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Designing a Flexible Desk for an Activity-Based Workplace

Master's thesis in Industrial Design Engineering

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Abstract

This is a master thesis performed during the spring of 2020 at Chalmers University of Technology in association with Kinnarps AB.

Multiple organizations are today replacing their cell or open offices with an activity-based workplace. When implementing an activity-based workplace strategy, the organization is set out to increase its office flexibility by encouraging the employees to frequently change the workstation. This to gain strategic benefits, enhancing employee productivity and satisfaction through stimulation of interaction between employees and initiating opportunities for collaborative work and signalling creativity.

This project's aim was to develop a flexible and mobile desk for temporary workstations, that is, ABW compatible. To do so, user needs were established through interviews and observations, the current market and Kinnarps own products were analysed, which resulted in a requirements specification to fulfil. Besides fulfilling the discovered requirements, the desk shall also comply with Kinnarps fundamental requirements about the desk being: foldable, height-adjustable, mobile and provide electrical energy to the users' electrical devices.

The result of the project was a concept, communicated as a CAD-model, that fulfils the fundamental requirements but also is versatile, aesthetically pleasing, ergonomic, durable, intuitive, safe and offers flexibility. This through being multifunctional in how it can be used, having a unique design expressing both professionalism and playfulness, easily rolled aside and stacked when not in use, complies with set standards giving an ergonomic experience, has interchangeable parts and material that handles wear and tear and lastly, is safe to use by preventing accidents.

Keywords: ABW, activity-based workplace, desk, product development, locking mechanism, foldable, workstation, furniture, office

Glossary

Activity-based workplace (ABW) - *Is an office structure with the intention of letting the employee freely choose their own workstation depending on which activity they are to perform that day.*

CAD - *Computer aided design: a program that helps create, analyse and optimize a 3D-model of a design with the use of a computer.*

Collective instruments - *Office supplies that all employees can use, for example, a monitor or chair.*

Folded desk - *The desktop is in a vertical position*.

Individual instruments - *The users' personal belongings, for example, jacket or bag.*

Monitor - *a computer monitor/screen*

Unfolded desk - *The desktop is in a horizontal position.*

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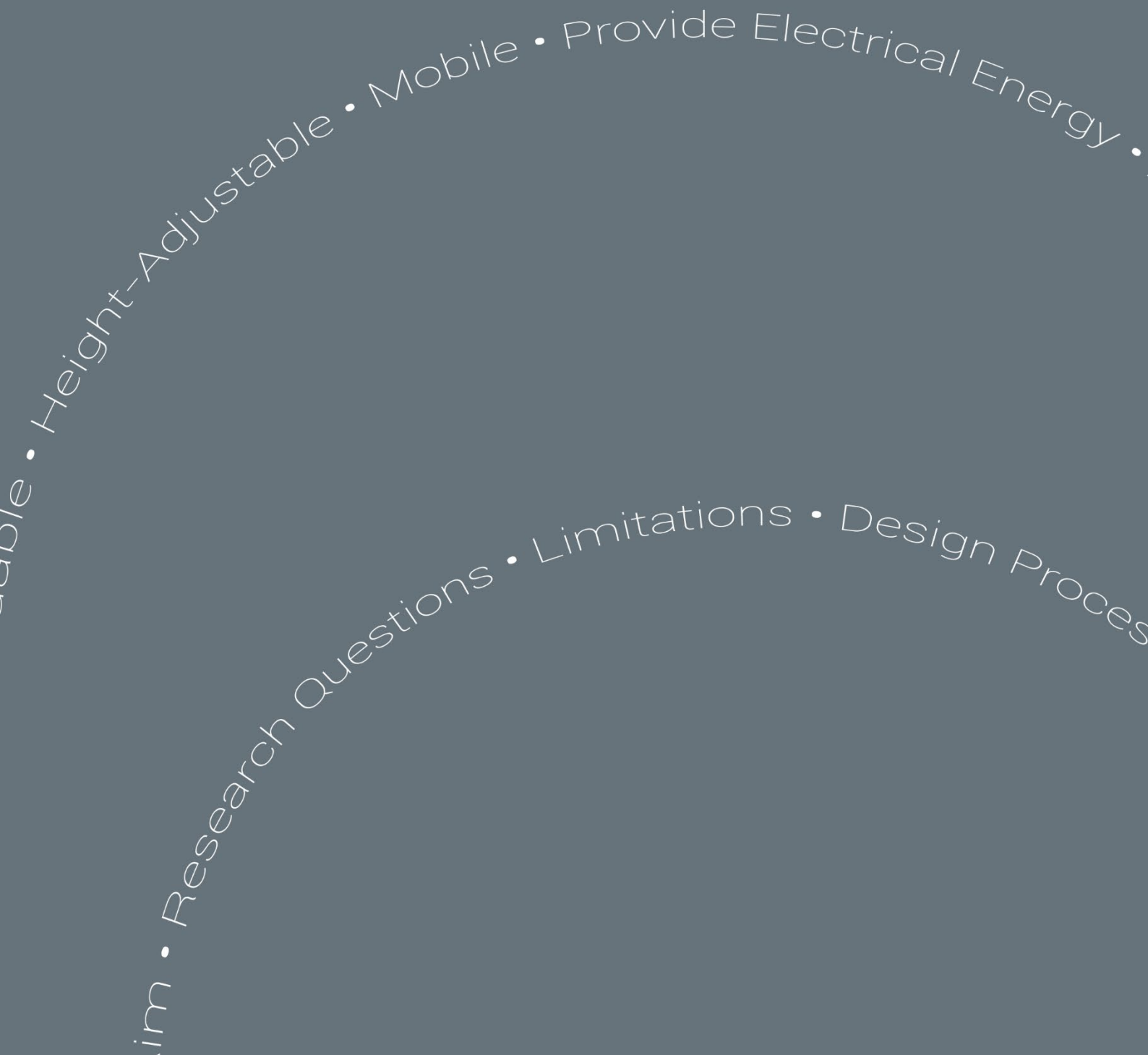
01
Introduction



Today, multiple organizations are implementing new operating strategies to gain strategic benefits by transforming their cell offices or open offices into a more activity-based workplace (ABW). When applying an activity-based workplace structure, the organization is set out to increase its office flexibility, reducing its occupancy costs and at the same time strengthening the corporate image. Meanwhile enhancing employee productivity and satisfaction through stimulation of interaction between employees when encouraging frequent change of workstation, thereby initiating opportunities for
collaborative work and signalling creativity (Appel-Meulenbroek, Groenen & Janssen, 2011; Babapour Chafi, Harder & Bodin Danielsson, 2019). According to Appel-Meulenbroek et al. (2011) findings, there is a gap between intended use and how the actual use is in some ABW, which is causing illness and dissatisfaction among employees resulting in loss of productivity. Factors for this can come from both management faulty implementing ABW or misuse of the concept from a user perspective.

The intention of ABW is to let the employee choose their own workstation depending on which activity they are to perform that day (Babapour, 2019). The activity or work task can change during the day. For example, the employee starts the day by placing all personal belongings in a locker, expect for the bag that contains the computer. Then takes a cup of coffee with some co-workers in a break-out space, then during the day the employee attends two meetings in two different enclosed meeting rooms, transfers to a touch-down space to answer some emails and finishes the day in a semi-quiet zone writing a report, see Figure 1.

Figure 1: An example of an activity-based workplace

The different spaces go from private concentrated work with quiet-speech policy to spaces for informal meetings and collaborative work. Quiet zones, mentioned above, is where the employee is intended to work with something that needs high concentration, these zones can be divided into enclosed spaces and semi-enclosed spaces, depending on the work task. Semi-quiet zones are the next step from quiet zones, concentrative work but small talk and interruptions are allowed. Active zones are where both individual and collaborative work take place which is very similar to touch-down spaces, but the difference with touch-down is that this workspace is used for a shorter time. Break-out spaces and open meetings spaces are for informal meetings and collaborative work and there are also walk-in rooms for both individual and smaller collaborative work and they go after the rule; first-come-first-served (Babapour, 2019).

Kinnarps, which is the market leader in Europe within the development, manufacturing and selling of office furniture, sees an opportunity in the growing trend of an activity-based workplace (Kinnarps, 2020). Thus, they are looking to expand their production lines within this field and aim to have a new desk line-up matching the needs that emerges from an ABW office. Kinnarps ambition is to always deliver high-quality furniture with low environmental impact, for the entire chain – from raw material to finished solutions for the workspace (Kinnarps, 2020). Even though desks are a small part of the ABW environment, it can still create friction between the user and its capability to perform its responsibilities, because a consequence of an unsatisfactory design can lead to misuse of the ABW concept. Therefore, an improvement on it will ease users acclimatization to ABW (Appel-Meulenbroek et al., 2011).

1.1 Aim

The aim is to develop a flexible and mobile desk for temporary workstation, that is, ABW compatible. A desk able to adapt to the ever-changing needs of the worker, giving the choice of setting for a variety of workplace activities, by being easily transformable to fit different situations while always being ergonomic and providing support for the user's typical technical office devices. To fulfil this aim, Kinnarps have named four fundamental requirements for such a desk. They require the desk to be foldable, mobile, height-adjustable and provide electrical energy while being ergonomic.

1.1.1 Foldable

By folding the desktop to a vertical state, desks can be stacked together and moved aside in a simple and quick manner, stated in this case, by one person in the event of changing needs.

1.1.2 Height-Adjustable

To fulfil the aim of being flexible and ergonomic, the desk shall allow for the user to work in both a sitting and standing position. Thereby, offer good ergonomics within a larger proportion of the standard deviation for adult individuals.

1.1.3 Mobile

The ability to be mobile makes for a flexible and versatile set-up well suited in an ABW, therefore it is a requirement. The common way of making a desk mobile is to put wheels on it.

1.1.4 Provide Electrical Energy

A vision from Kinnarps is that the solution should be self-sufficient, providing energy thus supporting the users' energy needs by giving the possibility to connect all their technical office devices to the desk and

provide charging ability, by using a USB-C port.

1.1.5 Additional Requirements

In addition to the following demands, the solution must meet “relatively high standards of aesthetics”, as expressed by Kinnarps, comply with safety requirements, prioritize profitability and quality. Furthermore, when creating a mobile desk, it must be able to clear a standard threshold when being moved for different activities, be anchorable when in use and be lockable in both folded and unfolded positions. Also, to easily be stacked together when not in use, have the measurement for the desktop area to be around 1000-1400 x 600-700 millimetres. There is also a set production cost put on the product which, is a part of Kinnarps’s business strategies therefore, it is considered sensitive information and will not be declared in the report.

1.1.6 Research Questions

1. Who are the users of an activity-based workplace?
    1.1. What are their needs when using a desk within an ABW?

2. How can a desk be designed to fulfil the ABW users' needs?

1.2 Limitations

The limitations concern the development of circuit boards, height-adjustment actuators, and switches, which are ready-made modules already utilized by Kinnarps. The development ends with a research of specifications and potential implementations for batteries and electronics, and with suggestions for material choice. The final concept should be presented as a completed CAD-model, thereby setting the scope for how far the development of the desk will progress.

1.3 Design Process

The development process, sought to be used in this project, follows the traditional four-stage product development process (Cross, 2008). For illustrative purpose it is presented in a sequential manner in Figure 2, however, this is rarely the case. The design process is an iterative process far from a straight line. The exploration phase consists of a series of methods and acts that are meant to clarify the problem, its context, the user needs, and gaining general knowledge within the field, in order to be able to develop a solution (Wikberg Nilsson, Ericson & Törlind, 2015). The gained knowledge can be condensed into a requirement specification which steers the following work. In the generation phase, design solutions are ideated and evaluated in each section within different methods until there is only one final concept. This solution gets a final and last evaluation in the evaluation phase against the requirement specification. Lastly, the result will be communicated via, for example, drawings or cad-models.

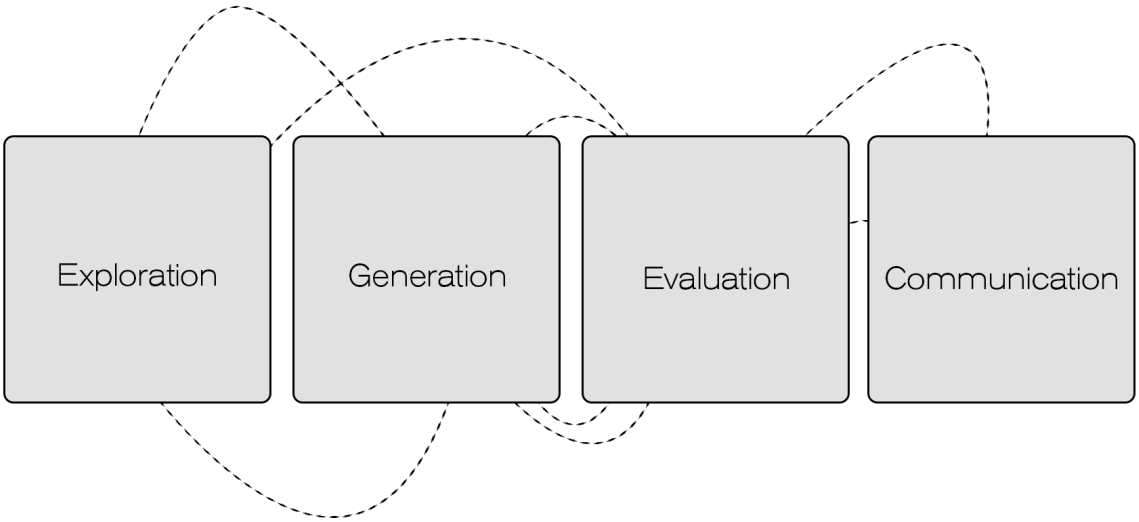


Figure 2: A visualization of the design process

For this project, a flow chart of the process was made as a foreseeable guide for the work to come, see Figure 3. Here, the four stages are illustrated as black gates. The process starts with the brief given of Kinnarps consisting of fundamental requirements that go straight into the requirements specification. The other two parts of the requirements specification are user needs and remaining requirements that come from four different sub-categories. The two following phases, generation, and evaluation are an iterative procedure where concepts are being generated and evaluated until a result is achieved that satisfies the requirements. In addition to the design methods, this iteration also contains concept optimization methods Design for manufacturing and assembly (DFMA), Failure mode and effect analysis (FMEA), and Design for environment (DFE) for ecological aspects of the product. The fourth and last phase, communication, is about mediating the result via a prototype and CAD.

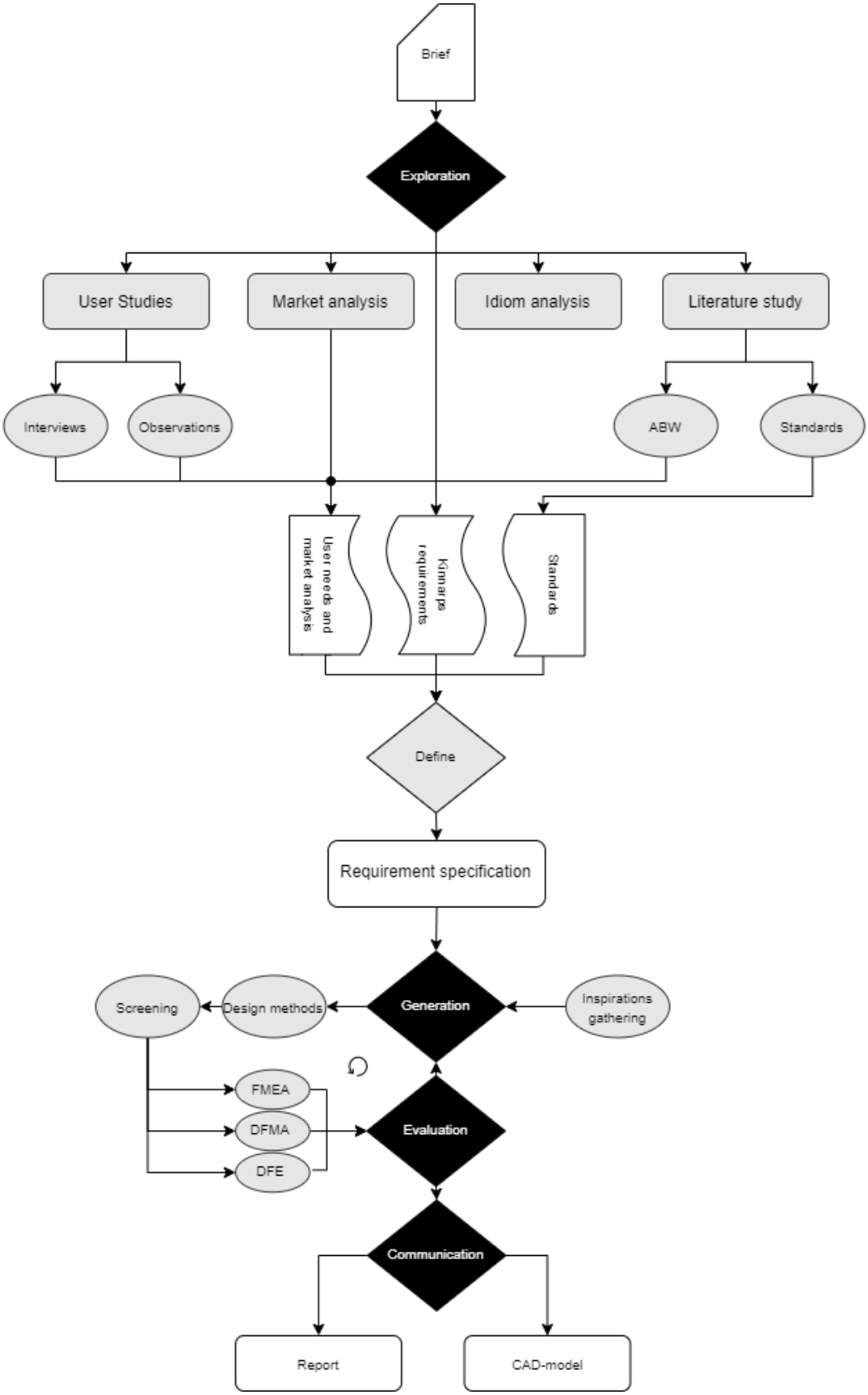


Figure 3: A flowchart of the project's process

02
Methodology

A day in life • Use 2 Use Toolkit • KJ Method • Objec

Braindrawing • Benchmarking • Workshop • Kesselring Mat

In the coming section, methodologies used during the product development phase are explained. First methods used during the exploration phase and then the methods used during the generation and evaluation phase

8.1 Market Analysis

It is always important to understand what the competitors are up to. What they are doing right now and what could their possible strategies for the future be? Other reasons are to find voids in the market that can be exploited for opportunities for development (Wikberg Nilsson, et al., 2015). It is also a good opportunity to gather inspiration, and ideas for solving different technical or mechanical problems or in general see how competitors work within a chosen development segment. Collected information will act as part of the inspiration in the ideation phase, both esthetical design choices and features.

8.2 PNI

PNI is an acronym for positive, negative, and interesting and is used to encourage evaluation of concepts or artefacts from more than one perspective by extracting features in said categories (Österlin, 2010).

8.3 Interviews

By performing interviews, the interviewer obtains knowledge regarding how the user experiences the product, what they like and dislike about the product and their behaviour when interacting with the product (Wikberg Nilsson, et al., 2015). A semi-structured interview is when the interviewee is asked a series of questions but is allowed to side-track from the question, the same rules go for the person interviewing, who can ask follow-up questions (Wikberg Nilsson, et al., 2015).

8.4 A day in life

A day in life method is an observation method where the user re-enacts how they normally would perform different tasks where the interviewer observes the user (Curedale, 2013).

8.5 Use 2 Use Toolkit

The Use2Use design toolkit is a set of tools to help designers design products or services for circular consumption using the user's perspective. It comes in five different packages such as the thinking activation pack, the circular journeys exploration pack, the multiple use-cycles exploration pack, the circular designs ideation pack, and the circular designs evaluation pack (The Use2Use Design Toolkit, 2020).

8.6 KJ Method

A KJ analysis is used to compile a large amount of data and provide an overall picture. The data, for example, the user needs from an interview, are written on post-its and placed together in different groups based on similarities. Each group is given a heading that explains what the category is about, and these categories can later in the process be used in a more optimal manner (Kaulio, M., Karlssson, M., Grubb, H., & Melby, C. 1999)

8.7 Objective Tree

An objective tree is a hierarchical diagram which shows the relationship between the needs. If traveling upwards in the tree the answer to why a need or function exists is presented and downwards gives the answer to how a need can be fulfilled. The main function or need can branch out into several sub-objectives that together fulfils the main function. By defining sub-objectives, the main function will get divided into smaller and smaller sub-

objectives and finally, measurable requirements (Österlin, 2010).

8.8 Mood Board

Mood boards are a way of visualising a feeling, by combining pictures representing an emotional experience. It can, for example, explore the emotion of modern, soft, and calm and can be used as guidance when designing new products (Wikberg Nilsson et al., 2015).

8.9 Requirements Specification

The requirements specification is the result of information gathering, analysis, problem dissection and acts as a checklist for what the product in development shall achieve. Examples are dimensions, functions, design cues, ergonomics, and stages of det products life cycle like construction, production, assembly and so on (Österlin, 2010). The requirements specification list's design can vary depending on the nature of the projects but usually comprises measurable metrics of requirements, corresponding value, and units (Ulrich & Eppinger, 2012). However, the requirements specification does not have to exclusively contain a list with bullets but also stories, descriptions, or pictures for an easier understanding of what the product shall fulfil (Österlin, 2010).

