

6.4 Future Work

When evaluating the UX of MMIs, it’s important to consider the interaction from start to finish. The evaluation should also encompass MMIs during both normal and extreme conditions. In Tetra Pak’s case, I’d recommend to follow the general design guidelines for hardware UX design defined in section 6.3 of this report, see Figure 83. The end user’s point of view should always be included already in the early stages of product development and should be considered an important aspect of the performance of the final product.

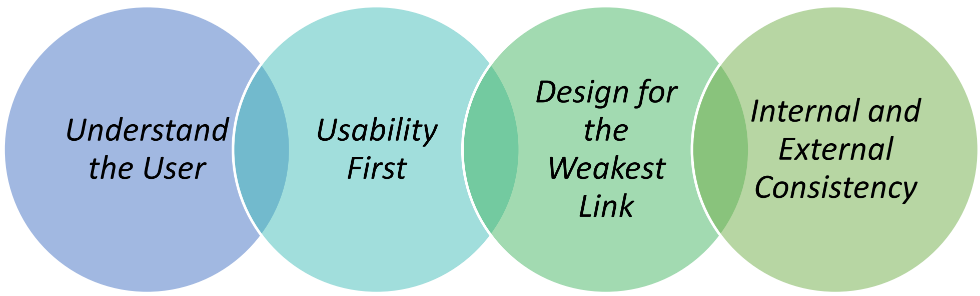


Figure 83: General design guidelines for hardware UX design.[5]

Regarding the results from this thesis, there several interesting things left to explore in the future. One such thing is the Stop Block concept, which offers a promising opportunity for improving hardware configurations in the next generation of cardboard packers. It is especially suitable for integration in settings with low visibility or with components moving in the vertical direction. It would be interesting to see the Stop Block be developed further and have its usability performance compared to that of the CaseMarker presented in this report. The impact on the usability performance by utilizing different levels of system feedback is an intriguing subject that could contribute a lot to the field of physical UX design.

Secondly, the design and implementation of a standardized signage system across the entire production line would be an intriguing venture. A standardized signage system holds great potential for improving the navigation and usability of a machine system and could provide more valuable insight into the usability of signage and icons.

6.5 Conclusion

It is my hope that this report will prove a valuable frame of reference for anyone who wishes to conduct similar case studies about physical UX design. That physical UX often seems to come as an afterthought, result in missed opportunities to improve people's daily lives and their work environment. The positive feedback this report has received from both users and stakeholders proves, that there is value in investigating and improving the UX in analogue MMIs.

To be really effective, however, the UX must already be considered early on in product development. The later in the development process that new ideas or perspectives are included, the more complicated and expensive it becomes. This is not to say that there is nothing to be done about the UX of products that have reached a high level of maturity, however. If anything, the results presented in thesis shows, that there is a good chance that relatively simple solutions can produce significant UX improvements.

Design opportunities can be identified by numerous methods. UX designers would benefit greatly from taking a holistic approach, analyzing the entirety of an MMI both under normal and extreme working conditions. The UX can be noticeably improved by small means, such as finetuning the system feedback or other signifiers.

The advantages of designing a good UX in MMIs are both commercial and humanitarian. Therefore, it's my belief that UX and usability should be considered important aspects of a product's performance; product developers should treat them as such.

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Appendix A – Project Plan and Outcome