8.10 Fish Trap Model

The Fish trap model is a systematic process for designing a product in stages with an increasing level of details and meaning. It utilizes vision-spatial thinking, that is, imagining and exploration by sketching what is essential for the current level of details and criteria (Muller, 2001).

8.10.1 The Structural Concept

The first level is about defining the basic functional components that are needed for product use. These are then ordered in different structural orientations which make up ways of solving the problem. The structural concepts are evaluated against the criteria (Muller, 2001).

8.10.2 The Formal Concept

The most promising structural concepts are brought on to level two for further development. The concepts enter a materialization stage where form meets material and the physical components that connect to each other. The evaluation of the concepts should be made by estimating their viability (Muller, 2001).

8.10.3 The Material Concept

In the final level, the fidelity is brought up by determining manufacturing processes, assembly specification of materials, and colour. Evaluation against the criteria is important in this stage (Muller, 2001).

8.11 Brainstorming & Braindrawing

Brainstorming is conducted to achieve a large number of ideas in a short period of time, by idea generating freely. There are no limitations, no ideas are bad ideas and the aim is to strive for quantity over quality. This can be carried out by using pencils and post-its or writing directly at a whiteboard. Being more than one person gives the possibility for discussions and creating an opportunity to be inspired by others (Wikberg Nilsson et al., 2015). Braindrawing on the other hand is a similar method with the exception that the focus for idea generation lays on sketching and that the generated ideas are presented and then built upon by other participants (Wikberg Nilsson et al., 2015).

8.12 Benchmarking

Benchmarking is the study of similar or close related products. This external research can reveal existing solutions solving a particular problem to the product under development. Benchmarking can also be performed on products in different markets but with similar functionality to broaden the scope of solutions by inspiring new ideas that the project team's internal knowledge and contacts cannot produce.

8.13 Workshop

A workshop is when a group of people, it could be users of the product, experts, or randomly picked people without a connection to the subject gather and together generate new creative ideas. The intention of using a workshop is to take advantage of the group's creativity and at the same time solve different problems that are planned out beforehand by the designer (Wikberg Nilsson et al., 2015).

8.14 Kesselring Matrix

Kesselring matrix is used to evaluate if potential concepts fulfil different criteria, for example, requirements from the requirement specification. The potential concepts are then evaluated against a reference concept, which is set as an ideal concept, to measure if they are better or worse than the already existing concept. A scale that suits the project should be selected, for example, 1-5 or 1-10. This scale should also be used to weigh the criteria against each other to highlight the more vital criteria. Afterward, the weight of every criteria is multiplied with the number that the concept gets on the specific criteria. Which in the end shows the concept with the highest point and therefore is the "best" concept (Johannesson, H., Persson, J-G., & Pettersson, D, 2013).

8.15 SWOT Analysis

The method is useful for determining the strengths and weaknesses and uncover exploited opportunities and make consideration for potential threats with a business opportunity. The four headings are categorized into two groups: strengths and weaknesses into internal and opportunities and threats into external. Those in internal can be acted upon whereas external cannot be affected (Curedale, 2013).

8.16 Dot Voting

The dot voting method lets a number of participants use their group wisdom to collectively converge on a selection of ideas or concepts by individually scoring them. This is done by placing a number of dots, decided beforehand, on the concept that the participant likes the most. The concept or concepts with most dots will be selected as the winning concepts (Österlin, 2010).

8.17 Failure Mode and Effect Analysis

The method is used to generate improvements for concepts. It is an effective way of exploring and investigating potential failures, the potential cause, the consequences, and how to correct them before they occur. In this way, the risk of faulty or even dangerous products reaching the customer can be reduced, which in turn leads to more consistent quality on the products. The method may include components, systems, processes, and functions. The analysis can be carried out by utilizing a table with six columns; process step/input, potential failure mode, potential failure effects, potential causes, recommended action and risk analysis, where the latter consists of severity, occurrence, detection which multiplied together results in the risk priority number

(RPN). The greater the RPN the more demanding is the need for action. (Ullman, 2016)

8.18 Design For Manufacturing and Assembly

DFMA is a methodology utilized to address manufacturing and assembly costs and thereby increasing the profit margin without compromising product quality, development time and development cost. DFMA is performed throughout the development process, in all stages, even though cost estimates in many early phases are highly subjective and an approximation. For example, when functions and specification are being determined or when screening concepts. Though the estimations can be improved by applying cross-functional teams with individual specialties, that is, project teams consisting of participants (Cross, 2008).

The process for designing for manufacturing can be condensed into a list:

- Estimate the manufacturing costs
- Reduce the costs of components
- Reduce the costs of assembly
- Reduce the cost of supporting production
- Consider the impact of DFMA decisions on other factors

Subsequently a list for designing for assembly:

- The part is self-aligning
- The part does not need to be oriented
- The part requires only one hand for assembly
- The part requires no tools
- The part is assembled in a single, linear motion
- The part is secured immediately upon insertion
- Error proofing
  (Cross, 2008)

8.19 Design For Environment

Environmental impact is inevitable when it comes to products; they all consume resources in some form. The impacts can be energy consumption, natural resource depletion, emissions, or waste. In DFE these impacts are divided into two broad categories: energy and material. Addressing the energy problem means developing a product that uses less energy. However, materials are not as easy, therefore the focus of the DFE method is put on materials. That is, choosing the right material and ensuring that the product can be recycled. The core of DFE is life cycle thinking, all the way from raw material to recycling and some of the impacts in the manufacturing phase are global warming, resource depletion, solid waste, and water pollution. To limit the impact in the manufacturing phase DFE provides a process that includes activities that are implemented throughout the development process, where one important activity is to set DFE goals. These goals are meant to define how the development team and the organization comply with regulations and how they strive to minimize the environmental impact. (Ulrich & Eppinger, 2012).

03
Exploration

What is an Activity-Based Workplace? • What Safety Requirements are The

is • Foldex in Depth • Design Cue Analysis • Pr

The first part of the project consists of gathering information about; ABW, the target group, the market, Kinnarps's own products, the users' needs, standards, and the products needed performance. The findings of the exploration phase are later concluded and presented in a requirement specification, which lies as a base for the development phase.

3.1 What is an Activity-Based Workplace?

To increase the knowledge base surrounding ABW and acquire a greater understanding of the target group, a literature study was conducted regarding ABW. To achieve this, multiple articles within the subject were read through, information that were of relevance was selected and analysed and is presented below.

3.1.1 Theory Regarding ABW

When implementing ABW some issues occur, as mentioned earlier, can both come from individuals or management misuse. For this project, the individuals' misuse is more in line with what the desk can offer to make the ABW experience better and thereby, lead away from misuse of the concept. One of the bigger challenges that Babapour (2019) mentions, is that "rules" or "policies" appears when the ABW concept is implemented, for example, clean-desk rule or desk-sharing policy where the employee is to leave the desk in the same clean state as they found it in and with no items left. The existence of the clean-desk policy is quite obvious, hence the consequences of ABW desks is that when employees do not feel belonging to the desk, they do not feel any responsibility for it and thereby become careless and leave it a bit messy. The result is that someone else must clean the desk in a later stage.

Not having your own desk has been problematic for some of the ABW users since it takes time to set up the workstation. Both bringing along individual instruments, like a bag or a computer, and installing these at the workstation with the collective instruments. Such as, monitors, keyboard, and as well adapting the height of the desk and chair to the right settings. This has led to some employees either not changing the workstation, therefore leaving belongings at the desk, and not following the share-desk policy or not setting the right settings of the desk and chair, leading to physical discomfort.

The features of the collective instruments that help the employees adapt for the desk-sharing policy, besides quick set up time, is that the furniture should have material that hides traces of previous users, tolerate repetitive use, easy to clean to keep the clean-desk rule, instructions for the furniture intended functions, storage or hooks for individual instruments and some kind of mobility. The transition from having an own desk, where it is possible to stack and store all paperwork, to where it is required to move around and therefore keeping all information on the computer requires some kind of digitalization (Babapour, 2019).

Another reason for the employees to not be willing to adapt or failing to implement ABW can come from the natural instincts of a human, wanting to feel security. When starting a workday the employees need to choose a desk for the day and some participants in Babapour Chafi et al. (2019) user study experience stress when having to compete for the "best" desk every day and not knowing specific social codes, like if they may or may not sit somewhere.

In summary, the theory on ABW shows that the user requires an activity-based workplace desk to; simplify the exchange of workstation by having an easy and fast set up time, have material that handles wear and tear and storage for individual instruments.

3.2 What Safety Requirements are There?

Both goods and services have safety requirements and regulations that contain technical specifications that explain the requirements that need to be met in order to be able to sell the product. The result of not doing so may imply an injunction on a sales prohibition (Konsumentverket, 2020). Therefore, the desk in development needs to comply with the safety requirements. The standards that are relevant are already utilized by Kinnarps and the following work is therefore only a matter of understanding them.

3.2.1 Standards and Certification

According to the Product Safety Act, goods must be safe for consumers and must not lead to any injuries. The act stipulates that a safe product is a product that, under normal or reasonably foreseeable conditions of use, does not present any risk of inflicting injuries (Product safety rules, 2020). This also applies to furniture so, in order to comply with this act, Kinnarps certifies their products according to EN 527-1:2011 and EN 527-2:2016. They include dimensions for legroom, desk height, working surface (SS-EN 527-1:2011, 2020), and rules for stability, structural strength, sharp edges, and shear points (SS-EN 527-2:2016, 2020).

The researched standards EN 527-1:2011 and EN 527-2:2016 have specific and measurable requirements and are therefore directly inserted into the requirement specification, except for EN 527-2:2016 strength and durability requirements. Due to the fact that it can only be approved by performing tests on a physical product, which is outside the scope of the project. Therefore, it will be excluded and instead seen as further development.

3.3 What is Out There?

In order to create a desk that is competitive on the market and at the same time aligned with Kinnarps design cue, a market analysis and a design cue analysis was performed. The market analysis was conducted to obtain more knowledge about already existing products and to gather mechanical solution insights. Kinnarps' own desks; Foldex and their height adjustable desk Oberon, were also included in the market analysis in order to get an understanding of Kinnarps's own line-ups. The design cue analysis was performed on Kinnarps's current product line to ensure that the new desk will conform with the same design cues, by expressing the same attributes and emotions.

3.3.1 Market Analysis

In order to map the competition, different showrooms and exhibitions were visited with the intention to examine office desks and preferable ABW adapted desks with Kinnarps's identified needs. That is desks with wheels, height adjustment, and folding mechanism. To evaluate the desks the design method PNI was utilized, special notices were taken to interesting features or attributes of various other furniture on display at the exhibitions and to gain a deeper understanding of a folding desk internal mechanisms, Foldex were examined further. Below is one of the desks that were analysed with the PNI, see

Figure 4. For the remaining PNI, see Appendix II - PNI of the market analysis.

Balzar Beskow

Figure 4: The desk in a horizontal and upright position, showing the desk when stacked

Standard bent tubing as the frame. Foldable desk by pulling the locking lever beneath and then tilting the desk. Big wheels for transporting the desk easily when not in use and stackable.

+ Large wheels that can clear obstacles
+ No spring
+ Stackable when not in use
- Poorly designed locking lever, hard to pull out to initiate folding
- Badly balanced when folded, due to unbalanced centre of gravity
- Not height-adjustable
⧫ Rounded edges
⧫ Distinct clicking feedback sound when locking

3.3.1.1 Foldex in Depth

During the project, the desk Foldex was accessible for deeper analysis. To examine Foldex (Figure 5) it had to be disassembled. This showed how the desk had been manufactured, how the mechanism works, and how many parts it consists of.

Figure 5: Kinnarps's desk Foldex

The desk's exterior is to a large extent built with stock materials such as sheet metal and square tubing welded together. The internals on the other hand contain several purposes and special made parts, both plastic and metal castings of complex vital parts and multiple fasteners to make everything stay put. Such a configuration entails extensive assembly time. One acknowledgment made is that the translation of the locking pins vertical motion to a twisting motion of the lock actuator at the front of the desk results in more components, see collage in Figure 6.

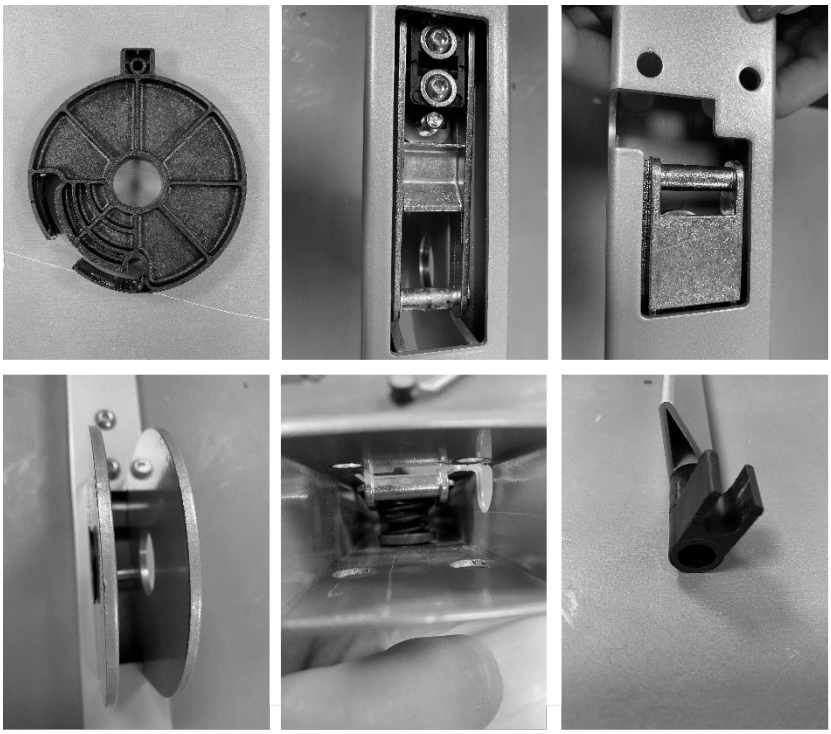


Figure 6: Parts of the internal mechanism of the Foldex desk

3.3.2 Design Cue Analysis

The design cue analysis was produced by drawing black lines alongside the products to visualise their geometry and to easier be able to express them with words, see Figure 7. When performing the design cue analysis, a random selection of products was picked out from Kinnarps's own website, Figure 7. The furniture expresses professionalism and office strictness, with its straight lines and fundamental geometry, but at the same time expresses joy and calmness through colours not traditionally found in an office. Though some of the furniture has organic and almost artistic shapes, they still clearly express their intended use by utilizing shapes modelled after the human body - "You are supposed to sit here". The furniture is squarely but organic in the details like corners and edges, also tapering legs and cut-outs signals airy and light products.

Figure 7: The design cue analysis with the complementing black lines and expressions

In summary, the *What is out there* section gave insight about features and criteria that the desk needs to fulfil to be competitive on the market. The features and criterions collected during the market analysis were categorised into different categories; practical, technical, user experience and production, which are presented below. Also, after the disassemble of Foldex, a decision was made that Foldex will stand as a benchmark in this project to compare the new desk against. Even though Foldex does not fulfil Kinnarps's fundamental requirements for an ABW, by not being height adjustable, it is still Kinnarps's marketed desk for flexible activities. Therefore, established details, for example, the part count shows what the desk needs to improve upon or equivalent.

3.3.2.1 Practical

In order for a desk to be practical some required features were identified. The desk needs to have lockable wheels or some sort of anchoring to the floor, to stop it from sliding around. When testing some desks on a carpet, it stood clear that only locking two out of four wheels was not enough. The possibility to stack desks in a row when not used were common, this was sometimes made more convenient by making the legs asymmetric to easier fit into each other. In this folded state some desks had rubber knobs as protection on protruding parts between the desk. Some smaller desks utilized a docking mechanism for interlocking desks together and the market analysis also gave a sense of user-friendly lock actuators.

3.3.2.2 Technical

Technical features that stood out was utilizing an expandable frame that enables easily scaled desks, that is, the mainframe parts can be the same and instead the desktop comes in various sizes. Many of the more economical desks were constructed with easily acquirable shelf parts and materials like flat bars and round stock, which keeps the costs down. Some salesmen at the exhibition, often highlighted the fact that they did not use mechanical parts that fatigue over time like springs, an important fact to have in mind when designing a desk that potentially gets adjusted many times a day. Other features were movable panels that can be placed on the table, hooks placed underneath the desktop, and the possibility to attach cabinets underneath the desk.

3.3.2.3 User Experience

For a more pleasant user experience a greater focus was put on cable management, especially on the underside since this is something that gets exposed when folded. Some desks gave off a distinct clicking sound as feedback when engaging and disengaging the folding lock. New height-adjustment switches were discovered which, much like an electronic handbrake, were pulled up or down in the direction of travel which made it easy to use without looking and intuitive. Some manufacturers had spent more effort on the folding lock mechanism, some could easily be operated by one person and one hand, whereas others had to use two hands and sometimes even a knee. Some competitors also had rounded and chamfered edges, felt covered compartments and slidable desktop, which could be argued that it gives a more aesthetically pleasing look and touch.

3.3.2.4 Production

One distinction made was that the more exclusive desks with more costly manufacturing methods like die casting were built on demand contrary to the mass-produced ones consisting of standard components and shelf material. They also, to a larger degree, consist of solid materials instead of veneers. With that said, that puts

a limit on potential material choices able to be made for this product to be developed with Kinnarps's intended production cost.

Furthermore, the design cue analysis showed what geometry, attributes, and emotions the product ought to comply with. This information was concluded into two mood boards, by searching online after pictures representing the captured emotions, for easier visualization and to express specific emotions to use during the generation phase.

3.4 What Does the User Need?

This section is focused on the user. To develop a successful product, it is essential to not only create a product that is competitive on the market and follows Kinnarps design cue but also satisfies the user. By finding which the users of an ABW-desk are, exploring and understanding the users' needs an appropriate product can be developed. First, the found users from the theoretical research were categorized by using Janhager´s (2005) user categorization system, to make it easier to visualize who the users are. Then to explore the user needs, interviews and observations were performed on three eligible companies having an ABW environment and within these companies' facility managers, employees and cleaners were interviewed, in total, seven users were interviewed. The gathered information was analysed with help of two analysing methods resulting in a clearer view of the user needs.

3.4.1 Who Uses an ABW-Desk?

Primary users, secondary users, side-users, and co-users are defined categories that follow Janhager's (2005) user categorization system, which is used to describe all users. Where primary users' use the product for its intended purpose whilst secondary users are defined as those who come in contact with the product somewhere during its life cycle but do not use it for its primary purpose. Side-users involuntarily get affected by the product, either with a positive or negative acknowledgment. Finally, the co-users are those who cooperate with a person who uses the product (Janhager, 2005).

3.4.1.1 Primary User

Primary users consist of everyone working in the ABW environment that uses desks, both experienced and inexperienced users. In this case, the focus is on offices that utilize ABW, though flexible and active workstations can be found elsewhere, for example in educational contexts.

3.4.1.2 Secondary User

The secondary users are cleaners, maintenance personnel, salespeople of the product and buyers of the desk, for example, the facility manager or the head manager buying desks for their office.

3.4.1.3 Co-User

Co-users are those who are situated in the same location that see and hear the desk, from one perspective, they could also be primary users, but the focus is more on how a person, that is not using the desk, can be affected. For example, the experiences of a co-workers sitting in the same room and being disturbed by the product's sound when being height-adjusted by the primary user.

3.4.1.4 Side-User

Side-users are those who assemble the desks, people who handle logistics and manufacturing.

Developing a desk with all user categories generated, the project scope would be too extensive, therefore the attention will be placed on the primary user, the other user

categories will be under consideration during the development phase. The facility managers stood for most of the information gathered during the interviews, due to them being both primary users, as they work at the office daily, and that they have plenty of knowledge regarding ABW. Although, keeping in mind that they are the spokesman for ABW at the company, thereby a bit biased.

3.4.2 Interviews & Observations

With these four identified categories of users (primary users, secondary users, co-users, and side-users) a mix of people at the companies were interviewed. Focus was on, as mentioned above, the primary users, which could be employees and facility managers. To both acquire information about how it is working in an ABW-environment and thoughts around how the companies have implemented ABW, two facility managers, four employees and one cleaner were chosen and for more input. “A day in life” method was used to gather information regarding how the user interacts with the desk, what collective and individual items they have and how they install them self at the desk.

For more details, a semi-structured interview was chosen as it can help acquire the users underlying needs. When formulating the interview questions the multiple use-cycles exploration pack from the Use2Use design toolkit was used as a foundation for the interview. The multiple use-cycles exploration pack consists of 14 sets of empathy cards (Figure 8), which helped to identify the user’s challenges and gave insight into how the user interacts with the product in different activities (The Use2Use Design Toolkit, 2020).