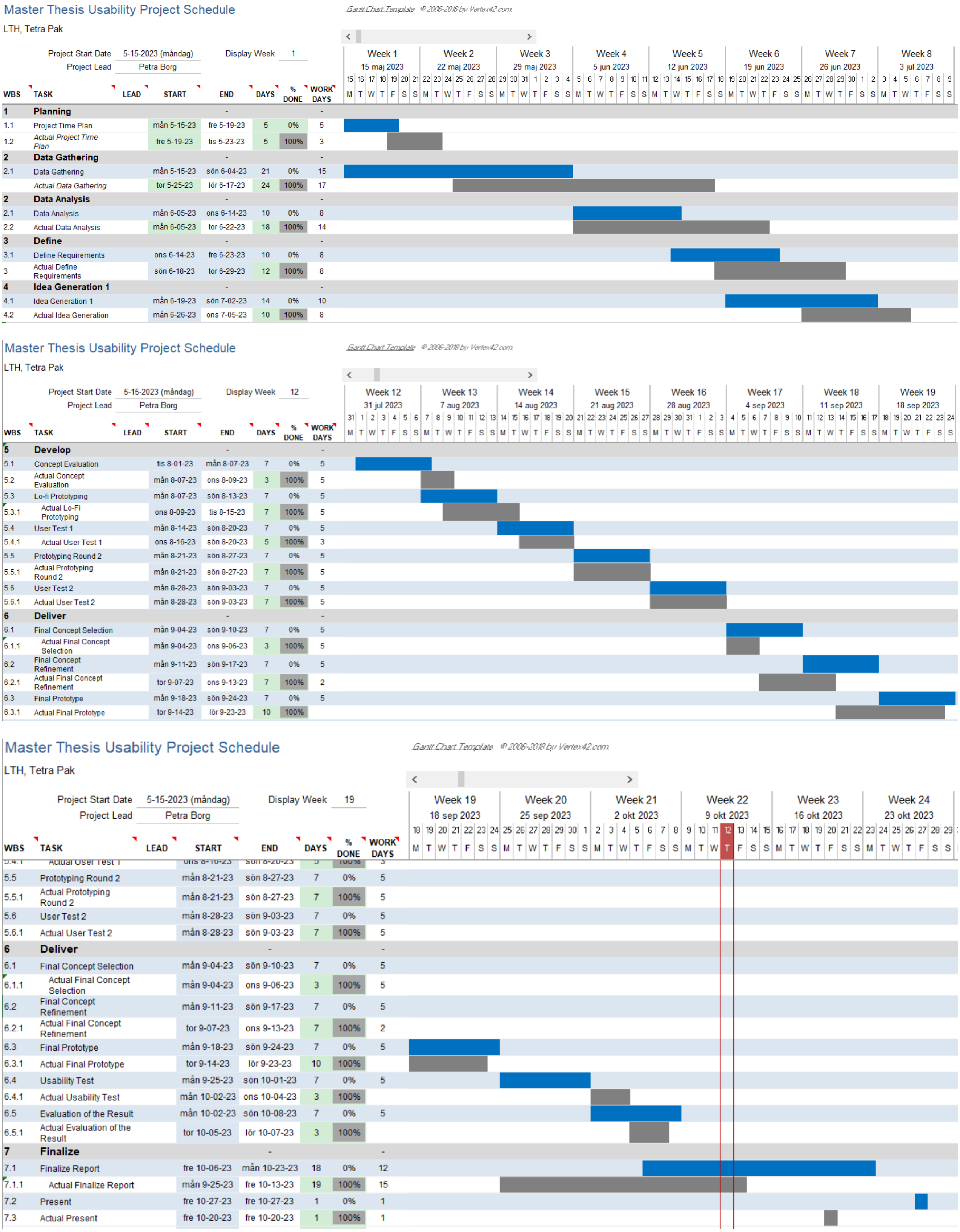
The student(s) need to demonstrate the ability to plan such a project and possibly reflect on the planning, execution and follow-up. This can be presented in the body of the document or in an appendix.

A.1 Project Plan and Outcome

The original project plan was created during the initial planning phase of this thesis, and the progress of task completion was continuously updated along the way, see Figure 84.

The project plan was structured with the intention of all activities occurring in succession of one another, which means the iterative nature of my work don't really show in the project plan. For example, Project Week 12 in Figure 84 was spent going back to the Define Phase to redefine some of the requirements and scope, instead of immediately initiating the concept evaluation.

In general, the activities took longer to complete than expected, which was partly due to challenges in completing activities that are dependent on several people's participation. I also noticed that it was not always easy to estimate the time needed to complete a certain task, especially since in reality, several activities would often overlap and/or happen more or less simultaneously.



WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
1	**Planning**			-			-
1.1	Project Time Plan		mån 5-15-23	fre 5-19-23	5	0%	5
1.2	*Actual Project Time Plan*		fre 5-19-23	tis 5-23-23	5	100%	3
2	**Data Gathering**			-			-
2.1	Data Gathering		mån 5-15-23	sön 6-04-23	21	0%	15
	Actual Data Gathering		tor 5-25-23	lör 6-17-23	24	100%	17
2	**Data Analysis**			-			-
2.1	Data Analysis		mån 6-05-23	ons 6-14-23	10	0%	8
2.2	Actual Data Analysis		mån 6-05-23	tor 6-22-23	18	100%	14
3	**Define**			-			-
3.1	Define Requirements		ons 6-14-23	fre 6-23-23	10	0%	8
3	Actual Define Requirements		sön 6-18-23	tor 6-29-23	12	100%	8
4	**Idea Generation 1**			-			-
4.1	Idea Generation 1		mån 6-19-23	sön 7-02-23	14	0%	10
4.2	Actual Idea Generation		mån 6-26-23	ons 7-05-23	10	100%	8

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
5	**Develop**			-			-
5.1	Concept Evaluation		tis 8-01-23	mån 8-07-23	7	0%	5
5.2	Actual Concept Evaluation		mån 8-07-23	ons 8-09-23	3	100%	5
5.3	Lo-fi Prototyping		mån 8-07-23	sön 8-13-23	7	0%	5
5.3.1	Actual Lo-Fi Prototyping		ons 8-09-23	tis 8-15-23	7	100%	5
5.4	User Test 1		mån 8-14-23	sön 8-20-23	7	0%	5
5.4.1	Actual User Test 1		ons 8-16-23	sön 8-20-23	5	100%	3
5.5	Prototyping Round 2		mån 8-21-23	sön 8-27-23	7	0%	5
5.5.1	Actual Prototyping Round 2		mån 8-21-23	sön 8-27-23	7	100%	5
5.6	User Test 2		mån 8-28-23	sön 9-03-23	7	0%	5
5.6.1	Actual User Test 2		mån 8-28-23	sön 9-03-23	7	100%	5
6	**Deliver**			-			-
6.1	Final Concept Selection		mån 9-04-23	sön 9-10-23	7	0%	5
6.1.1	Actual Final Concept Selection		mån 9-04-23	ons 9-06-23	3	100%	5
6.2	Final Concept Refinement		mån 9-11-23	sön 9-17-23	7	0%	5
6.2.1	Actual Final Concept Refinement		tor 9-07-23	ons 9-13-23	7	100%	2
6.3	Final Prototype		mån 9-18-23	sön 9-24-23	7	0%	5
6.3.1	Actual Final Prototype		tor 9-14-23	lör 9-23-23	10	100%	

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
5.4.1	Actual User Test 1		ons 8-16-23	sön 8-20-23	5	100%	3
5.5	Prototyping Round 2		mån 8-21-23	sön 8-27-23	7	0%	5
5.5.1	Actual Prototyping Round 2		mån 8-21-23	sön 8-27-23	7	100%	5
5.6	User Test 2		mån 8-28-23	sön 9-03-23	7	0%	5
5.6.1	Actual User Test 2		mån 8-28-23	sön 9-03-23	7	100%	5
6	**Deliver**			-			-
6.1	Final Concept Selection		mån 9-04-23	sön 9-10-23	7	0%	5
6.1.1	Actual Final Concept Selection		mån 9-04-23	ons 9-06-23	3	100%	5
6.2	Final Concept Refinement		mån 9-11-23	sön 9-17-23	7	0%	5
6.2.1	Actual Final Concept Refinement		tor 9-07-23	ons 9-13-23	7	100%	2
6.3	Final Prototype		mån 9-18-23	sön 9-24-23	7	0%	5
6.3.1	Actual Final Prototype		tor 9-14-23	lör 9-23-23	10	100%	
6.4	Usability Test		mån 9-25-23	sön 10-01-23	7	0%	5
6.4.1	Actual Usability Test		mån 10-02-23	ons 10-04-23	3	100%	
6.5	Evaluation of the Result		mån 10-02-23	sön 10-08-23	7	0%	5
6.5.1	Actual Evaluation of the Result		tor 10-05-23	lör 10-07-23	3	100%	
7	**Finalize**			-			-
7.1	Finalize Report		fre 10-06-23	mån 10-23-23	18	0%	12
7.1.1	Actual Finalize Report		mån 9-25-23	fre 10-13-23	19	100%	15
7.2	Present		fre 10-27-23	fre 10-27-23	1	0%	1
7.3	Actual Present		fre 10-20-23	fre 10-20-23	1	100%	1

Figure 84: The time plan for the thesis. Blue indicates the original time plan, grey indicates the actual time spent on each activity.