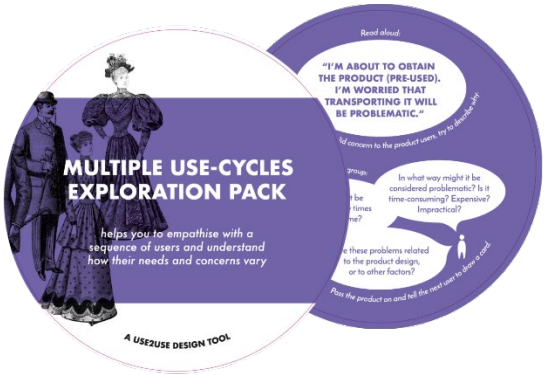


Figure 8: The empathy cards from Use2Use design toolkit (The Use2Use Design Toolkit, 2020)

The interview started with some formal questions about the interviewee, for example, what their daily responsibilities are and how long they have been working in an ABW environment. Then the remaining questions were divided into three categories; topic specific questions, product opportunity questions and a day in life scenario, for better structure, see the whole interview material in Appendix I - Interview material. The topic specific related questions were about what they and their co-workers thought of ABW, how they became accustomed to working with ABW and adapting their workstation. The second category, product opportunity questions, were more focused on the product such as what kind of desk they have, what electronic & practical features the desk should possess and if there are any improvements to be made on the current desk. After knowing more about the interviewee and the companies’ desks, the interviewee was to show A day in their life. The task given to the interviewee was to select and get settled at a desk, set the right settings of the desk and chair, illustrate how they would work by the desk and additionally show how they would leave the desk when both going for lunch and leaving for the day. The interviews are summarized below and highlight some of the user needs that were found.

3.4.2.1 Company 1

First company that was investigated is a company that has used ABW for about two years and are working in an Agile way. The first interviewee is a facility manager at this company, that is working with the implementation of ABW. The way they are following ABW is that every team has their designated spot, which means that a team of four people have four desks to share between each other and if they need to have a meeting or similar, there are meeting/workshop spaces for this nearby. Each team also creates a team-mascot which is put on the wall behind their team to indicate that this is their area and they are also given a whiteboard, which is used for meeting or just putting team information on.

"Designs for the team instead of the individual"

- *The facility manager at company 1*

At this company, each desk was equipped with; one or more screens, a keyboard, a computer-mouse, a hub with USB-C connection, cables for the screen etc, electrical and network outlets. Individual instruments that the employees brought with them to the desks were a bag, a laptop, their phone and sometimes headphone or similar. The facility manager also thought of the importance of having a surface which allows the employee to use a computer-mouse without a mousepad, thereby keeping a cleaner workstation. The company also enforces a desk-sharing policy and clean-desk rules. To keep the clean-desk rules they store spray bottles and wipes in different locations for employees to take if needed. Three interviewed employees liked the idea of ABW but does not choose a different desk each day. Instead they have their own desk within their team, with their screen adjusted after them, same with the desk settings which also means that they leave personal belongings on the desk after each day. They mentioned that switching desks each day did not come natural to them and that this was something that felt quite uncomfortable, due to not having their safe zone that they routinely can go to. They feel that switching desks would only make them more stressed, not knowing where to sit the next day.

The facility manager liked the idea of having wheels or something similar underneath the desks making them mobile but was concerned that the wheels would leave marks on the floor or just gather hair and dirt. After completing the interview questions the interviewee role played A day in life, Figure 9 shows the interview installed at the workstation with its individual instruments and the desk and chair set in the right settings. Figure 10 shows how the interviewee would leave the desk after completing its work tasks for the day and thereby following the desk-sharing rules.

Figure 9: The user's desk when installed

Figure 10: How the user leaves the desk

3.4.2.2 Company 2

The interviewee has worked with ABW before and helped the company to implement an ABW environment in 2014 as a facility manager. How this company distinguishes itself from the first company was that they do not have designated spots for each team, but it is very likely that the teams sit together anyway. At this company more people accepted the ABW structure and changed desks frequently due to the fact that they had more options regarding where to sit and perform different work tasks, more semi-quiet zones, which seemed appreciated by the employees. Some frustrations that the interviewee had noticed by the employees was that some felt that even though the desk changed height in a matter of seconds, the employee could still feel that it took way too long to adjust

> "10 second could feel like 10 minutes"
>
> - *The facility manager at company 2 citing the employees*

Therefore, setting the desk and chair to the right settings becomes an irritation and can lead the employees to either not changing the settings, which leads to a non-ergonomic workstation, or no changing desk as often as demanded from an ABW environment. To fix the problem of having a non-ergonomic workstation the employees were given information on how to set up their workstation. Unfortunately, some employees took this information too literally and continued to have the same height on the desk even if the conditions changed. For example, having different shoes which alters the initial height, thereby creating a non-ergonomic workstation. To have a pre-set height for both sitting and standing for everyone, in this case, would lower the irritation of the setting up-time but would enable for a non-ergonomic workstation. Same as at the first company, they have a clean-desk rule. To make the employees more comfortable with the clean-desk rule they prefer to call it a standard instead of a rule and also have wet wipes in different locations to make it easier for the employees to clean the desks. They also prefer to use material that

can handle wear and tear this to have furniture that has a longer lifespan and at the same time try to remove the feeling of “used furniture”. Each desk is equipment with the same collective and individual instruments as company 1 except that they also use mouse pads. The interviewee mentioned how important it is to have panels on the desk to make it easier for the employees to concentrate and hooks underneath the desks for the employees bags due to the fact that they always bring along all their individual instruments. Figure 11 and Figure 12 show a day in life for the interviewee, which is similar to company 1.

Figure 11: How the user leaves the desk

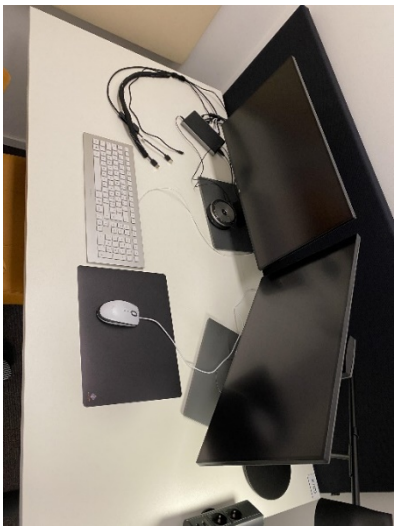


Figure 12: The user’s desk when installed

3.4.2.3 Company 3

The third interview was conducted at a company that has used an ABW structure for about one year. The first interviewee is an employee at the company and has worked there for about six months as a project manager. The employee sees this kind of workplace structure as a perfect match for consultants, who only visit the company in shorter periods and therefore do not need a permanent workstation. Thoughts on having panels for concentration and a desk-sharing policy is the same for this company as the others above, however, there were differences in which collective instruments they used and how they applied the clean-desk rule. As seen in Figure 13 and Figure 14, which is a part of the A day in life observation, the collective instruments are one larger screen with USB-C connection, electrical outlets, and cables for the screen etc. The individual instruments therefore also contained a keyboard and a computer mouse. Instead of having a clean-desk rule it was common sense to clean up with a cloth from the kitchen if one were to spill

something, but they also had the cleaning staff wipe all areas
more frequently. The cleaning staff at this company mentioned a few things that would make the cleaning easier, the space between the legs of the desks big enough to fit a mope or similar, having the same height on the desks and also something collecting all the cables because there is no time to lift them all up when cleaning. New problems that have occurred for the cleaning staff was cleaning of the electrical outlets**,** now when they are facing upwards from the desk it collects more dust due to the fact that it does not have a cover protecting it.

At this office, the employees moved around depending on the work task, many stayed close to their own lockers. The lockers, containing personal items, were placed so people of the same team had their lockers in the same place, thereby making people in the same team sitting close to each other. For more creative work tasks, they had a workshop room with movable whiteboards, tv-screens, and fixed standing desks.

The interviewee mentioned that some of the corners and edges of the desks were damaged when height-adjusting them, due to collision with other desks or furniture, therefore some kind of protection would be needed. Pre-set settings of the desks were commented as a pleasant feature, but not something to use every time. To have a desk with a depth suited for using a screen all day was important and also somewhere to place the computer, some sort of magazine holder.

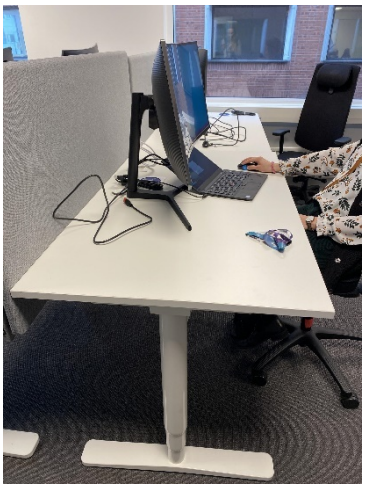


Figure 13: The user's desk when installed

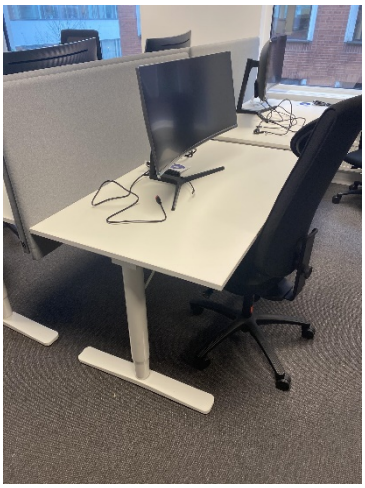


Figure 14: How the user leaves the desk

In summary, all statements above including the unmentioned user needs, such as good cable management and lock with auditory feedback amongst others, are the derived user needs. The user needs are generally stated in an informal language as subjectively expressed by the user and are not easily objectively concluded as fulfilled in that state. Therefore, these are converted to requirements which is a precise description of what the product has to do (Ulrich & Eppinger, 2012).

Before converting the needs from a subjective statement into something measurable a KJ analysis was performed, this to group the user needs together based on similarities and give them a category name. Seven categories were identified, see Figure 15 for an example of the versatile category:

- easy to use
- sound ergonomics
- Inviting
- Cleanness
- Durability
- Easy to adjust
- Versatile

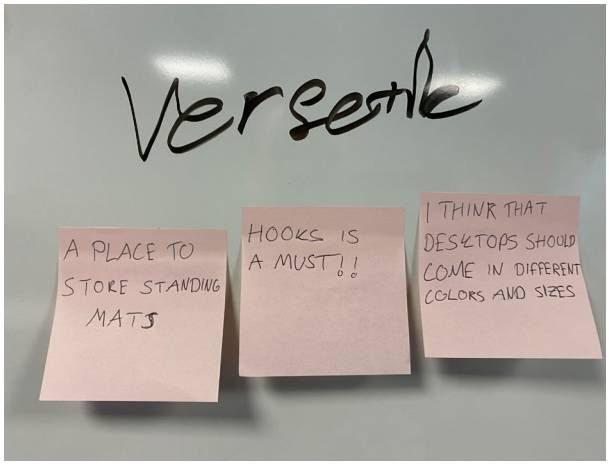


Figure 15: One of the seven categories and the associated needs on post-its

Next step was to transform the needs into a measurable state, which was done by creating an objective tree with the seven categories, which can be seen in Appendix III – Objective three.

3.4.3 Contradicting needs

Before concluding this section, the extracted and analysed needs were supposed to be weighed against each other to know the internal ranking of each need in case all needs cannot be fulfilled or are counteracting, a prioritization can be made. But what was discovered is that the interviewed company's way of implementing an ABW differs from Kinnarps' view of implementing ABW. The literature describes ABW as when the employee chooses their own workstation depending on which activity they are to perform at the moment, which opens up for different ways of implementing an ABW (Babapour, 2019). Hence in this case, employees relocate from one workstation to another, choosing the workstation that fits the work task OR the actual workstation/room transforms into the desired activity. The three companies follow the former implementation of ABW due to the fact that they have space and capital to create each zone and therefore not needing to have these flexible workstations/rooms. Whilst Kinnarps' goal is to develop a desk for the latter implementation of an ABW. Kinnarps argues that companies in Europe and dense cities have gained interest in these flexible workstations/rooms and therefore the companies, mostly in Sweden, do not know that they want it, yet. This information was confirmed during the market analysis where other company representatives and sales personnel claimed that Asia and more dense cities in Europe, have a large demand for modular and flexible offices due to physical space restriction whereas in Sweden, as mentioned, there is no particular space shortage. This showed that all needs gathered in this section are from companies that expectantly will, in the near future, require these kinds of furniture. Therefore, a company that implements an ABW as a flexible workstation/room that transforms into the desired activity, will need to validate the derived needs. Because of external circumstances this was not possible. Therefore, an executive decision had to be made concerning the user's needs. The decision, based on the knowledge gained from the literature study, the interviews and Kinnarps fundamental requirements, was that all users' needs that were collected will be seen as features that delight the user if they are implemented, making the product more appealing, rather than basic requirements.

Regardless of the implementation of ABW, the users that were interviewed are still users of desks in an office environment and their needs are still applicable but some of them clash with the latter, flexible workstation implementation. Therefore, some needs have to be eliminated. The user needs, mentioned in the interviews and displayed in the objective tree, *network outlets, 230 outlets, housing cleaning supplies, collective instruments* and *colour coordinate desks* will be removed from the list of needs. Network outlets and 230 outlets do not align with Kinnarps'

fundamental requirements of being self-sustained and using a USB-C port. Housing cleaning supplies and collective instruments clashes with having a clutter free desktop. Because, having unnecessary space creates an opportunity for leaving behind stuff, for example, old post-its or trash and most importantly, having a lot of loose stuff attached to the desk makes for a cumbersome folding and storing process. Colour coordinated desks help strengthen the team spirit, but this does not help the user to change workstation every day, which might not be optimal when having an ABW.

In summary, the collected user needs will be included in the development phase but seen as features to make the product more appealing. For example, *easy to adjust, connectivity by USB-C* and *material that is easy to clean*. The priority will be to fulfil Kinnarps' fundamental requirements first, therefore, proceeding with a flexible workstation/rooms that transforms into desired activity as an ABW. To visualise how the desk could be used and what is needed of the desk within a flexible workstation/rooms, three scenarios were created.

3.4.3.1 Scenario One

Four employees working together for one week on a project that needs frequent communication and plenty of space to discuss work material, mainly using laptops, paper and pencils. Therefore, needing four desks that have electricity and a desktop size to fit all material.

3.4.3.2 Scenario Two

An employee that varies between standing and sitting by the desk and needs a monitor to be able to have multiple windows open at the same time. Therefore, needing a desk that is height-adjustable, has electricity, a monitor and a desktop size that fits both monitor, laptop, keyboard and computer-mouse.

3.4.3.3 Scenario Three

A team of six people sitting separately by their own desk, some with only laptops and some with monitors due to different work tasks. They also rearrange four desks each week to a conference desk to have workshops. Therefore, needing six desks that are mobile, stackable, and foldable to be able to stack away the unwanted desks, height-adjustable and have electricity, monitors, keyboard, and computer-mouse.

3.5 What are the Target Values?

Before inserting the users' needs as well as Kinnarps fundamental requirements, the features, and criteria from the market analysis into the requirement specification, some requirements have to be defined and therefore, require further testing to obtain a target value. These requirements are desk size, easily adjustable, battery capacity, wheel size for thresholds and cleaning space.

3.5.1 Desk Size

To determine a functional desktop area for the user and investigate Kinnarps proposed area of 1000-1400 x 600-700 mm, user tests were performed. Before starting the test, three pilot tests were conducted on four students and these pilot tests showed which scenarios to use during the formal test and some small details that needed to be improved. After the pilot tests, users familiar with an office environment participated in the tests. However, to make the participants as similar as possible to the target group, their individual and collective instruments were the same as the interviewees had during the interviews. The tests consisted of two scenarios:

In the first scenario, see in Figure 16, the participants were told to imagine an ordinary day where they arrive at work around in the morning, they are supposed to send some emails or do a smaller work task and then, before lunch, leave the desk to go to some meetings. This scenario only lets the participant have individual instruments, such as a phone, laptop, computer-mouse, coffee mug (or similar) and one more personal item, for example headphones.

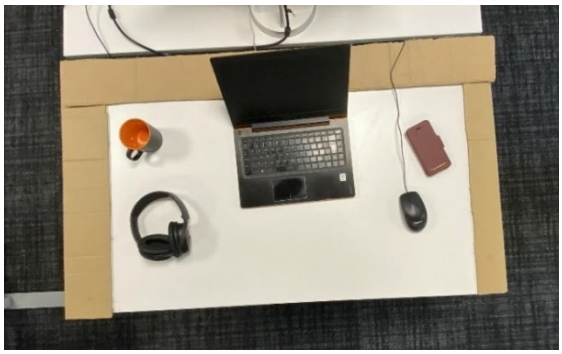


Figure 16: First scenario

In the second scenario, Figure 17, the participant should imagine that they and their team are going to work together for about 3-14 days on the same spot, thereby having to sit for a longer period of time at the desk. For this scenario, the participant has the same individual instruments as in the first scenario and also collective instruments as a screen and a keyboard.

Figure 17: Second scenario

The tested depth was 50-70 cm, since the recommended viewing distance to the screen is 50-80 cm (Arbetsmiljöverket, 2018) and Kinnarps request for desk depth is 60-70 cm. When performing the pilot test a depth of 50 cm was considered too narrow to even be able to work with a laptop, therefore the following tests had 60-70 cm depth. The width was tested from 120 cm down to 80 cm, the same issue of the desk being too narrow was seen here as well, thereby not testing smaller width than 80 cm. Each test started with a desktop area of 120x70 cm, then the participants were told to “Spread out and sit comfortably as you would normally”, and then area was decreased incrementally with help of three cardboard pieces, see figure 16. First was the depth tested and then the width with the already determined depth. After each reduction of area, the participants were asked about how they felt about the new area given. When a satisfying area had been determined a desk and a figurine was placed next to the original desk to see if the personal space would be affected and thereby require a greater area to distance themselves.

The collected opinions were summarized, see Tabell 1. The result stagnated and therefore, the test was terminated after four participants were tested. The result shows that a depth of 70 cm is required for both screen and laptop, but the screen requires more width then a laptop; 110 to 120 cm. Since unused rental space in an office is a waste of money, more desk means more material and both widths were ok according to the test, the smaller width of 110 cm was chosen. Smaller desktop widths than 110 cm was rejected by the participant when another desk and figurine was placed next to it and thereby confining the participants personal space.

“The desk area could be smaller because my stuff on the desk would still fit and it would be possible to work but my personal space would be invaded”

- *Participant three in desk size test*

Tabell 1: The collected opinions of the desk size tests

No screen (cm)			With screen (cm)		
Depth	Width	Comment	Depth	Width	Comment
60 70 70	120 95 80	Unpleasant* Ok* Unpleasant	60 70 70 70	120 110 95 80	Unpleasant Ok Less Ok* Unpleasant
60 70 70	120 110 100	To close* Ok To close	60 70 70 70	120 120 110 95	Unpleasant Ok Less Ok Unpleasant
60 70 70 70	120 110 100 95	To close Ok Less OK Unpleasant	60 70 70 70	120 120 110 100	To close Ok Ok Unpleasant
60 60 60 60	120 110 95 80	Ok Ok Less Ok Unpleasant	60 70 70 70	120 110 95 80	Unpleasant Ok Ok Unpleasant

***Ok** = Not perfect but not bad either.
***Less Ok** = The user does not feel that it is perfect but could work like this for a shorter time.
***To close**= The desk area satisfies the need for the user, but it is too close to co-workers which makes it uncomfortable for the user
***Unpleasant** = The user is not comfortable working with this size of desk area

The “standard” rectangular shape was chosen due to ease of manufacturing but foremost due to the fact that chamfers, rounds, and other attributes just are aesthetically aspects but at the same time decreasing the efficiency by not

maximizing the usable area. Rectangle is also the easiest to pair together with another to avoid gaps. The shape is also exclusively used by the competitors, which tells that it is a requested shape for an office desktop.

3.5.2 Easily Adjustable

One user need that arose during the exploration phase was that the desk has to easily be adjustable and one aspect of that is time. During the interviews it was mentioned that some employees who are struggling with the adoption could experience that the few seconds it took to set up their chosen workplace felt as minutes, therefore smooth and swift adjustment is essential. The most prominent feature to adjust on a “ready to use” desk is the height of the desktop, the other one being the time to fold and unfold the desk when it is in a stored state (folded). These two features were tested separately on four office employees, unfortunately not users working in an ABW environment, due to external circumstances.

Setting a target time for height adjustment time is not a straightforward task since the time is based on the distance the desktop has to travel; from the original height to the preferred height, which varies from occasion to occasion. Therefore, the velocity for the desk’s vertical motion was determined. To test what a preferred velocity could be, the participants were asked to rate two different types of a height-adjustable desk, one being Kinnarps own desk Oberon. The desks were set to a height that ergonomically is not correct for the participant, and then they were to set the desk to a height that they prefer. Afterwards, the participants were asked if they were satisfied with the time it took to adjust the desk, if it was quick enough, did it feel fast or slow. With this information the preferred velocity was calculated.

Setting the target time for folding and unfolding the desk was done by having the desk Foldex as reference. The reason for that is that it is a straightforward, single action procedure, carried out by one person, as described in the requirements of Kinnarps. To test the folding time of Foldex the participants were clocked on the time it took them to fold and unfold the desktop. However, the tasks were performed in a competition-like fashion. Therefore, to get a more credible time, the participants were secretly clocked during their more casual trials during the following discussion. The average over all time was then calculated.