Appendix B

B.1 User Research

Based on observations and user statements, a number of useful insights relating to workflow, navigation and ergonomics were gained. Table 26 below details some general insights, and the statements/observations that inspired them.

Table 26: Data from field observations and user interviews described in section 2.4.1. [11], [15]

General	
Observations and User Statements	***Insights***
"The CBP34 is very expensive as-is."	The product should be cheap to produce and implement.
"The CBP34 is a complex machine with little possibility of revamping the architecture without affecting the functionality."	The product should be easy to implement. The implementation and use of the product should not affect the surrounding components in a substantial way.
There are many different bank levels.	The configuration process is rather complex and non-intuitive, requiring external data storage.
"Operator training is often done by TP staff while they install the machine at the customer's site. This means there is not a lot of time to teach the customer how to configure CBP34, especially if the customer's staff are not already highly trained."	Operators should be able to understand how to handle the CBP34 without a lot of special training.
"Operating CBP34 requires a high level of skill (above average)."	The CBP34 is an advanced machine that is difficult to operate.
The customer operators have minimal technical support available if problems arise on the field.	The operators are expected to be able to solve most problems on their own.
"Configuration and calibration of settings halts production, leading to production losses."	The ability to perform configurations quickly is key.
Workflow	
Observations and User Statements	***Insights***

Changeovers can happen 1-2 times per 24 hours. Each changeover takes 30-60 minutes depending on the operator's experience. "Often we have many small batches with different products; therefore, there are a lot of different small aspects and settings that can cause issues (e.g., different ingredients, packaging materials, temperature parameters)."	Changeovers take up a substantial amount of resources in terms of staff, time and productivity.
Sometimes multiple actions are required to configure one component. Multiplied across the entire machine, it is time consuming.	Changeovers are complicated and time consuming due to the large number of steps involved.
"Some settings are identical but are adjusted individually. It's annoying. "	Staff has to repeat the exact same procedure with several components, leading to frustration.
"The margin of error is small, increasing the necessity of calibrations. Even 1 mm out of alignment can stop production."	The operators must complete the settings' configurations with a high level of accuracy.
"It's easy to break something if you don't know what you're doing."	The machine is not fool proof.
The order of configuration steps listed on the cheat sheet can differ from reality. "You learn eventually when the order has to be changed."	The operators must rely on their own memory and experience to complete the changeover.
"Identifying the components can be tricky. We run back and forth between manuals, blueprints and the machine. "	Navigating the machine layout is not easy. Translating the 2D information to the 3D world is hard.
"The components are usually adjusted on a sliding scale. It's hard to adjust the position accurately on the first try. Usually you need to calibrate the component position several times."	The component design negatively impacts the operators' ability to configure the component on the first try.
"Some customers remove internal modules and components that they don't need, because it makes it easier for them to maintain and configure the CBP34." "You can just take away two screws and then you do not get the door alarm. Sometimes an easy fix like that could allow for continuing the work faster."	Customers find the machine layout unnecessarily complicated. They feel compelled to simplify the layout to make their work easier.
Mistakes happen when recipe parameters must be calculated/measured manually by staff, and information is passed on verbally.	Lack of simple, standardized procedures and reliance on verbal communication can cause confusion, leading to mistakes during changeover.
	Some components lack features to check alignment, position etc. in a convenient way.
Access to blueprints/MMs are required to navigate the CBP34 layout.	The operators' ability to navigate the machine layout and complete all changeover tasks require access to additional information.