The fastest desk was unanimously chosen as the preferred one. Therefore, a target velocity of 3,6 cm/s is set to the requirement. It is important to note that having a too fast adjusting desk can carry a risk of accidents by reducing the reaction time. The folding test showed that the average time to fold the desk was 3,72 seconds and 3,98 seconds to unfold, therefore the time of 3,5 seconds was chosen as target value.

3.5.3 Battery Capacity

A vision from Kinnarps is that the solution should be self-contained, providing energy thus supporting the users’ energy needs by giving the possibility to connect all their technical office devices to the desk and provide charging ability. To be useful, the battery needs to have a capacity that is large enough. However, the capacity has a strong correlation to volume due to energy density of batteries and the price, which are two restricting factors in this project. Therefore, in agreement with Kinnarps, the target capacity should be set so that the desk can provide energy for one day, for one computer, one cell phone and a

monitor. Consequently, the energy capacity for an average laptop battery, cell phone battery and the energy consumption for a monitor for eight hours, were investigated. This by doing external research about the energy consumption of a number of different models of the objects and then an average was calculated.

Three laptops, two cell phones and four monitors were used in the calculation of finding an average energy consumption value, see in Tabell 2. The total amount of energy needed for one day sums up to almost 300 Wh, where the monitor contributes with the major part. Kinnarps's supplier of electronic control systems for their desks supplies a battery with a capacity of 65 Wh. Apart from occupying a lot of space and being heavy, supplying a capacity five times larger than the existing 65 Wh, would cost more than the production budget for the whole desk. Therefore, it was concluded to not incorporate the monitor in the calculation and the sum of the needed capacity for the cell phone and laptop is 64,7 Wh, which makes one battery sufficient.

Tabell 2: The calculation of the laptops, cell phones and monitors

Object	Laptop	Cell phone	Monitor
Consumption (Wh)	51	15,04	192
	35	11,67	240
	68		288
			200
Average consumption	**51,3**	**13,4**	**(230)**

3.5.4 Thresholds

To clear thresholds when rolling the desk through a door, the ground clearance is important and more so, the wheel size so that the desk rolls over the thresholds in contrary to bouncing over or getting stuck. The ground clearance will be determined with a margin to common thresholds, the wheel diameter will be set with a test. The wheel diameter test was done by taking an available desk with wheels and rolling it over, in the threshold spectra, a large threshold to be on the safe side. The used threshold was 23 mm high and made for sound proofing doors, see Figure 18. Then based on the performance of the wheel, whether it gets over or not and in what way, a target value could be determined.

Figure 18: The threshold used for testing the wheels

In summary, the target value for ground clearance was set to 30 mm so that it clears

common thresholds. The wheel size diameter was set to 75 mm. However, there was only one type of desk available for the test and thereby only on wheel size, more specifically, a 75 mm one. So, to be able to perform the test at all, the 75 mm wheel was used, and it fulfils the requirements of not getting stuck or bouncing over the threshold,
but it was just enough and could optimally be slightly larger.

3.5.5 Cleaning Space Between the Desks

The cleaning space between the desks is about the cleaning staff having a hard time getting in between the legs of two lined up desks to clean the floor between them if the legs are placed near the edge of the desktop. To ease the job of the cleaning staff the space needs to be sufficient to fit cleaning supplies in between. However, making the gap too large entails in a confined space for the office worker sitting at the desk. To determine the needed space, measurements of the depth for flat mops were investigated.

The investigation of flat mop showed that the space in between the legs of the desks to be 12 cm.

3.6 Conclusions of the *Exploration* Phase

The findings of the exploration phase regarding; ABW, the target group, the market, Kinnarps own products, the users' needs, standards, and the products needed performance is concluded and presented in the requirement specification below, see Tabell 3. The requirement specification will serve as the foundation which all product decisions are matched with throughout the development process. The requirement specification is structured by the three main categories; standards, Kinnarps' requirement and user needs & market analysis, followed by sub-categories and the definition of the requirement. Then, each definition is given a unit, a value, which is the minimum value to achieve and an optimal value, which is a preferred value to achieve. As mentioned earlier, the user needs are treated as features thereby are, they only given an optimal value. Some needs cannot easily be translated into quantifiable metrics and are therefore marked with "subj" for a later subjective evaluation. Other non-quantifiable data elicited from the exploration phase, for example, the mood board, are not part of the requirement specification, nevertheless it will be a part of the development phase. Furthermore, duplicates that are to be found in both, for example, standards and user needs like sharp edges, are only specified once in the requirement specification.

Tabell 3: The requirement specification

nr	categories	sub-categories	definition of requirement	sub definition	value / range	optimal value	unit	source	date	comments
1	Standards	Dimensions	Height of the work surface	Sit/stand	650-1250	618-1306	mm	EN 527-1:2011	2011	
2			Max. desk top thickness	At the front	55		mm	EN 527-1:2011	2011	klass D
3				At 500 mm from the front edge	80		mm			
4			Min. height of knee clearance for standing position only	Applies only to tables with a height more than 850 mm	700		mm	EN 527-1:2011	2011	
5			Min. depth of clearance for standing position only	knee	80		mm	EN 527-1:2011	2011	
6				foot	150		mm			
7			Min. height of min. foot clearance	Sitting only and sit/stand From 600 mm to 800 mm from the front edge	120		mm	EN 527-1:2011	2011	
8				Standing only from front edge to 150 mm	120		mm			
9			Minimum legroom depth	Sitting only and sit/stand	800		mm	EN 527-1:2011	2011	
10			Minimum desktop depth		800		mm	EN 527-1:2011	2011	
11			Minimum legroom width	Sitting only and sit/stand	1200		mm	EN 527-1:2011	2011	
12				Standing	790		mm			
13		Safety requirements	All edges and corners are free from burrs and rounded or chamfered.		Pass		Pass / Fail	EN 527-2:2016	2018	
14			Edges/corners of top surfaces are	Chamfered	>1		mm	EN 527-2:2016	2018	
15				Rounded	>2		mm			
16			Ends of feet and hollow components are capped or closed.		Pass		Pass / Fail	EN 527-2:2016	2018	
17			Movable & adjustable parts designed so injuries avoided.		Pass		Pass / Fail	EN 527-2:2016	2018	
18			Not possible any load bearing part to come loose unintentionally.		Pass		Pass / Fail	EN 527-2:2016	2018	
19			All lubricated parts designed to protect users from stains.		Pass		Pass / Fail	EN 527-2:2016	2018	
20		Shear and squeeze points	During setting up & folding - S&S points created are acceptable (unless 21 or 22 are applicable).		Pass		Pass / Fail	EN 527-2:2016	2018	
21			Powered mechanisms – no S&S points which close to <25mm unless always <7mm.		Pass		Pass / Fail	EN 527-2:2016	2018	
22			During use – no S&S points close <25mm unless always <7mm.		Pass		Pass / Fail	EN 527-2:2016	2018	
23		Stability requirements	Stability under vertical load		Pass		Pass / Fail	EN 527-2:2016	2018	
24			Stability for work tables extension elements		Pass		Pass / Fail	EN 527-2:2016	2018	
25	Kinnarps	Client Requirements	Mobile	Mobile	Pass		Pass / Fail	Brief	21-1	Can easily be transported
26				By one person	Pass		Pass / Fail	Brief	21-1	
27			Lockable	When folded	Pass		Pass / Fail	Brief	21-1	Can not be folded/unfolded without intention
28				When unfolded	Pass		Pass / Fail	Brief	21-1	
29			Foldable	Foldable	Pass		Pass / Fail	Brief	21-1	With two hands maximum
30				By one person	Pass		Pass / Fail	Brief	21-1	
31				Quickly		≤3,5	Seconds	Brief	21-1	
32			Stackable	Stackable	Pass		Pass / Fail	Brief	21-1	With two hands maximum
33				By one person	Pass		Pass / Fail	Brief	21-1	
34			Aesthetically Pleasing		Yes		Subj	Brief	21-1	Evaluated by Kinnarps
35			Provide electrical power		65	>65	Wh	Brief	21-1	Derived from "provide charging ability" For computer, cellphone, monitor, desk.
36			Desktop width		1100		mm	Brief/test	21-1	
37			Desktop depth		700		mm	Brief/test	21-1	
38			Production cost			5000	SEK	Brief	21-1	
39			Height-adjustable		Pass		Pass / Fail	Brief	21-1	
40			Clear standards threshold	Ground clearance	30		mm	Brief/test	21-1	
41				Wheel diameter	75	>75	mm	Brief/test	21-1	
42			Anchorable	Lockable wheels	Pass		Pass /	Brief	21-1	

43	User needs and market analysis	Cleanliness	One standard height			Pass	Pass / Fail	Interview 3	w.8	To make the cleaning easier for the cleaners
44			Protection for the vertical outlets	Hinder dirt from entering the		Pass	Pass / Fail	Interview 3	w.8	
45			Cleaning space between the desks			>100	mm	Interview 3	w.8	
46			Material that is easy to clean			Pass	Pass / Fail	Interview 3	w.8	
47			Prevent hair cumulation in the wheels			Pass	Pass / Fail	Interview 3	w.8	
48		Durability	Interchangeable parts	Legs	Pass		Pass / Fail	Market analysis		
49				Wheels	Pass		Pass / Fail			
50				Desktop	Pass		Pass / Fail			
51				Electronics	Pass		Pass / Fail			
52			Durable material			Pass	Pass / Fail	Interview 3	w.8	Collision. have inte mind (not glass etc)
53			Side/lateral edge protection	Folded	Pass		Pass / Fail	Market analysis		
54				Unfolded	Pass		Pass / Fail			
55			Minimize use of textiles	On wear surfaces		0	mm^2	Interview 1	w.7	
56			Minimize wheel marks			Pass	Pass / Fail	Interview 1	w.7	On carpets
57		Easy to use	Easy to adjust	Pre-set settings		Pass	Pass / Fail	Interview 3	w.8	
58				Velocity		3,6	m/s	Interview 2	w.8	konkurent vs kinnarps reference
59				Lowest/highest		Pass	Pass / Fail	Interview 3	w.8	Button
60				Communicating the intended function		Yes	Subjective	Literature study	2019	
61			Lock with auditory feedback		Pass		Pass / Fail	Market analysis		
62			Connectivity	Wireless charging		Pass	Pass / Fail	Interview 1,2,3	w.7-8	
63				USB-C	Pass		Pass / Fail	Interview 3/Brief	w.8	
64			Desktop enables use of mouse			Pass	Pass / Fail	Interview 1	w.7	
65		Inviting	Maximal stroke in both directions	Provide physical comfort		Pass	Pass / Fail	Interview 1,2,3	w.7-8	
66			Clutter free desktop			Yes	Subjective	Interview 1,2,3	w.7-8	
67			Cable mangement	Coordinate outlets with close proximity / same side		Pass	Pass / Fail	Interview 2	w.8	In case of multiple outlets and dock
68				Cable storage/hidden cables		Pass	Pass / Fail	Interview 1,2,3	w.7-8	Look clean and no cables interfering the cleaning
69		Sound ergonomics	Quiet desk	Minimize mechanical noise		Yes	Subjective	Interview 1	w.7	Konkurent referens. testat utan vetskap
70			Panel compatible			Pass	Pass / Fail	Interview 1,2,3	w.7-8	Accepts Kinnarps panels
71		Versatile	Provide a range of desks	Different colors and sizes		Pass	Pass / Fail	Interview 1	w.7	
72			Provide storage	Individual instruments		Pass	Pass / Fail	Interview 1,2,3	w.7-8	
73				Stand for laptop		Pass	Pass / Fail	Interview 1,2,3	w.7-8	
74			Multipurpose desktop	Whiteboard		Pass	Pass / Fail	Interview 1 & 3	w.7-8	

04
Generation

Elements of a Desk • Defining the Desk • Selection of Locking Mechanis • Ways of Locking • of Folding

In the generation phase, different methods for developing and analysing products were conducted, which in the end resulted in a final concept. A modification of the fish trap model was made, instead of thinking of all parts of the product, the development was centred around the locking mechanism and other parts were instead designed around it. This to simplify a complex system by developing it component by component and thereafter, adding non-structural details in the end. It is the fact that this product is complex, a large ecosystem consisting of many components that depend and build on each other, that the method is utilized. It breaks the problem down into more manageable parts.

4.1 Basic Elements of a Desk

In this level, the basic functional components are defined, and different structural orientations are investigated, which helps develop an understanding for the components' dependency. By performing brainstorming sessions, screenings and workshops, this level generated a few rough concepts that in the next phase will go on for further development.

To even start to define the core components, the ways in which the desk can be folded had to be investigated. It sets the rules for which components are needed. To determine in what way the desk could be folded, brainstorming was used. The result was sketched on a whiteboard (Figure 19) and followed up with a screening based on pros and cons with each idea.

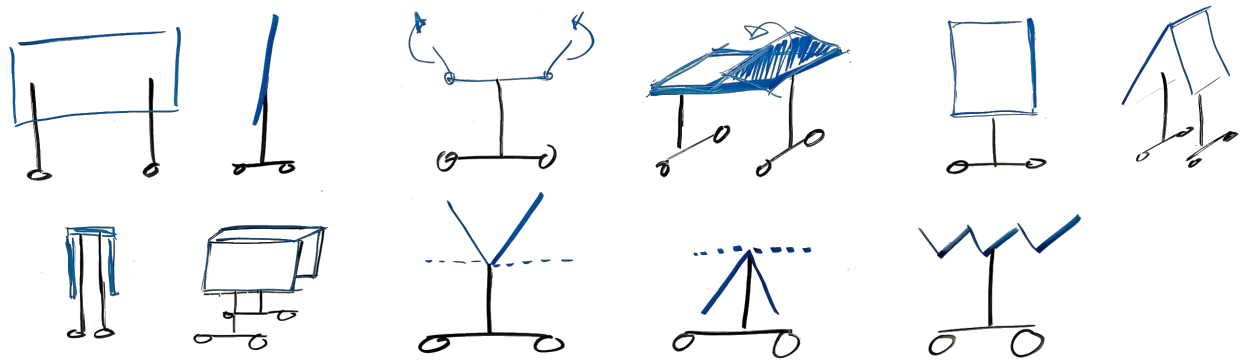


Figure 19:Sketches from the brainstorming session

Multiple ways of folding were generated, see Figure 19. Solutions where the desktop consists of more than one part that folds increases the part count and complexity, this was observed in the market analysis. It also entails a complicated frame since the frame needs to fold in the same way while supporting the desktop. Desks that fold the frame by letting the legs approach each other were perceived as unstable in transport in the market analysis. The chosen way of folding was a rectangular desktop that folds in one piece away from the user, the reason being that it fulfils the previous mentioned criteria and is one of the desktops that satisfies the requirement of using the desktop as a whiteboard in a folded state.

To summarize, the core components are the desktop(1), a frame(2) that supports the desktop, two consoles(3) that connect the frame to the legs(4), a support bracket(5) that connects the two legs which makes it

more rigid and finally, a cable tray(6), see Figure 20.

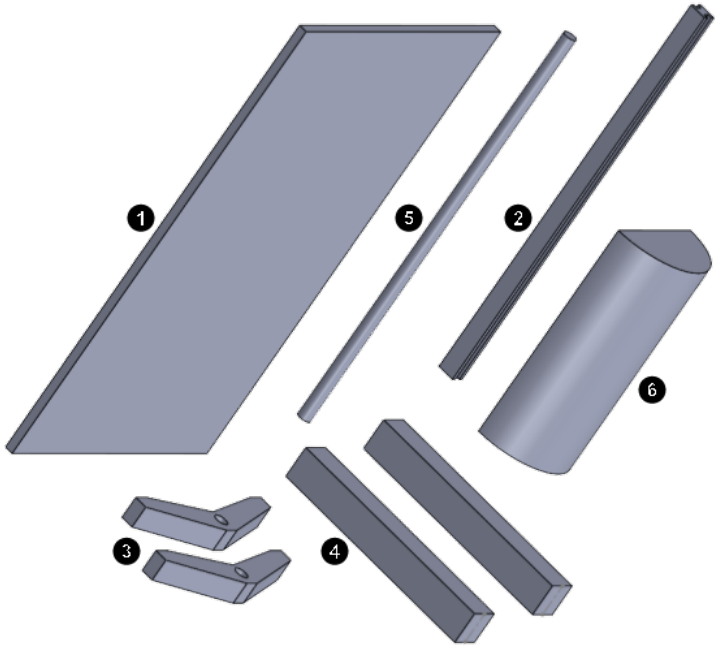
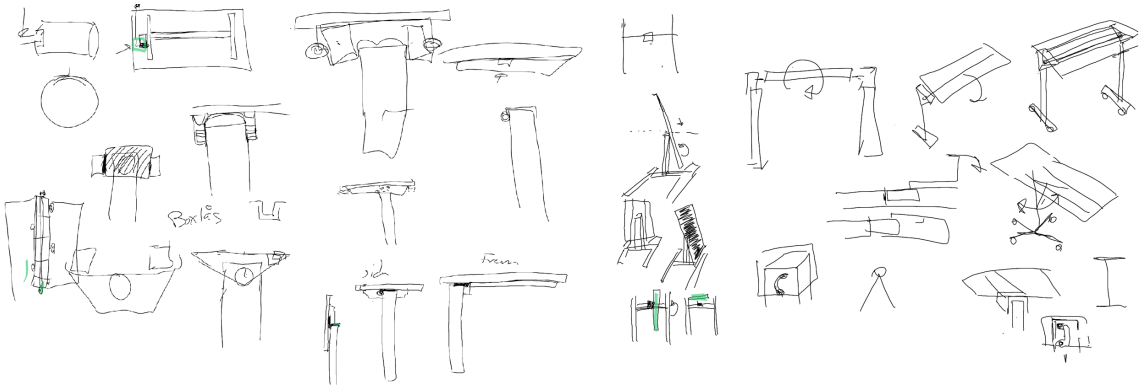


Figure 20: The core components of the desk

4.1.1 Ways of Folding

To generate variants of ways of folding the chosen desk, a Brainstorming session was performed to compose the core components together in different ways. Four people participated in the method and the ideas were sketched on a whiteboard, see Figure 21. The core components acted as a starting point for concept generation and also a means of explaining the boundaries, that is, the four fundamental requirements.



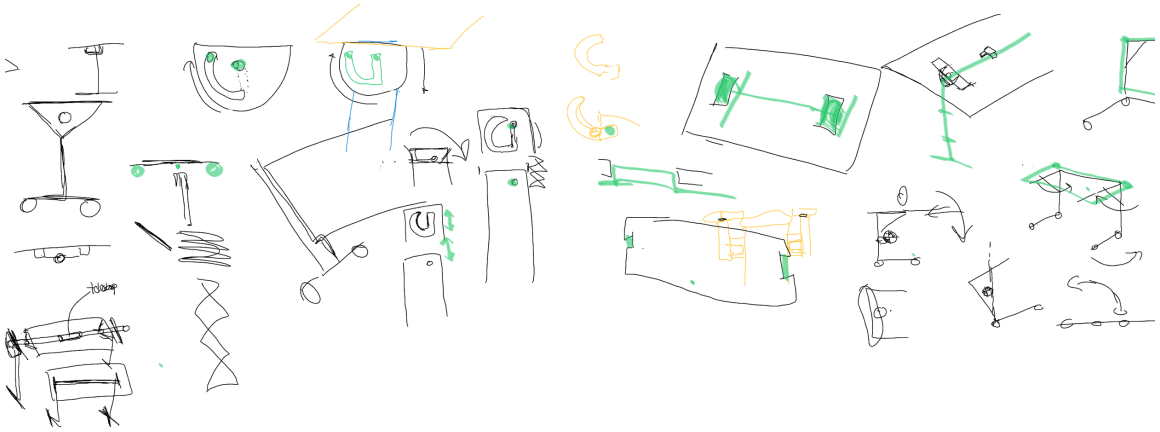


Figure 21: Sketches from the brainstorming session

The brainstorming resulted in four ways of folding the desk; a hinge, like the desk Foldex - rotating around a shaft, slide & fold and like an architect table. In total six concepts and these were each constructed as CAD-models for easier understanding, see Figure 22. Thereafter, these were presented to Kinnarps for screening. Which eliminated the hinge and slide & fold concepts due to their inherent squeezing points (Figure 23). The Foldex lookalike and the architect table, which basically have the same kind of folding but with different appearance, was chosen as the main way of folding the desk, since the shaft acts as the pivot point which entails no shear or squeeze points. The combination of these two will later be referred to as the shaft.