"In response to customer complaints, we created a cheat sheet and a conversion manual that list each step in the configuration process with short descriptions on how to do them. There are so many components and steps involved that it's hard to remember."	The operators' own memory is not sufficient for navigating the machine layout. It is hard for the operators to remember every detail of the configuration process.
Navigation	
Observations and User Statements	***Insights***
Color coded labels are used to navigate the hardware layout. "We print them ourselves."	It's hard to navigate the machine layout without signage.
It can be hard to find labels that belong together and which ones that belongs to each setting.	The sheer number and differing locations of the relevant labels cause unnecessary confusion.
There is no standard size or shape for each type of sticker.	The lack of standardized signage causes unnecessary confusion.
A LED display informs the operators when and what type of error has occurred, but not the error location in the 3D model.	The error handling process is not fully supported.
"In response to customer complaints, we've added measurement scales to make it easier to adjust each component properly."	Customers have had troubles completing changeover tasks on the first try.
Ergonomics and Environment	
Observations and User Statements	***Insights***
Low visibility of stickers and labels in a busy environment.	Low signage visibility makes it hard to get a good overview of the machine layout.
It can be hard to adjust the components and check the alignment at the same time, see Figure 16.	Changeover tasks are not optimized for the simultaneous actions required.
Some settings are hard to reach, even though most components are placed above thigh height. "Some places are difficult to reach when changing the product sizes."	Changeover tasks are physically demanding.
The machine hall is bright, loud and with lots of movement from heavy machinery. "The constant noise from the machinery is tiring."	The machine environment is taxing on human senses.
Monochrome color scheme and many components.	It's hard to get a clear overview of the component layout.
The architecture is split in 2 main modules. The modules are accessed on the opposite hand side from each other.	The split architecture aids navigation. The separate access points aid access to only the relevant machine modules.
"It's annoying to configure each component as it requires adjusting, checking, re-adjusting etc. each component many times before the task is done properly."	The configurations are very hard to complete accurately on the first try. This is due to the fact that many components are mounted on a sliding scale without proper measurement scales implemented.

Components not normally intended to be accessed can be knocked out of alignment by mistake, which is hard to fix.	The machine is not fool proof. The lack of modularity is challenging.
“Only 2-3 operators can work on the machine at the same time, due to lack of space.”	Lack of space impacts the teamwork negatively.
Some parameters are communicated verbally, which can cause confusion.	Reliance on verbal communication is a weak point.
Alignment of components is sometimes best done using eyesight.	There is not always an easy way to check if the components are in alignment.
During changeover, operators need access to tools such as wrenches, pliers etc.	Special tools are needed to be able to configure the CBP34. Configurations are done by hand.

B.2 Idea Generation

Table 27: Action sequence when using the standard distance tool.

Action Sequence
The operator sets the tool to the intended standard case distance (case B).
The operator releases (unlocks) the component. The component is now free to move along the slider.
The operator slides the component from position A to an approximate position B.
The operator checks the component’s position using the distance tool to compare the distance from the component’s edge to the end point.
The component is now in the standard B position.
The operator locks the component. The line is ready for production.

Table 28: Action sequence when using responsive indicators.

Action Sequence
The operator identifies the current setting by checking the position indicator.
The operator releases (unlocks) the setting.
The operator adjusts the component based on feedback from the position indicator.
The operator locks the setting. The line is ready for production.