Figure 22: Cad-models of the four ways of folding the desk

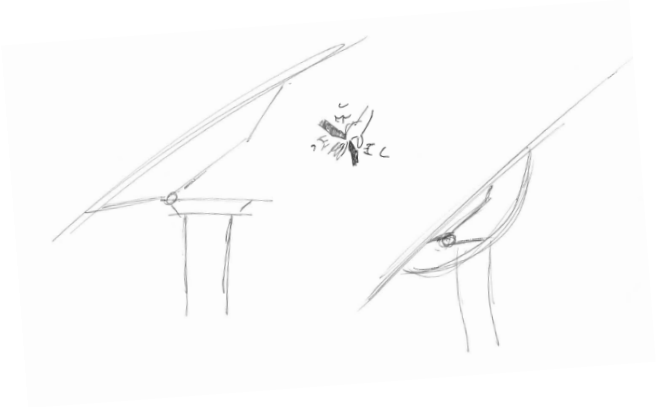


Figure 23: Squeeze points

4.1.2 Ways of Locking

Before entering the next level, which included details, further screening of the concepts needed to be done and a selection of the most suited locking mechanism. A Brainstorming session during a workshop was performed and generated multiple ways of locking. Inspiration for the workshop was gathered from the market analysis and external research about already existing kinds of locking mechanisms in general. In the section about Foldex in depth, the acknowledgement that translation of motions when connecting components will generate more parts was made. In an effort to mitigate that, compliant mechanisms were used as inspiration and in particular products that used them were investigated. Compliant mechanisms are flexible mechanisms that transport forces via elastic body deformations which entails advantages like fewer components and less risk for backlash among others (Arumugam & Kumar, 2016).

The workshop was performed by four people with mechanical engineering backgrounds on a whiteboard, where the participants were told that the intention was to create a locking mechanism that can be locked in both folded and unfolded state. The workshop resulted in three ways of locking that fulfilled the intended function; either clamping the movable parts, using friction or a sprint, Figure 24, Figure 25 and Figure 26 shows some samples of ways of using these locking mechanisms.

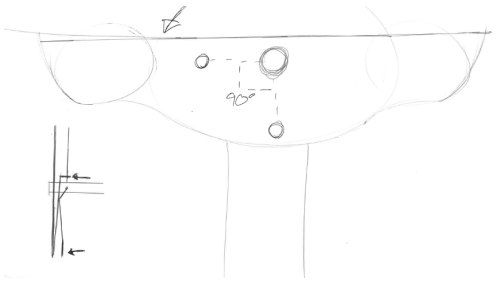


Figure 24: Shows a classic nail-clipper, which is a compliant mechanism, inspired sprint that goes in from the short side of the desk

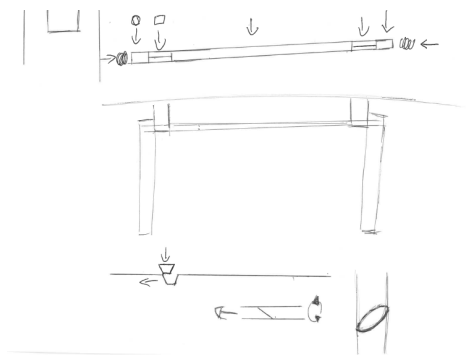


Figure 25: Shows a keyed shaft which means having a square end that enters a square hole, that is inspired by both the clamp and friction lock and pushed horizontally back and forth, thus locking the desk

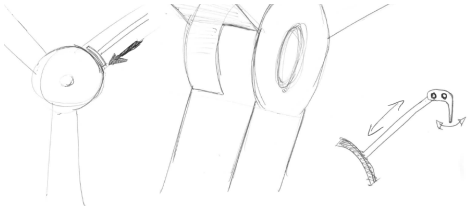


Figure 26: Shows a friction and clamp inspired lock

To move forward with the different ways of locking, a discussion with Kinnarps was required to determine if they are feasible to use and the negative aspects of each locking mechanism, since they have experience within this area. The insights from this discussion was:

Clamps
To use clamps the tolerances need to be low or almost zero otherwise backlashes will occur, but this creates high friction, which means that to unlock, an extreme force will be needed. Depending on design, there is a risk for an abrupt snatch when realising the clamp.

Friction
Is very unreliable depending on outside forces and will often need maintenance to ensure quality.

Sprint
Can potentially have backlash depending on the geometrics.

Since the sprint has only one negative aspect according to the information above, and that this only depends on the design of the geometrics, the sprint was chosen as the most optimal solution for this project.

To sum up the first level, it gave more an understanding of what locking mechanisms are feasible, rather than specific concepts and an orientation of the basic components that fulfils the requirement. The lock will have a sprint locking mechanism and have the shaft folding. This level also generated insights about what to have in mind when developing the desk. The two most important are to keep the height of the concepts low so that they will comply with the standards and if there is the slightest backlash in the locking mechanism it will scale to a much larger backlash on the edge of the desktop. Therefore, a zero-tolerance solution is preferred if the friction can be solved. Moreover, the folding mechanism's pivot point should be located as near the desk's centre of gravity as possible, so that it does not cause a jerk and uncontrolled folding. The desktop should also have locks on each side so that the desktop does not flex on the opposing side of the lock. The lock should also be locked in the folded state and always be locked in its normal state (normally closed) to prevent accidents and withstand the torque when placing a weight on the edge of the desktop. When folding the desk, it should not change its occupational area of the desktop. For instance, making it deeper when utilizing a sliding desktop, so that the desk could be folded when standing against a wall or next to a sound panel. The last insights were that the desktop needs support between the consoles, if frameless and avoid using parts that need frequent maintenance.

4.2 Defining the Desk

This level takes the gathered information about concepts from the previous chapter, diverging and builds upon them and then develops them further by increasing the level of detail. Other components then the core components are developed and analysed by both performing a SWOT and PNI and later added to the concept. Ways of connecting components are also investigated. The concepts are then screened again with a Kesselring matrix where one concept is chosen to be finalized.

4.2.1 Selection of Locking Mechanism

At this point, the solution scope for the locking mechanism has converged to just conclude locks with a sprint like solution. However, it suffers from the same weakness as the keyed shaft solution; it only generates zero backlash if the sprint and corresponding hole are perfectly made with very high tolerances which in its turn makes for a sprint that is hard to withdraw. Therefore, new geometrics that automatically generates high tolerances were investigated. This was done by external research for other applications where minimizing backlash is important.

The research gave an evolved sprint lock with, instead of a cylindrical rod, a cone shaped rod that slides into a round hole. The cone takes care of all demands put on manufacturing by automatically taking up the tolerances when fully seated. The research also generated two inspiration sources; the locking mechanism on folding knives and hirth couplings. The former has a simple but effective, so called, spine lock that consists of a bar with a latch retained on one side with a spring and with a pivot point in the middle. This solution is from now on referred to as the latch, see Figure 35. The other inspiration source is a hirth joint, see Figure 27, which is a cylindrical shaft with star shaped teeth milled on the end face. The advantages of having a hirth coupling is that the large surface area can cope with large amounts of torque and that the star shape automatically eliminates backlash ("Hirth joint", 2020).

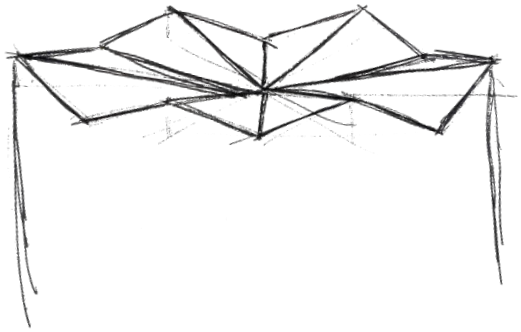


Figure 27: A sketched hirth joint

The new diverged solution base for locking mechanisms can now be the starting point for a Brainstorming session. This was done by simultaneously combining it with the previously developed shaft concept. This resulted in three new sprint concepts, two latch concepts and one hirth concept, see Figure 28, Figure 29, Figure 30, Figure 31, Figure 32, and Figure 33.

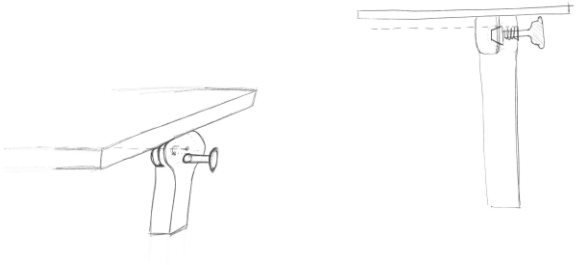


Figure 28: Concept S1: A sprint that is inserted directly into the folding joint and which is released by pulling outwards on the handle

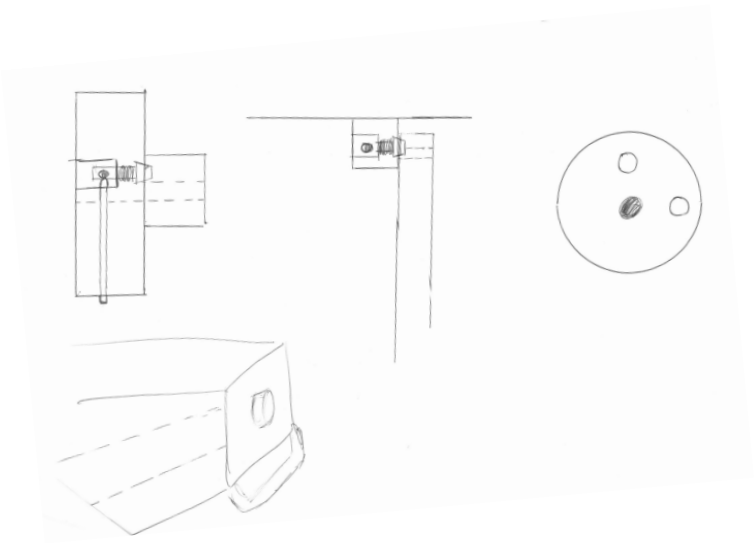


Figure 29: Concept S2: A sprint that is enclosed by the folding joint which is released with a rod that presses the sprint outwards and is located inside the console.

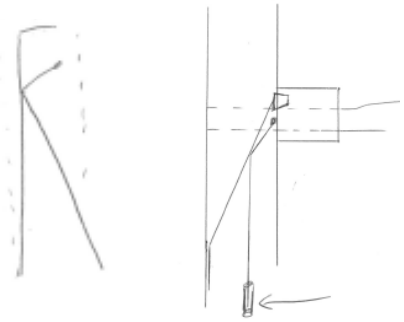


Figure 30: Concept S3: A sprint that also is enclosed by the folding joint and hidden inside the console but has drawn inspiration from the nail clipper

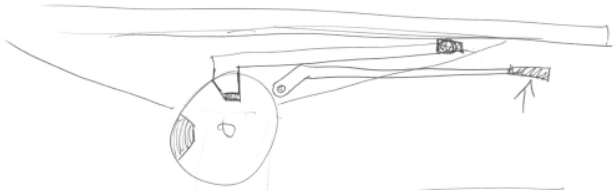


Figure 31: Concept L1: A latch is inserted in the receiver that is located on a separate part than the latch

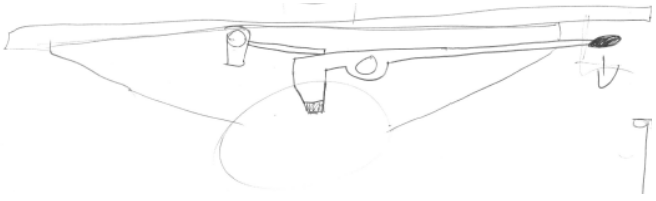


Figure 32: Concept L2: Basically, the same as L1 but has drawn inspiration from the nail clipper in the way it is disengaged

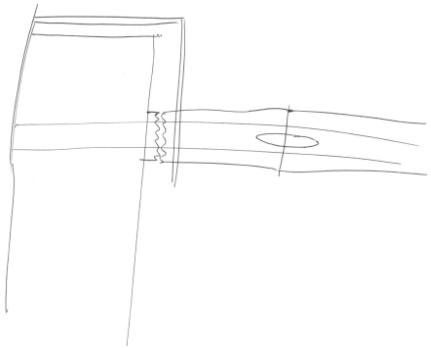


Figure 33: Concept H1: One coupling is fixed to the leg and one is fixed to the console. They are forced together with a rod that is inserted into the shaft and slitting to sleeves apart

These five concepts were then screened against each other, with a modified version of the kesselring matrix (*Tabell 4*). This is to eliminate concepts that do not meet the criteria, shown in the matrix below, to be able to continue with only one or two concepts to the next level. Instead of making the existing concept, Foldex, as an ideal concept it was rated with 3 on a scale of 1-5. This is to be able to let the potential concepts be better than the ideal concept, which is very similar to a Pugh's matrix (Ulrich & Eppinger, 2012) but in this evaluation, the range is wider for a more varied and accurate result. The criteria derived from the result of the conclusion of the first level, for example, fail safe comes from the fact that the lock needs to handle torque, have end stroke locks and be normally closed.

Tabell 4: The kesselring matrix result

Criteria	Weight 1-5	**Ideal**		Sprint						Latch				Hirth	
				S1		S2		S3		L1		L2		H1	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Viability *Functional*	5	3	15	3	15	3	15	2	10	4	20	2	10	2	10
Part count *Number of parts*	3	3	9	4	12	4	12	5	15	5	15	4	12	1	3
Complexity *Complex mechanics*	3	3	9	4	12	4	12	4	12	4	12	4	12	1	3
Durability *Long term use*	4	3	12	2	8	2	8	2	8	3	12	3	12	4	16
Maintenance *Low need*	4	3	12	3	12	3	12	4	16	3	12	3	12	3	12
Fail safe *Possibility for failure*	5	3	15	2	10	3	15	2	10	2	10	2	10	3	15
Totalt		18	**72**	18	**69**	19	**74**	19	**71**	21	**81**	18	**68**	14	**59**
Rank		-		4		2		3		1		5		6	

According to the result of the kesselring matrix, one sprint concept and one latch concept are the two locking mechanisms that are the most feasible ones and are chosen for further development, see Figure 34 and Figure 35 .

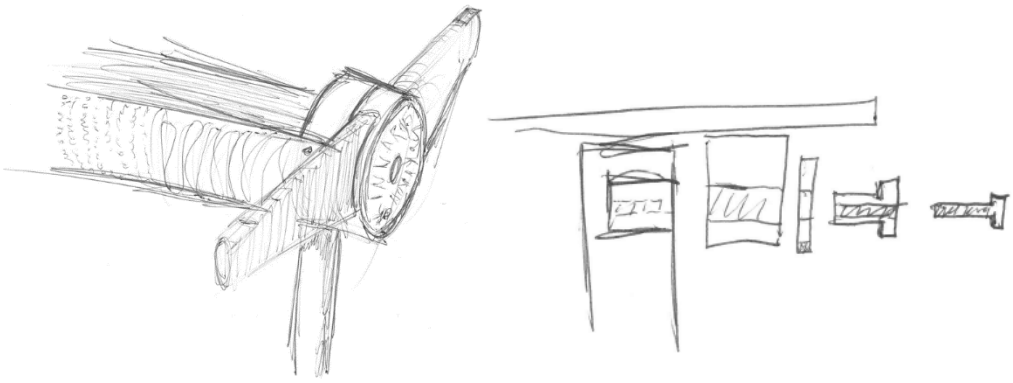


Figure 34: The sprint concept that was chosen for further development

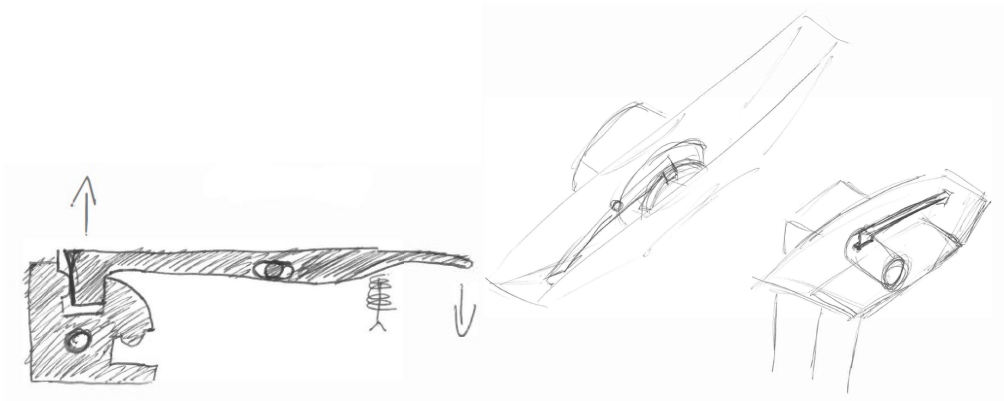


Figure 35: The latch concept that was chosen for further development

4.2.2 Lock Actuator

After screening the locking mechanism concepts, the next step was to decide which lock actuator to use. The actuator is defined before choosing its shape, for example, should it be a push or pull actuation to disengage the lock. There are three variables to be taken into consideration when developing an actuator for a desk: what kind of motion should the actuator perform, one or more interaction points, where should it be placed, and how does these three variables affect the user. The variations of variables were analysed by performing a SWOT analysis, the chosen variation from each variable were combined and analysed with the PNI method, thereafter, one actuator concept was chosen.

The variants of the first variable, what motion the actuator could have, was push, press down, press up, pull, twist horizontal, twist axial and a combination twist and pull. Due to deal breakers, for example, accidentally triggered or squeeze points can appear, twist horizontal and twist axial where the chosen variant from the SWOT analysis (Figure 36 and Figure 37), the SWOT analysis on the remaining motions is seen in Appendix IV - SWOT.

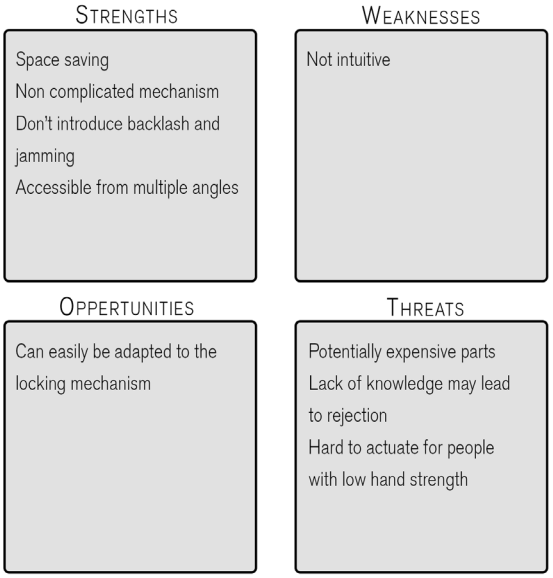


Figure 36: The SWOT on the twist horizontal motion

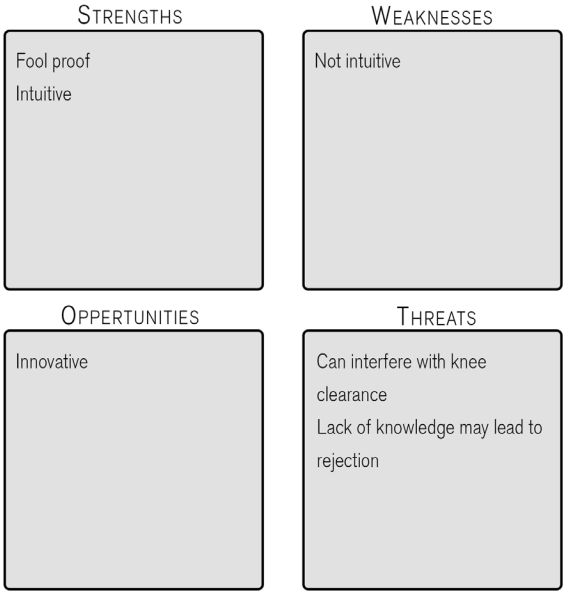


Figure 37: The SWOT on the twist axial motion

The variants of the second variable, number of interaction points, was either a single, a double or a combination of both. Single meaning using only one actuator to disengage the lock, double meaning using two actuators to disengage the lock and a combination is having two actuators but only having to use one to disengage the lock. From the SWOT analysis, (Figure 38), the combination actuator was chosen, also due to deal breakers. For example, a weakness for the double actuator was that it cannot be used by all users if the desk is too wide and the single actuator is not seen as fool proof, other deal breakers from the SWOT analysis can be seen in Appendix IV - SWOT.

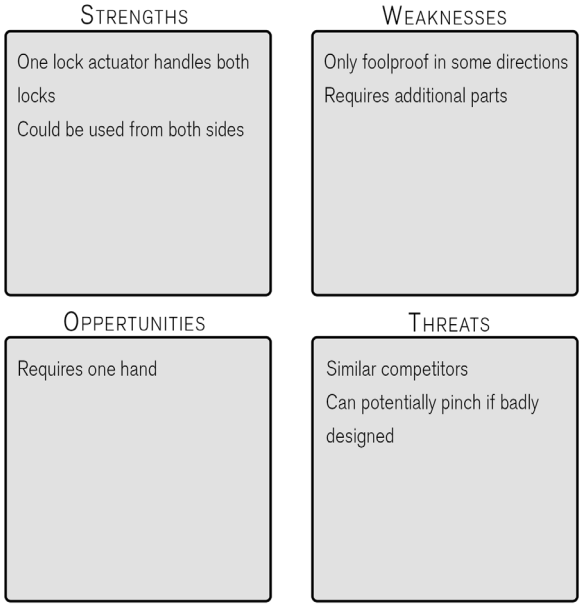


Figure 38: The SWOT on the combination of interactions points

The variants of the third variable, location, were either at the front or side. Front meaning the long side of the desk and side meaning the short side of the desk. The SWOT analysis, (Figure 39 and Figure 40), showed that both variants have threats that depend on the other two variables.