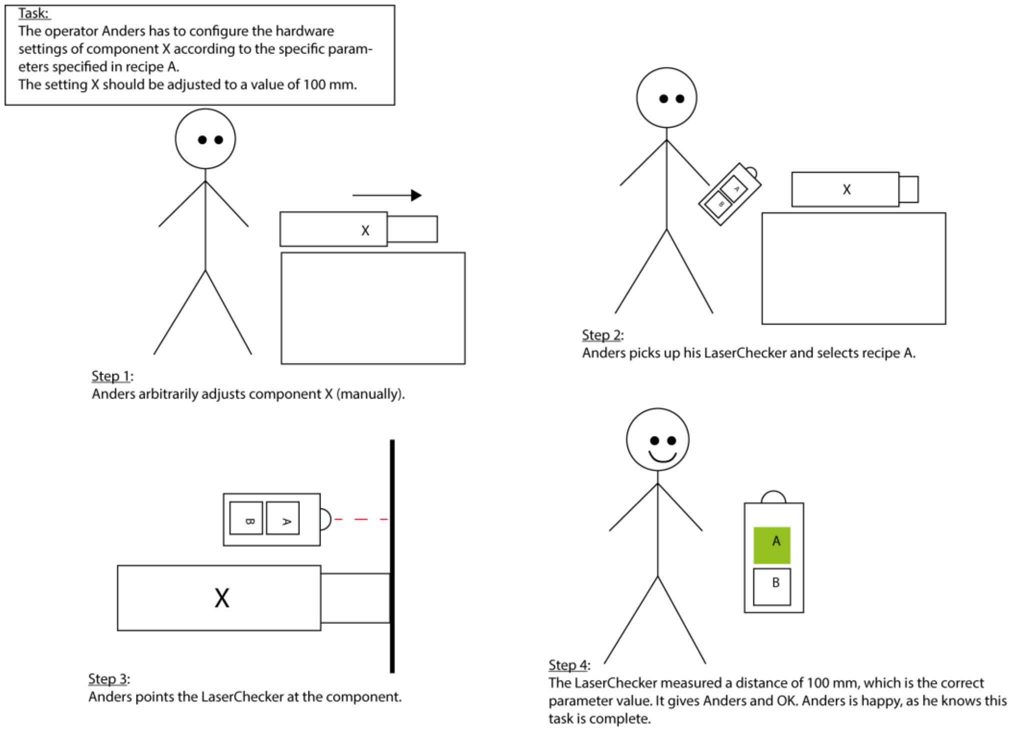


Figure 85: The action sequence when using the Laser Measurement Tool.

B.3 Cheat Sheet Iterations

Tetra Pak		Recipe 1 TBA1000E 3x6 Tray	Recipe 2 TBA1000E 2x3 WASF	3 TBA200SL 3x8 straw 5 mm open tray
A1	Fallen package detector	130	130	130
A2	Infeed guide	75	75	57.3
A3	Infeed guide	75	75	57.3
A4	Belt brake – width	69,5	69,5	38
A5	Belt brake - offset	-1	-1	2
A6	Fallen package detector	90	90	80
B1	End stop grouping	914	914	773
B2	Stop arm	922	922	781
B3	Grouping Pusher Rail - Height	200	200	120
B4	Grouping Pusher Rail - Length	230	230	85
B5	Grouping top support – Length	230	230	85
B6	Grouping top support – Height	175	175	105
B7	Grouping top support – Width	70	70	44
B8	Grouping Dolly - Length	230	230	92
C1	Transfer Stop Plate - Width	276	275	275
C2	Transfer Unit - Width	232	152,5	151
C3	Box Pusher top – Width	230	149,5	151
C4	Box Pusher	230	150	150
C5	Box Pusher - Length	428	214	315
C6	Volume Plate	Plates = 207mm	Plates = 127mm	128
C7	Packing End Stop - Width	72	32	32
D1	Feed Unit – Length	445,6	224	330.0
D2	Bottom Support	yes	no	No
E1	Magazine – Flap Length	40	75	52
Prior to adjustment of Magazine Height: shift Tray Guides (G2) to avoid interfer shift Picker support rollers (G1) to avoid interfer				
E2	Magazine - Height	445.5	371.0	287.0
E3	Top Support - Height	218	410	125
F1	Picker - Height	225	412	128
F2	Picker – Width	434	209,7	327.7
G1	Upper Support Rollers – Height (2x)	19	22	**10**
G1	Upper Support Rollers – Width (2x)	10	28	28
G2	Guides – Height	16	19	**7**
G3	Lower Support Rollers – Height (2x)	1	1	3
G3	Lower Support Rollers – Width (2x)	15	30	28
H1	Flight bar – Position	middle	narrow	Narrow
J1	Flap Guide – Height (4x)	2	2	2
J2	Flap Guide – Centering (4x)	40	75,5	52
J3	Bottom Glue Gun - Height	30	65	40
J4	Bottom Squeezer - Height	40	75	50
J5	Tray Support - Width	/	19,5	N/A
J6	Tray Support – Length (2)	/	83	N/A
J6	Tray Support – Length (3)	/	199	N/A
J6	Tray Support – Length (4)	/	/	N/A
K1	Conveyor Discharge – Stop Plate	/	/	N/A
L1	Wrap Around Glue Gun - Height	/	155	N/A
Prior to lower WASF unit: lower first WA hotmelt guns to avoid interfer				
L2	Wrap Around - Height	287	212,6	N/A
L3	Wrap Around - Width	/	162,3	N/A
L4	Wrap Around – Length	/	226	N/A
L5	Pressure Unit – Length 1st	/	84	N/A
L5	Pressure Unit – Length 2nd	/	199	N/A
L5	Pressure Unit – Length 3rd	/	/	N/A
L6	Glue Gun WA – Length (2)	/	112	N/A
L6	Glue Gun WA – Length (3)	/	223	N/A
L7	Wrap Around Unit - Kicker	/	135	N/A
L8	Pressure Unite WA - Length	/	75	N/A