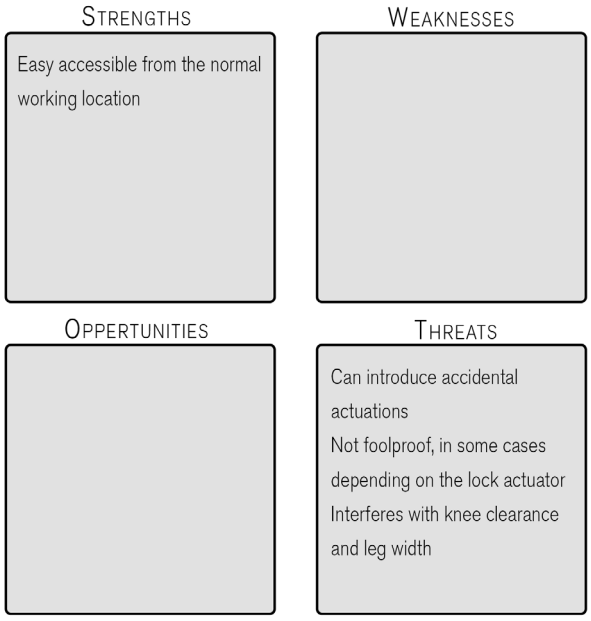


Figure 39: The SWOT on the front location

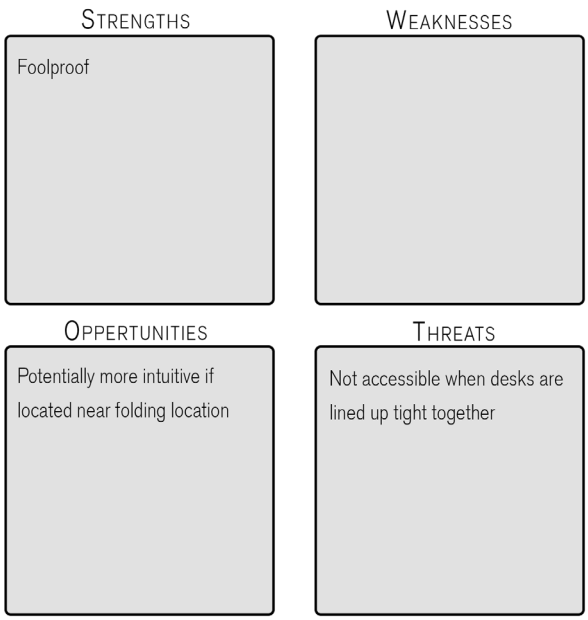


Figure 40: The SWOT on the side location

Therefore, both front and side were chosen as suitable locations. To determine the most suitable actuator, combinations of the chosen variables were constructed, and two combinations were identified as workable, TCF (twist horizontal, combined and front) and TSS (twist axial, combination and side). The two combinations were analysed with the PNI method, see result below.

TCF - Twist h, Combined, Front

- Needs to be close to the front, resulting in a larger console, otherwise it is not possible.
- Depending on orientation, it either becomes a cumbersome hand motion or it can be accidentally triggered.
+ Easy motion depending on the orientation.
- Tests with similar mechanisms “foldex” showed confused first-time users, because it seemed hidden and unconventional.

TSS - Twist a, Single, Side

- Not accessible when desks are being placed against each other.
+ Intuitive.
+ Easy to put leverage on since you use your whole hand, excessive hand strength is not needed.
+ Creates opportunity for multiple purpose use.
+ Do not interfere with leg space.
+ Do not affect the size of the consoles.
- Needs a connecting rod to the other side because both lock actuators cannot be used at the same time due to desk width.

The result, from the PNI, showed that the most suitable actuator combination is TSS. Due to solving the negative aspect of not being able to reach the actuator, by making the actuator reachable from the long side of the desk as well, and also using a connecting rod to disengage both locks with one actuator.

4.2.3 Choosing one Concept

To sum up, two concepts with different types of locks and the same actuator have been developed. These two concepts have the same way of folding but to cover the different locks, one has a closed console and the other an open console, due to squeezing points and the form of the lock. To converge further and move to the third and final level for detailed design, one concept needs to be eliminated. To do this, the low fidelity concepts need to be more defined to be able to determine if they are feasible on a mechanical level at all. CAD was thus used with the intentions to increase the fidelity and conclude one concept as non-manufacturable or less promising, see Figure 41 and Figure 42.

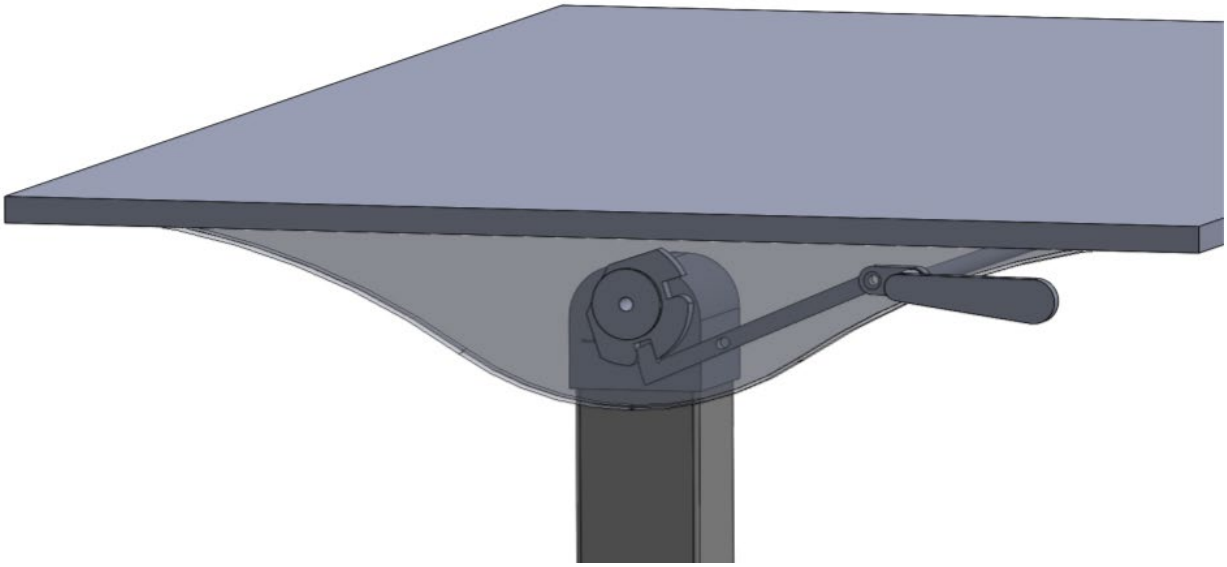


Figure 41: Concept L1. Handle is a dummy for illustration

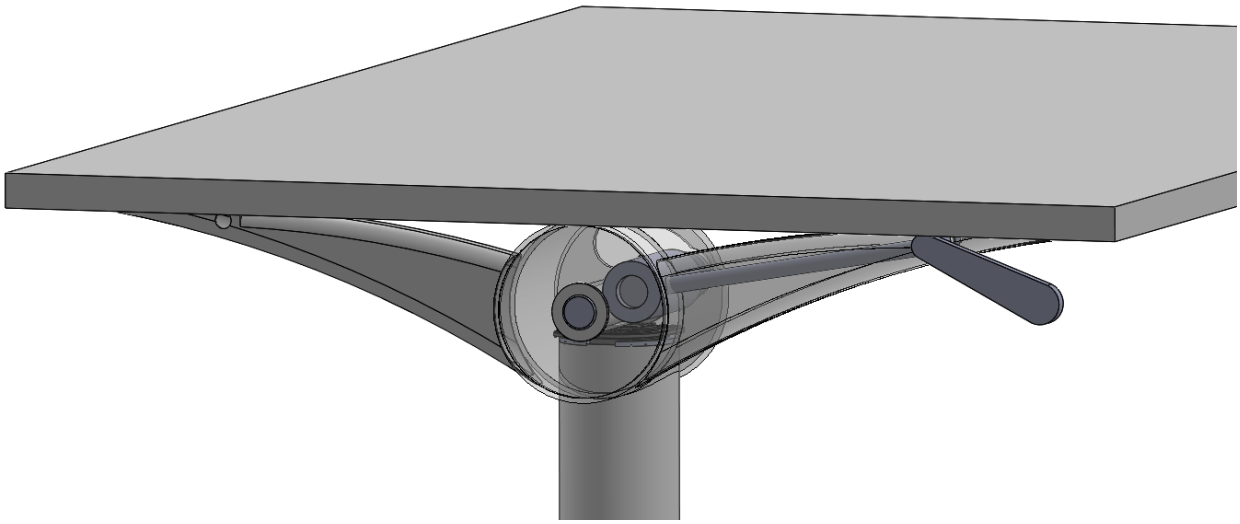


Figure 42: Concept S2. Handle is a dummy for illustration

None of the concepts could be concluded as the superior one. Therefore, Kinnarps were consulted, to support the decision making about settling the verdict of which concept to develop further. The screening with Kinnarps resulted in the sprint-based concept, S2, being chosen. It was considered the most promising due to that it distinguished itself from L1 by being more technically interesting, more interesting in general, aesthetically pleasing with its round geometrics and radiates harmony, as expressed by Kinnarps. This level ends with one concept, S2, that emerged as the winner. It is now ready for detailed design and being complemented with the remaining components necessary to the desk.

4.3 Detail Design and Optimization

The final stage of the development, before acquiring a final concept, is to establish and

develop the details and sub-functions of the concept and optimize the concept. It needs to be optimized in order to be environmentally friendly, durable, cost efficient and fail-safe. To develop the details and sub-functions, brainstorming, braindrawing, workshops, and dot voting was performed together with information from the market analysis, mood board and requirement specification. To optimize the concept, a DFE, a DFMA and a FMEA was performed as well, which can be viewed after the remaining details and sub-functions.

4.3.1 Lock Actuator

The lock actuator needs to be given a shape, to do that a workshop was arranged. braindrawing was performed in the workshop and had four participants. During the introduction of the workshop, the participants were told about the placement of the lock actuator, that it needs to mediate its intended use, preferably be multifunctional by double acting as a hanger for individual instruments and that the actuator needs to be turned counter clockwise, when standing on the left side and vice versa. The outcome of the workshop (seen in Figure 43 and Appendix V - Lock actuator) was then dot voted on.

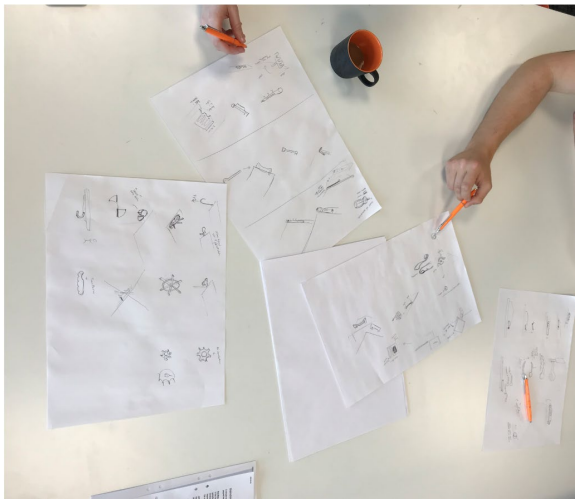


Figure 43: Workshop on the shape of the handle

The result of the workshop is a handle that can be used on both sides of the table, has a hook incorporated and can be used both from the side of the table and the front, see Figure 44. It is straight and stripped of details to not mistakenly indicate the wrong opening direction. The problem is that it has somewhat the shape of a conventional door handle which is opened by pressing down on it. That is the wrong direction in this case and would thereby consequently, not open since it needs to be turned in the opposite direction to open. Instead, the handle is angled downwards approximately 40 degrees which is sought to give the impression that it is in a state where it cannot go down and has to come up. The handle is also placed in the corner of the short side and front so that the desktop can be used for leverage. The handles have a connecting shaft that joins them together so that only one of them has to be actuated.

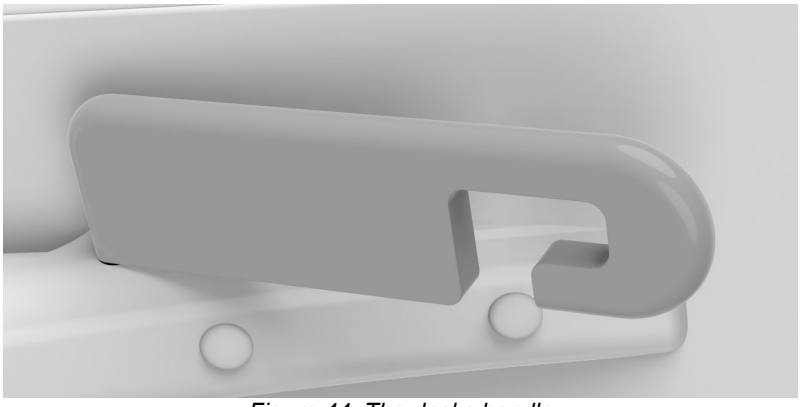


Figure 44: The desks handle

4.3.2 Base

The legs of the desk need to have a base to stand on. The criteria for the base are that it has to raise the desk 30 mm from the floor, house wheels on the ends in order maximise the stability area and increase the total height of the desk as little as possible. However, it is important to retain the height of the base since it affects the total minimum height the desk can achieve. It shall also not prohibit the possibility to clean the floor in between the legs of two desks standing next to each other. To come up with a design for the base braindrawing was used but with a desk in its current state as template to make sure that the base compliments the rest aesthetically, see Figure 45.

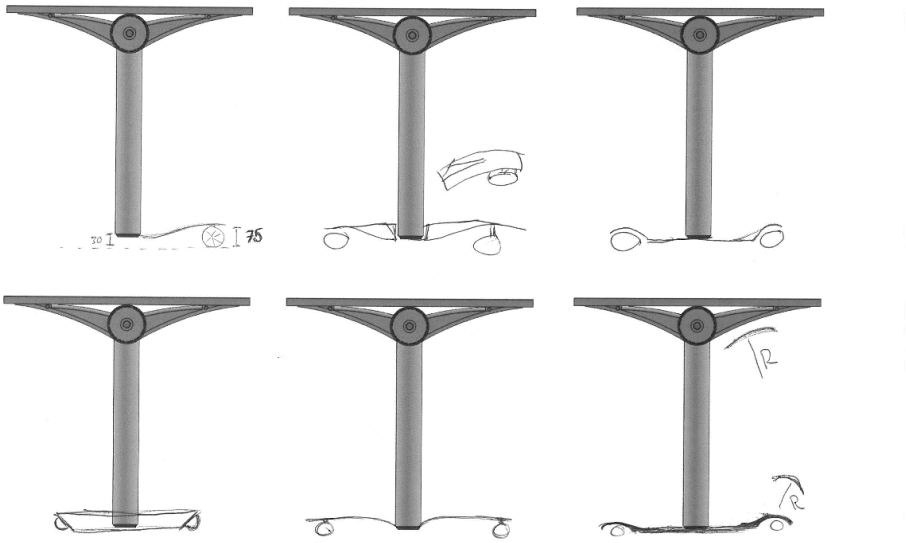


Figure 45: An example of the result of the braindrawing session

The concept, seen in the bottom left corner of the previous Figure 45, was chosen because of its cylindrical shape which makes for a seamless transition to the leg. The cylinder is cut diagonally in the ends so that the wheels can be mounted within. However, when the concept was modelled in 3D with CAD it turned out that the base cylinder had to be much larger than the 72 mm width of the legs in order to be able to house them within, which made them look like two large pontoons. They would have also made it hard to clean in between the desks. Therefore, all concepts were modelled in CAD to learn about eventual problems, see Figure 46. Some new concepts were also made in the process as evolutions of the sketches.

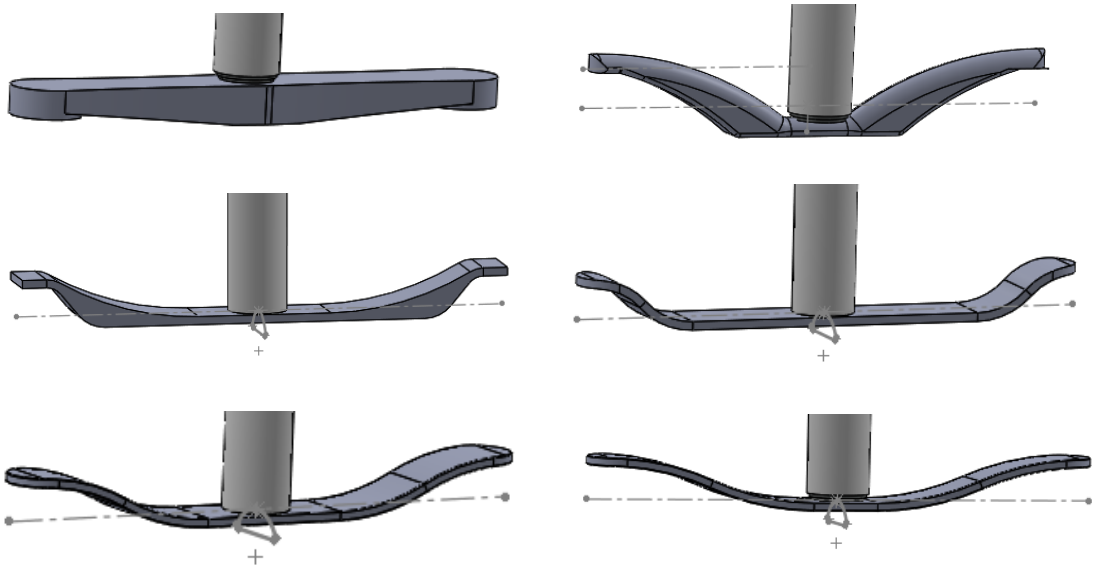


Figure 46: Cad-models of the base

A wave shaped concept was chosen due to its similarities with the consoles, see the concept down to the right in the figure above.

4.3.3 Cable Tray

The desk needs a place to house the control box for the height adjustment, the battery to be self-sustained and cables to connect everything. As described when investigating the core components, the desk also needs something that ties the two legs together to ensure stability and the logical solution to these problems was to solve them all with one component. To match the geometries of the rest of the desk, to make all parts tie together in a more pleasing way, the joint between the legs and the console were used as inspiration. Its round shape was used and extruded over to the other side.

The result was a cable tray that is tucked in under the desktop in between the legs, see Figure 47, and is held on with eight screws to ensure stability and counteract flex. To house the electronics, a plate is used that snaps into place inside the tray. The control box is mounted on the underside of the plate. The benefit of attaching the cable tray to the joint and on the leg, side is that it stays in place when folding the desk in comparison to conventional cable trays where it is mounted on the underside of the desktop.

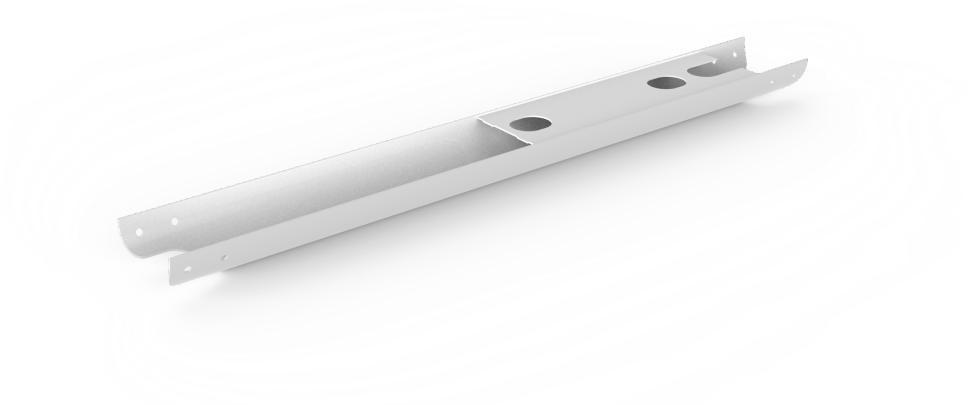


Figure 47: The cable tray

4.3.4 Side Protection

To protect the desk when stacked, moved and, or from accidental collisions side protection needs to be added, which was insights gained from the market analysis and the interviews. To know where to add the side protection all possible places where collisions can occur were analysed.

This resulted in side-protection being added to the desk's base, cable tray and side of the desktop, which were the identified locations for possible collision. The protection was placed on the edges of the base (Figure 48) and top of the screw head (Figure 49) that attaches the cable tray to the legs, these are the points that collide when the desks are stacked together. A rubber list was added on three sides of the desktop. Thus, protecting the desktops when accidentally colliding with each other during use or when moving them from one location to another. Also, when having a height-adjustable desk, there will be a front side where the user shall be positioned to use the height-adjustable switch. So, to indicate which of the four sides is the front side of the desk to the user, the rubber list is only placed on the side and back side of the desktop and not on the front side, due to symmetry of the desktop.