Figure 86: Original Cheat Sheet.[14]

CBP34		Recipe 1 TBA1000E 3x6 Tray	Recipe 2 TBA1000E 2x3 WASF	Recipe 3 TBA200SL 3x8 Straw 5 mm. Open tray
A1	Fallen Package Detector	130	130	130
A2	Infeed Guide	75	75	● 57,3
A3	Infeed Guide	75	75	● 57,3
A4	Belt Brake – width	69,5	69,5	● 38
A5	Belt Brake - offset	-1	-1	● 2
A6	Fallen Package Detector	90	90	● 80
B1	End Stop Grouping	914	914	● 773
B2	Stop Arm	922	922	● 781
B3	Grouping Pusher Rail - Height	200	200	● 120
B4	Grouping Pusher Rail - Length	230	230	● 85
B5	Grouping top support – Length	230	230	● 85
B6	Grouping top support – Height	175	175	● 105
B7	Grouping top support – Width	70	70	● 44
B8	Grouping Dolly - Length	230	230	● 92
C1	Transfer Stop Plate - Width	● ~~276~~	~~275~~	~~275~~
C2	Transfer Unit - Width	● 232	● 152,5	● 151
C3	Box Pusher top – Width	● 230	● 149,5	● 151
C4	Box Pusher	● 230	150	150
C5	Box Pusher - Length	● 428	214	● 315
C6	Volume Plate	● Plates = 207mm	● Plates = 127mm	● 128
C7	Packing End Stop - Width	● 72	32	32
D1	Feed Unit – Length	● 445,6	● 224	● 330,0
D2	Bottom Support	● Yes	No	No
E1	Magazine – Flap Length	● 40	● 75	● 52
Prior to adjustment of (E2): Shift Tray Guides (G2) and Picker Support Rollers (G1) to avoid interference				
E2	Magazine - Height	● 445,5	● 371,0	● 287,0
E3	Top Support - Height	● 218	● 410	● 125
F1	Picker - Height	● 225	● 412	● 128
F2	Picker – Width	● 434	● 209,7	● 327,7
G1	Upper Support Rollers – Height (2x)	● 19	● 22	● 10
G1	Upper Support Rollers – Width (2x)	● 10	28	28
G2	Guides – Height	● 16	● 19	● 7
G3	Lower Support Rollers – Height (2x)	1	● 1	● 3
G3	Lower Support Rollers – Width (2x)	● 15	● 30	● 28
H1	Flight bar – Position	● Middle	Narrow	Narrow
J1	Flap Guide – Height (4x)	2	2	2
J2	Flap Guide – Centering (4x)	● 40	● 75,5	● 52
J3	Bottom Glue Gun - Height	30	● 65	● 40
J4	Bottom Squeezer - Height	● 40	● 75	● 50
J5	Tray Support - Width	● /	● 19,5	● N/A
J6	Tray Support – Length (2)	● /	● 83	● N/A
J6	Tray Support – Length (3)	● /	● 199	● N/A
J6	Tray Support – Length (4)	/	/	● N/A
K1	Conveyor Discharge – Stop Plate	/	/	● N/A
L1	Wrap Around Glue Gun - Height	● /	● 155	● N/A
Prior to lower WASF unit: lower first WA hotmelt guns to avoid interference				
L2	Wrap Around - Height	● 287	● 212,6	● N/A
L3	Wrap Around - Width	● /	● 162,3	● N/A
L4	Wrap Around – Length	● /	● 226	● N/A
L5	Pressure Unit – Length 1st	● /	● 84	● N/A
L5	Pressure Unit – Length 2nd	● /	● 199	● N/A
L5	Pressure Unit – Length 3rd	/	/	● N/A
L6	Glue Gun WA – Length (2)	● /	● 112	● N/A
L6	Glue Gun WA – Length (3)	● /	● 223	● N/A
L7	Wrap Around Unit - Kicker	● /	● 135	● N/A
L8	Pressure Unite WA - Length	● /	● 75	● N/A

Figure 87: First iteration of the cheat sheet.[14]

CBP34		Recipe 1 TBA1000E 3x6 Tray	Recipe 2 TBA1000E 2x3 WASF	Recipe 3 TBA200SL 3x8 Straw 5 mm. Open tray
A1	Fallen Package Detector	130	130	130
A2	Infeed Guide	75	75	57,3
A3	Infeed Guide	75	75	57,3
A4	Belt Brake – width	69,5	69,5	38
A5	Belt Brake - offset	-1	-1	2
A6	Fallen Package Detector	90	90	80
B1	End Stop Grouping	914	914	773
B2	Stop Arm	922	922	781
B3	Grouping Pusher Rail - Height	200	200	120
B4	Grouping Pusher Rail - Length	230	230	85
B5	Grouping top support – Length	230	230	85
B6	Grouping top support – Height	175	175	105
B7	Grouping top support – Width	70	70	44
B8	Grouping Dolly - Length	230	230	92
C1	Transfer Stop Plate - Width	~~276~~	~~275~~	~~275~~
C2	Transfer Unit - Width	232	152,5	151
C3	Box Pusher top – Width	230	149,5	151
C4	Box Pusher	230	150	150
C5	Box Pusher - Length	428	214	315
C6	Volume Plate	Plates = 207mm	Plates = 127mm	128
C7	Packing End Stop - Width	72	32	32
D1	Feed Unit – Length	445,6	224	330,0
D2	Bottom Support	Yes	No	No
E1	Magazine – Flap Length	40	75	52
Prior to adjustment of (E2): Shift Tray Guides (G2) and Picker Support Rollers (G1) to avoid interference				
E2	Magazine - Height	445,5	371,0	287,0
E3	Top Support - Height	218	410	125
F1	Picker - Height	225	412	128
F2	Picker – Width	434	209,7	327,7
G1	Upper Support Rollers – Height (2x)	19	22	10
G1	Upper Support Rollers – Width (2x)	10	28	28
G2	Guides – Height	16	19	7
G3	Lower Support Rollers – Height (2x)	1	1	3
G3	Lower Support Rollers – Width (2x)	15	30	28
H1	Flight bar – Position	Middle	Narrow	Narrow
J1	Flap Guide – Height (4x)	2	2	2
J2	Flap Guide – Centering (4x)	40	75,5	52
J3	Bottom Glue Gun - Height	30	65	40
J4	Bottom Squeezer - Height	40	75	50
J5	Tray Support - Width	/	19,5	N/A
J6	Tray Support – Length (2)	/	83	N/A
J6	Tray Support – Length (3)	/	199	N/A
J6	Tray Support – Length (4)	/	/	N/A
K1	Conveyor Discharge – Stop Plate	/	/	N/A
L1	Wrap Around Glue Gun - Height	/	155	N/A
Prior to lower WASF unit: lower first WA hotmelt guns to avoid interference				
L2	Wrap Around - Height	287	212,6	N/A
L3	Wrap Around - Width	/	162,3	N/A
L4	Wrap Around – Length	/	226	N/A
L5	Pressure Unit – Length 1st	/	84	N/A
L5	Pressure Unit – Length 2nd	/	199	N/A
L5	Pressure Unit – Length 3rd	/	/	N/A
L6	Glue Gun WA – Length (2)	/	112	N/A
L6	Glue Gun WA – Length (3)	/	223	N/A
L7	Wrap Around Unit - Kicker	/	135	N/A
L8	Pressure Unite WA - Length	/	75	N/A

Figure 88: Final version of the cheat sheet.[14]