Figure 48: A silicone strip protecting the base, attached around the front side of the base

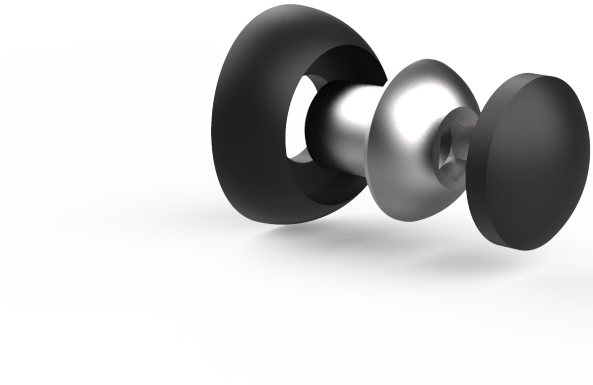


Figure 49: The shoulder of the screw head retains the inner part of the protection which the outer part is caped on top

4.3.5 Add-Ons

The user studies revealed that having the desk double acting as a whiteboard is a desired feature in, for example, a creative situation. To be able to have that, the desktop's top sheet needs to be able to handle whiteboard pens. As it turned out, Kinnarps desktop, amongst others, are made from high-pressure laminate (HPL) ("Decorative laminate," 2019) which is made of a resin infused cellulose, a material that resists wear and tear well. This is also a way of manufacturing whiteboards, with the difference that the outer layer is made from melamine ("Whiteboard," 2020) which makes it easy to clean.

One appreciated add-on to desks seen in the user studies are panels that give the user more privacy and sound dampening. Though they do not comply with the folding ability of the desk the panels can still be handy to compliment with in certain situations where the folding ability is not frequently used. So, to accommodate panels the desktop needs to have geometrics that allow for that.

To place USB-C outlets on the desk an illustrative figure representing the desktop from above was used, see Figure 50. Overlapping rectangles illustrated in red, were placed on areas that are occupied

with instruments identified in the interviews, which can be seen in the desk size tests. The least red area, top right, and left corner is the least occupied and therefore, suitable for an outlet.

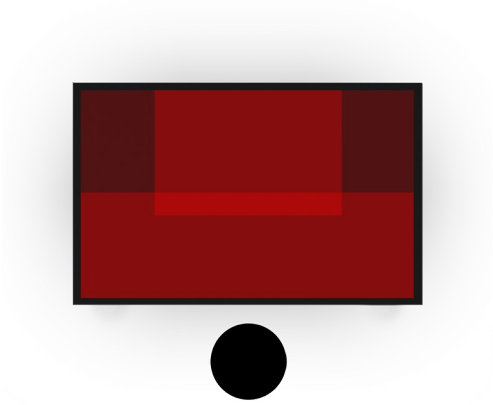


Figure 50: The desktop shown from above with red areas showing the user as the black dot, the user's belongings and the monitor or computer

The chosen material for the desktop is HPL with melamine to allow for the use of whiteboard pens and the USB-C will be placed in the user's top right corner to maximize space utilized for whiteboard. The desktop is not chamfered but instead square shaped to allow for panels.

4.4 Optimizing the Product

As mentioned earlier, it is important to set DFE goals that are followed through the development process and in this case, the project has followed goals concerning the product's material and the product's life cycle. In total three DFE goals, reduce raw material, extend the product's life, and develop a recyclable friendly product. The DFMA, which is an ongoing process through the project, has focused on reducing the amount of parts, thereby keeping down manufacturing costs for the product. Before concluding the result of the DFE and DFMA, a final review of the concept was performed, with a FMEA, to identify and redress potential failures.

4.4.1 FMEA

The FMEA analyses the risks in a production process, but in this case, it was used to analyse the risks that can occur whilst operated by the user. In order to find potential failures, each component was examined, and a concise Brainstorming session was performed to come up with ways each component can fail. Some components, like the desktop were compared to how competitors designed theirs to anticipate failures, whilst others, like
the base had to be evaluated with FEM (Finite element method) calculations in CAD software to determine if the potential fail is justifiable.

Tabell 5 below, shows the components in risk for failure, the reason for the potential failure, causes for these failures, their RPN, what recommended actions that need to be taken to redress these failures and which actions that were taken.

Tabell 5: FMEA analysis

Function / Component	Potential Failure Mode	Potential Failure Effects	Potential Causes	Risk Analysis (1-10)				Action Recommended	Actions Taken
				SEVERITY	OCCURRENCE	DETECTION	RPN		
Base	Bends because of vertical load	The desk becomes unusable - warped	Too thin material profile	9	8	9	648	Reinforce the construction	Reinforcements added underneath the base
	Breaks because of torque applied to desktop	The base breaks	Too thin material profile	10	9	9	810	Reinforce the construction	Reinforcements added underneath the base
	Wheel fastening bends	The desk becomes unusable - warped	To weak fastening point	9	4	9	324	Evaluate with tests	
Desktop	Breaks because of vertical load	The desk becomes unusable	No support	10	7	9	630	Make a support	Support made
	Damaged on the underside where the support contacts the desktop	Estetical, non structural, damage	No support	2	10	10	200	Add rubber strip along the support	Rubber strip added
	Collides with other objects when heigh adjustaded	Damaged to desktop and other objects	User is not observant	7	5	4	140	Use a control box with resistance sensor	Controlbox added
Squeeze points	Crushes fingers in the lock's sprint receiver	Injured fingers	Uncapped holes	10	5	7	350	Make the sprint receiver enclosed	Sprint receiver enclosed
	Pinches fingers between desk and desktop support	Injured fingers	Design of desktop support	10	2	7	140	Add rubber strip along the support	Rubber strip added
Locking mechanism	Breaks	Injured user, unusable desk	Components fatigues	9	4	7	252	Evaluate with	
	Jamms	Negative user experience, faulty function	High friction, metal to metal surfaces	8	10	6	480	Replace non structural metal surfaces with plastic for lower friction or consider grease	
Actuator	Misused	Negative user experience	Hard to understand by user	2	4	2	16	Evaluate with user	

The action taken for the base was that it got a reinforcement added to the undercarriage of it to withstand a vertical load applied to it. This was discovered when a force was applied to the edge of the desktop, which translates to torque being applied to the mounting point between the leg and base. Therefore, reinforcements had to be added, see Figure 51 and Figure 52.

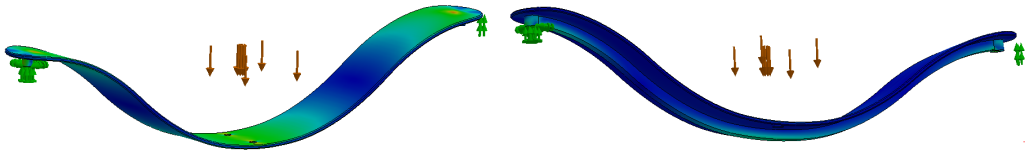


Figure 51: Vertical load stress test of base before and after

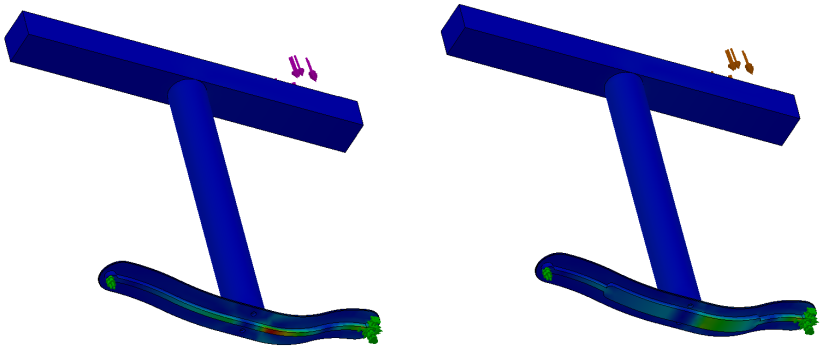


Figure 52: Torque load stress test of base before and after

Since, the desk does not have any horizontal support along the underside of the desktop like the desk Oberon, seen in Appendix II - PNI of the market analysis, it needs some equivalent to prevent the desktop from spitting in the middle if a too great of a force is applied in the middle of it. The solution was a support added in the middle of the cable tray that reaches up and relieves the desktop, Foldex has a similar solution.

Furthermore, the receiver for the sprint was covered up by sinking it into the folding joint. It was later covered with a rubber strip to prevent mechanical wear. Other failures found in Tabell 5 need further investigation to be able to determine the actual risk. For example, to test if the lock jammed due to friction, a prototype is needed.

4.4.2 DFMA & DFE

The first adaptation of the methodology was made by thinking “symmetry”. When creating parts with this mindset, production costs can be saved by not always needing to produce unique parts for each side of the desk. For example, the housing for the locking mechanism has a groove where the lock travels back and forth. First the groove was placed above and slightly off centre from the leg to match the intended side. However, to enable the part to be used on both sides of the desk, thus eliminating the amount of parts, the groove was placed both above and in the centre of the leg instead, as is illustrated in Figure 53. All other components are already symmetrical, everything from the internal parts of the lock, to the base and handle.

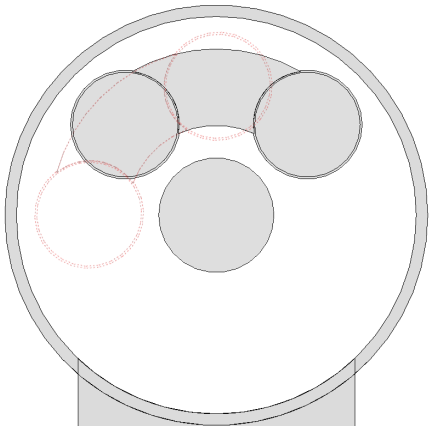


Figure 53:The revised sprint receiver in grey, original in red.

Furthermore, few unique parts and few non shelf parts that have to be manufactured specifically for the desk. For when this is not applicable, the components have been designed from stock materials like round bars.

Despite putting up guidelines for how to develop the desk in the first level about translating the lock's motion from one to another, the concept in its current state changes an axial motion to a twisting. This increases the part count and complexity. However, a combination of wedge-shaped sprints and springs as links between components reduces part and fastener count in comparison to Foldex. The advantage of the sprint concept is that it does not require calibration in the assembly like with a friction-based locking mechanism.

To reduce the use of raw material, components have been revised by minimizing the wall thickness and unnecessary material has been eliminated. Some examples of that are the middle support on the cable tray and the reinforcements on base. The support has had its centre cut out (Figure 54) and the solid reinforcements on base have been replaced with a bent box section that is later sealed with a cap, see Figure 55.

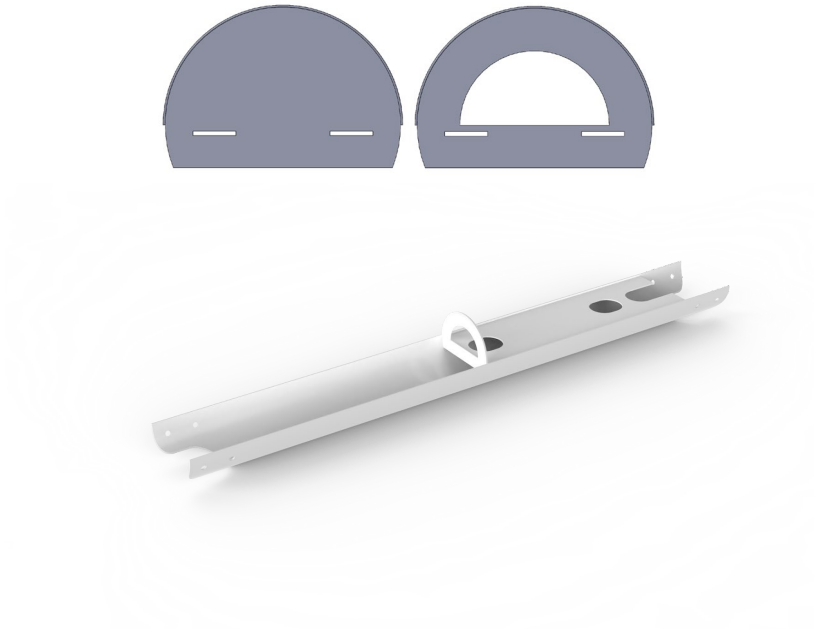


Figure 54: Cable tray and its middle support

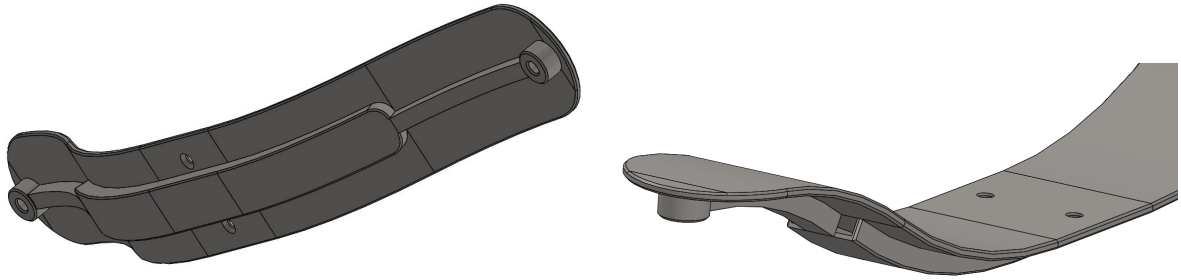


Figure 55: Reinforced base

To extend the useful product life of the desk, three actions have been taken. The first is to make sure that individual components or at least an assembly of components are interchangeable with a new if it breaks. This was added as a requirement in the requirement specification. Secondly, durable materials have been seeked to extend the life span of the product; the desktop has a scratch and wear resistant top layer, the frame and lock are made out of steel so that it endures the stress that is being put on it over time. Finally, to ensure that the components actually endure the stresses, FEM calculations in CAD software have been done.

To facilitate that the desk can be recovered and recycled, all components are accessible and disassemble and also, easily separated. The electronics are easily accessible on the underside of the desktop, most of the frame can go as one entity into metal recycling.

05
Evaluation

Though many smaller evaluations have been performed during the previous phases to create a final concept, the last phase of the development process is dedicated to the final evaluation of the final concept to determine if the requirements for the desk is fulfilled. Thereby, knowing if the aim is accomplished or if more iterations are needed. Most of the requirements can be easily and objectively determined as fulfilled or not with the information collected during the project. However, some remaining requirements need further evaluation or development. All requirements below are marked with their specific requirement specification number for easier location in the requirements specification. So, to see the requirement specification with fulfilment verification of every requirement in detail, see Appendix VI - Requirement specification 2. The requirements are signed with different marks depending on accomplishment:

✓ Fulfilled requirements
--- Requirements needing further testing/development
X Not accomplished requirements/future work

5.1 Subjective Verification

The subjective requirements, *communicating the intended function* (#60) and *aesthetically pleasing* (#34) was verified with two employees at Kinnarps, that works within product development and product management, using a two by two axis. Together with these two employees the components of the desktop were evaluated one by one, and also the concept as whole, both folded and unfolded by looking at rendered CAD-models of the final concept and placing them on the axis, Figure 56.

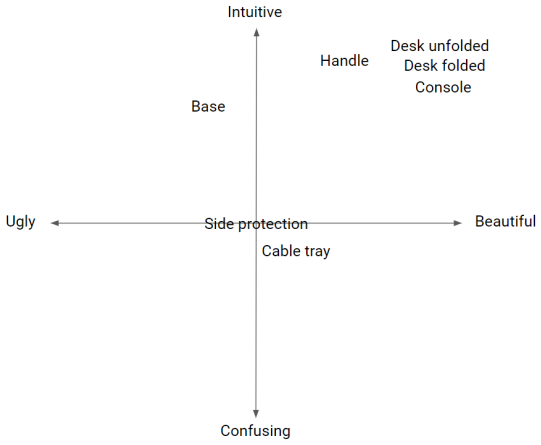


Figure 56: Two by Two axis with the evaluation result

Figure 56, shows that the cable tray was seen as confusing, due to not understanding the holes and therefore changes were made, see Figure 57 for old and new cable tray. It was also made symmetrical from the middle to be more appealing. With this change the cable tray moves above the line and into the up-right corner, showing that the two requirements, *communicating the intended function* (#60) and *aesthetically pleasing* (#34), are achieved.

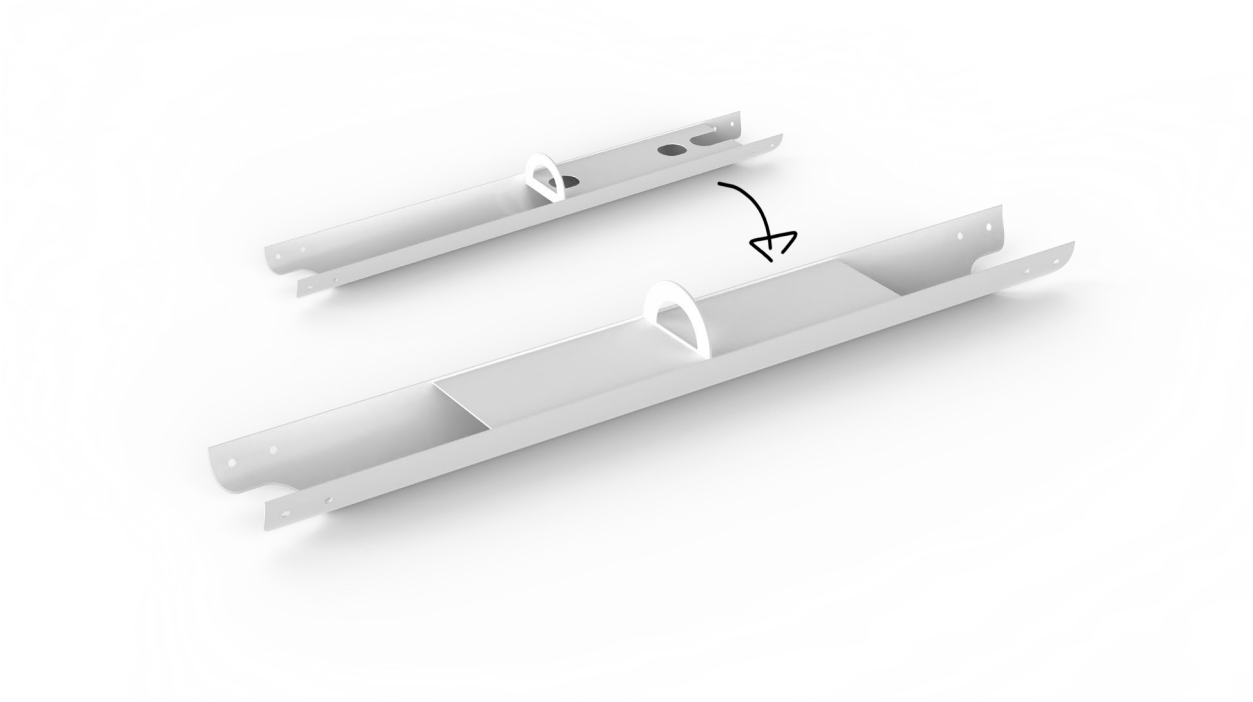


Figure 57: The changes made on the cable tray

5.2 Contradicting Requirements

Information gained from in the interviews, is that a monitor can be used, which contradicts the requirement *Clutter free desktop* (#66) due to more cable and products being placed on the desk, the monitor also prolongs the folding process of the desk and affects the mobility of the desk. However, they are both important and are only viewed as features therefore, they were both fulfilled by including the monitor in the battery capacity but not as a product that needs to be on the desktop when in use.

5.3 Sensitive Information

One of the fundamental requirements made by Kinnarps was a maximum production cost (#38). Information regarding Kinnarps's own prices on specific parts, for example, wheels and the electronic control unit of the legs, are also of sensitive nature and, therefore, not presented in this report. Therefore, an estimation, performed with help of Kinnarps, of the production cost of the developed components together with Kinnarps's own parts were made and concluded to reach the set target, thereby fulfilling the requirement.

5.4 Non-Achieved Requirements

The requirements *wireless charging* (#62), *one standard height* (#43), *prevent hair cumulation in the wheels* (#47)*, minimize wheel marks* (#56), *pre-set settings* (#57) and *lowest/highest* (#59)*,* were not fulfilled during this project and will be seen as further work, see section 7.6 further work for more information why.

5.5 Non-Confirmed Requirements

The EN 527-2:2016 standard requirements regarding stability (#23 & #24) are viewed as achieved in the requirement specification, but to fulfil the standard they need to be tested further with a physical product. The same goes for requirements

mobile by one person (#26*), foldable by one person (*#30*), foldable quickly (*#31*), stackable by one person (*#33*), velocity (*#58*), lock with auditory feedback (*#61) and *quiet desk (*#69), which the final concept in theory is designed to accomplish therefore, these are fulfilled according to the requirement specification, see Appendix VI - Requirement specification 2.

5.6 Recommended Requirements

The requirements *connectivity - USB-C (*#63) and *stand for laptop (*#73), are fulfilled but still need further development, both with evaluation regarding the design and placement. These can be viewed in the result as recommendations.

06
Communication

t • The Desk's Locking Mechanism • The Desk's Handle • The Desk

shape of the base and console • Side-

6.1 The Final Concept

The final concept is a desk that fulfils the aim of being flexible, mobile, easily transformable, provides electrical energy to the users' technical devices, and able to adapt to the varying needs of the users throughout the day. The desk is adapted to occupy less of the organization's real estate space, by being foldable and stackable, and the desk complies with industry standards to ensure a durable, safe, and ergonomic desk. It fulfils the four fundamental requirements and also incorporates delighting features as wished for by the users, for example, it has a whiteboard capability and a hanger for personal items. Following, features and the desks' different components will be explained and afterwards summarized with the previously created scenarios and lastly, the recommended requirements.

6.1.1 The Desk's Locking Mechanism

The locking mechanism, as seen in Figure 58 with the corresponding numbers, comprises three components; a *spring-tensioned cone shaped sprint (1)* that, which in its normal position, is inserted in the corresponding *sprint receiver (2)*, with end positions 90 degrees apart. The cone shape reduces the backlash due to its zero tolerance geometrics. To move between the end positions, the *spring-tensioned cone shaped sprint* needs to be retracted which lets the *cone's centre-shaft (*3) slide in between the end positions. As it does, the lock actuator can be released and the *spring-tensioned cone shaped sprint* makes contact while sliding and thereby creates friction that makes for a controlled folding and consequently, not slamming into the frame. To retract the cone, another sprint is inserted; the *actuator sprint* (4), in the gap between the almost *aligned holes* (5), in the cone's centre-shaft and its *seat sleeve* (6). Which, aligns the holes and by doing so, retracts the *spring-tensioned cone shaped sprint*. The lock's handle is fixated on the lock actuator on the end of the consoles to not jam like other locks with non-fixated sliding actuators that can end up skewed and therefore jam. The orientation of components in the lock and the utilization of sprints entails in no need for connecting joints in between joints and thereby fewer components are necessary.

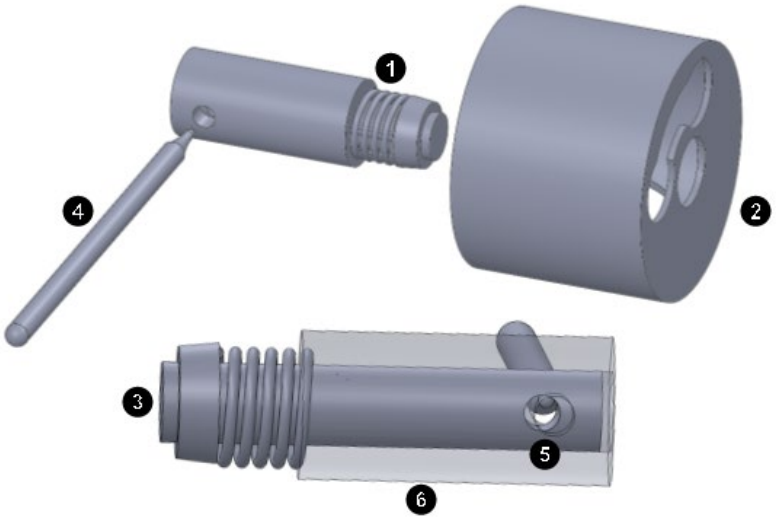


Figure 58: The locking mechanism as parts assembled to components. The lock actuator, that is the handle is not displayed.

6.1.2 The Desk’s Handle

The handle is placed with a 40-degree angle (Figure 59) against the desktop with the console tight behind so that the user cannot place its fingers between the desktop and handle, which indicates to the user that the handle should be grabbed from underneath and pulled upwards. The handle is pulled upwards against the desk and with help of the desktop that can be used as a means for leverage.

Figure 59: The desk’s handle placed 40 degrees from the desktop

There are two handles, one on each side of the desk, these are connected via a connecting rod, which enables the user to operate only one handle to disengage the lock on both sides, see Figure 60. This comes handy when, for example, multiple desks stand together thereby blocking one of the handles or when the desk is standing next to a wall. The user can then operate the handle on the other side of the desk or reach it from the front-side of the desk. The handle has also a multipurpose function that lets it be used as a hook for bags and other things, solving the users' needs for storing their individual items.

Figure 60: The desk's handle and the connecting rod

6.1.3 The Desk's Flexibility

When the desktop is folded (Figure 61) it can be used as a whiteboard, which was a need discovered during the user studies. This is possible due to the fact that the desktop is made out of high-pressure laminate with a melamine top layer. The HPL has also a manufacturing process that entails a wear and tear resistant surface that is also easily cleanable, which will help the user maintain the desk-sharing policy within ABW. The desk size is 70 x 110 cm which enables the user to work with a monitor or laptop.

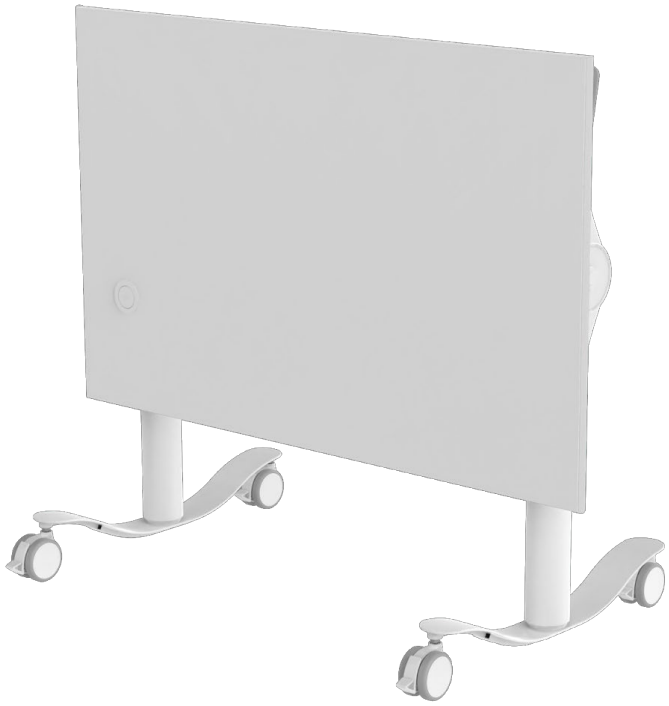


Figure 61: The desk in folded state

6.1.4 The Mobility of the Desk

By having wheels and folding capability the desk is mobile and can be tucked away in situations where the valuable space has to be used for a different purpose. To ensure that the desk is anchorable and does not move when both in folded and unfolded state, all four wheels of the desk are lockable. The desk is also designed to be stackable in its folded state to save space when it is not in use (Figure 62).

Figure 62: Three desks stacked together

6.1.5 Height Adjustable

The height adjustment is made possible by Kinnarps's electrically driven three-piece leg. The fact that it is three piece enables the desk to comply with the standards height range which entails in an ergonomically suited desk. The motors are internal to keep the overall height of the legs down. To regulate the height, the switch on the front of the desk is used, see Figure 63. However, the switch is a component of the third party that supplies the rest of the electronics, therefore it is a proposal.

Figure 63: The desk's height-adjusting switch

6.1.6 The Desk's Connectivity

The desk let the user power its electrical devices by using the USB-C outlet on the desk. The outlet is connected to a battery which is placed underneath the desktop, which also gives power to the desk's height-adjusting motors. The battery can be exchanged for a fully charged one when needed, therefore making the desk self-sufficient and not dependent on having an electrical outlet nearby (Figure 64).

Figure 64: The desk's battery-pack.

6.1.7 The Desk's Cable Tray

The cable tray is designed to connect and support the two legs to each other to make the desk more rigid and be able to be moved over thresholds without bending. In the middle of the cable tray there is a desktop support to guarantee that the desktop will not break when applied with a vertical load placed on the desktop, for example, if someone places something heavy on the desktop, see Figure 65. There are covers on both sides of the middle support, this to cover up the cables for the height-adjusting motors, the electrical control box and also to prevent users from seeing the tray as a possible place to leave trash, for example, old post-its. To easily assemble the desk and for maintenance, there is still an opening left on the cable tray.

Figure 65: The cable tray supporting the desktop

6.1.8 Shape of the Base and Console

The wave shaped base lets the desk comply with the set standards of having the correct lowest height of a desk, being movable with wheels and clear a threshold, see Figure 66. The shape of the console also complies with set standards as it protects the user from any shear or squeeze points, see **Fel! Hittar inte referenskälla.**. It also reuses the wave shape to achieve a uniformity in the desk.

Figure 66: The wave shaped base

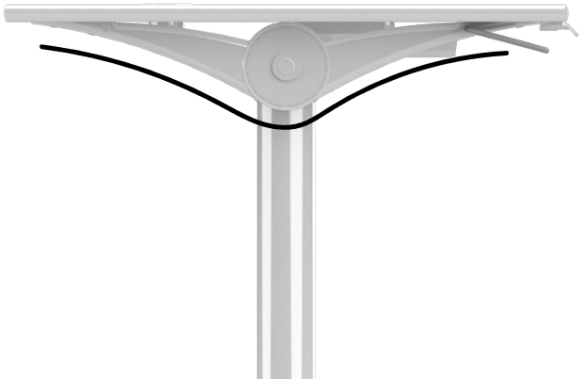


Figure 67: The wave shaped console

6.1.9 Side-Protection on the Desk

To extend the lifespan of the desk, various collision protections are added on the side of the desktop, ends of the base and on the cable tray. When the desk is in a folded state and stacked together with other desks, there is side-protection on the cable tray to separate the desktops frame from the adjacent desk and also on the base, see Figure 68.

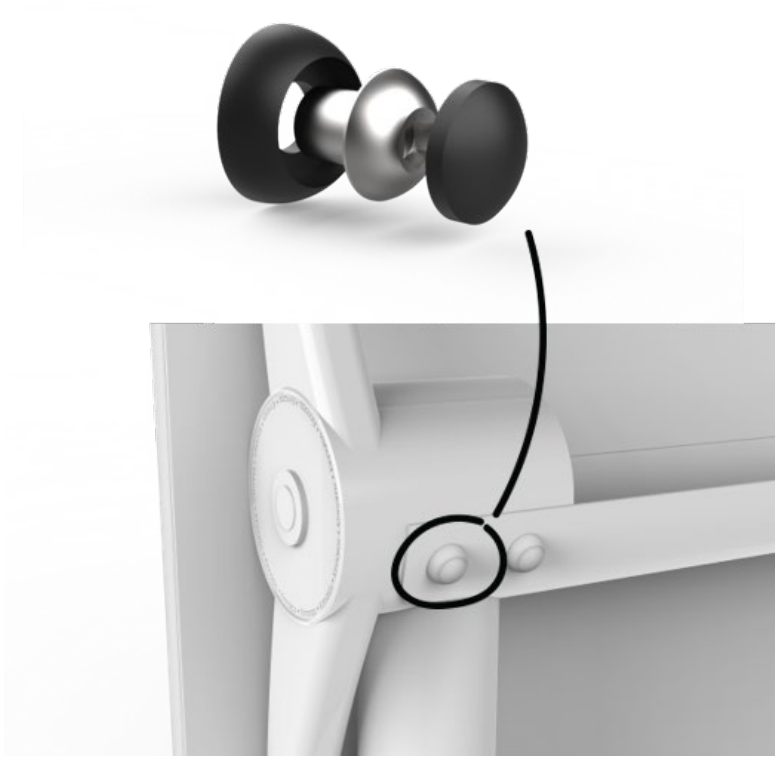


Figure 68: Collision protection on the cable tray

There are also side-protection strips added to the side of the desktop, this to protect the desk when in transport or standing next to another desk. However, there is no protection-strip added to the front-side of the desk, this to easier indicate which side is the front of the desk, see Figure 69.

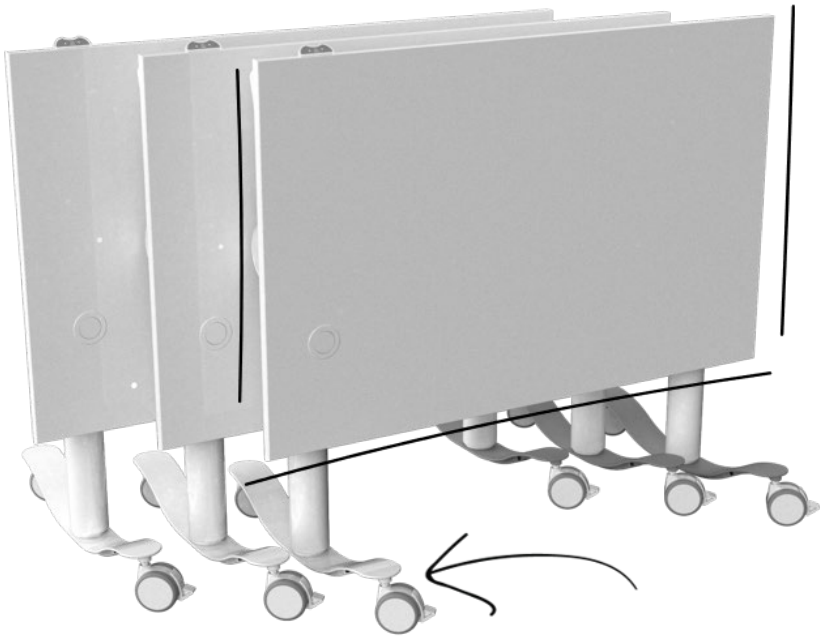


Figure 69: Stacked desks with collision protection

The three scenarios that were developed in the exploration phase, will be explained and illustrated below with silhouettes.

6.1.10 Scenario One

Four employees need to work on a project together for an extended period. They will cooperate and discuss a lot.

To help the users carry out their project, four desks are pulled from a row of stacked desks located in a corner of the room, these are then rolled on their wheels to a location where the employees can work in peace. The desks are then organized in a two by two orientation anchored with the locks on the wheels. The employees can then use large, conference-like, space for their work material such as laptops and paperwork where the laptops can be plugged into the hub for power, see Figure 70.

Figure 70: Scenario one

6.1.11 Scenario Two

An employee that varies between standing and sitting during the work session and also uses a software that requires a monitor to be used to its full potential.

By being height adjustable with a span wide enough to accommodate the vast majority for users, the desk lets the employee set the height to its liking and allows for altering between sitting and standing. The employee chooses a desk that has a monitor, grabs its USB-C signal cable and inserts it in the laptop, that then is placed on the laptop stand on the desk. Now, the employee can perform its work tasks, see Figure 71.

Figure 71: Scenario two

6.1.12 Scenario Three

A project team needs to work on separately delegated tasks, some are fine with just a laptop whilst others need a monitor. Once a week, the team members have a workshop and need a conference table.

The project team takes desks from the row of stacked desks and rolls them to a designated location, unfolds the desktops and locks the wheels. The team members that need it, fetch monitors and position them on the desktop, they can now start working. Three days later it is time for the workshop. Two desks are quickly folded with the handle, put away and stacked, and the other four are placed together to function as a conference table, see Figure 73.

Figure 72: Scenario three

What differs in these scenarios compared to when the desk of this project did not exist, is that before the users had to choose between having a desk that is height adjustable but not foldable, a desk that is foldable but not height adjustable or a desk that has this combination but does not comply with the safety regulations. This new desk allows for a more transformable and versatile furnishing.

6.1.13 Recommendations

As mentioned earlier in the evaluation section, here are two recommended design proposals for the requirements regarding USB-C hub and stand for laptop. Due to limited time, there are only suggestions created on how the USB-C hub and laptop stand can look like and where to place them. The USB-C hub is of a press-down-to-open outlet, which prevents dust or dirt from being able to accumulate inside them, see Figure 73. When the outlet is in its retracted position it should also be flush with the desktop to not interfere too much when the desk is used as a whiteboard. However, when adding these features, it is important to consider the cable management so that the desk does not become cluttered, something that is not contributing to an inviting desk. The reason for adding USB-C is that newer computers are chargeable with this standard and adding it, in combination with the battery, enables the user to discard their standalone charger. For backward compatibility, an USB type A is also included on the hub, however, it will only support low wattage charging of cell phones due to the specifications of the USB standard.

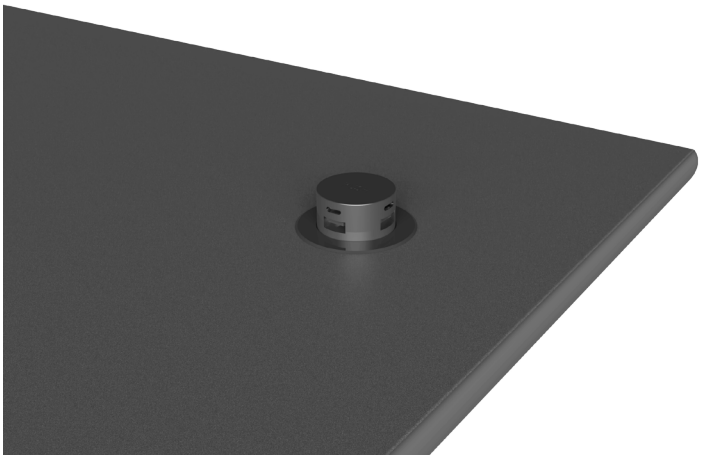


Figure 73: USB-C hub in deployed state

Based on the interviews, a delighting add-on of the desk would be a simple laptop stand (think newspaper stand) that can be used when docking to a monitor to get the laptop out of the way. The laptop stand can be placed anywhere on the desktop and allows the laptop to be both opened and closed, see Figure 74.

Figure 74: Laptop stand and USB hub

07
Discussion

esk • Exploration phase • Generation phase • Evaluatio

The final concept is considered to fulfill the project's aim and to be a successful product by Kinnarps. With its innovative locking mechanism that is easy to fold and lockable in both end positions, optimized to be as environmentally friendly as possible, for example by keeping the part count to a minimum, and has forms that expresses harmony. Therefore, it has an obvious role in the flexible office. Having to refurnish the room to fit the task ahead is obviously more time consuming than just changing room and by fulfilling the project's aim the refurnish can be done in a more efficient way. A result of an adoption of the desk would result in much more efficient real estate space utilization, the possibility to converge to a flexible workstation way of working, more versatile workshop rooms and the users gets a desk that helps them be more efficient. These are important factors to improve upon and design for since the space available gets shared by more and more individuals and the flexible workstation implementation will therefore be a more and more realistic alternative. It is however necessary to make clear that a transition to a flexible workstation is a prediction and not a certain outcome. Because one would argue that it is the last resort since it decreases the productivity by having the employees rearrange the room instead of doing actual work.

The discussion below will go through each phase, starting with the result and ending with remarks regarding the project as a whole.

7.1 The Result

The desk is multifunctional and can be used as a desk for swift tasks that are quickly completed, group tasks or for tasks that require a large monitor and more effort and time. Features and their purpose will be presented here.

7.1.1 Foldable and Mobile

With an intuitive and easily manageable handle, the desk can effortlessly, by one person, be folded and stacked away. This is important if the desk shall allow for refurnishing of the room and thereby having flexible workstations. This desk is designed, as mentioned, to be folded effortless, something that the market analysis revealed is a problem with existing desks. Here, only one hand is needed in comparison to two hands and a knee.

7.1.2 Aesthetically Pleasing

The desk has a unique design that will be remembered, for example, the organic shape of the base and console and the overall rounded appearance that differentiates from the conventional square shaped desks found in every office. As a whole the desk expresses professionalism and office strictness, with its straight lines and fundamental geometry, but at the same time expresses joy and calmness through its playful wavy lines. Therefore, the desk will be suited and well adapted for different offices and with its joyfulness create a creative environment. The result of being aesthetically pleasing and at the same time differentiated by not having a boxy shape and straight lines makes the desk more commercially viable.

7.1.3 Offering Flexibility

The desk offers flexibility by having a battery that can be exchanged for a fully charged one, which makes the desk self-sustained and can provide the user with energy. Therefore, the desk is suited for a flexible workstation because the desk does not have to be near any electrical outlets which allows it to be placed anywhere in the room. But, to ensure a completely self-sustained desk the batteries need to have more capacity. Currently, it just manages to provide both the desk, a laptop and cell phone with energy. Moreover, to be able to even charge the laptop and cell phone, they have to be compatible with the USB-PD standard which is used to charge various modern electrical equipment and

also send signals for, in this case, a potential monitor.

7.1.4 Ergonomic

By complying with the EN 527-1 standard the desk ensures that it is ergonomically adapted for productive endeavours. A nice feature with the cable tray is that it stays in place when the desktop is folded, which makes it easily accessible in contrast to conventional desks where the cable tray is connected to the underside of the desktop, which enables the user to route new cables without having to crawl underneath the desk.

7.1.5 Height-Adjustable

Having a three-piece leg makes for a wider height range to allow for a larger diversity of users to comfortably use the desk either sitting or standing. In order to make it easier for the user to set up the desk in the correct height, various ideas were explored but in the user studies it came out that users get too fixated to pre-sett settings and does not make adjustments based on their shoes and also making smaller adjustments over time for a slight change of sitting position and thereby adding variation to the work position which is considered a good thing. This fact led to the decision to omit that function. The outcome of not having a function that makes it quicker to find a more ergonomic setting can however also be discussed. It can result in that the user does not change the desktop height at all and thereby potentially having a worse height setting. It is a question of solving for users with lack of ergonomic knowledge or users that are lazy.

7.1.6 Durable

To be sustainable, the desk has interchangeable parts for an extended life cycle. It has excluded all use of textiles that will end up dirty and repulsive after being used by many users. The desk has incorporated edge protection on surfaces that are exposed, to make sure that it looks its best over time. By having a desk that looks pristine for a longer period of its lifespan, results in a user that does not feel that the desk is used and sullied by others, and thereby is more comfortable sharing desks.

7.1.7 Intuitive

The desktops edge protection indicates which side is the frontside, it has a handle that is accessible from both the side and front of the desk and has a design that shows how it should be operated. An intuitive desk is important in a flexible environment where the set-up is changed continuously by different users. This to make for a more efficient refurnish by not having to “teach” a novice user how to, for example, fold the desk.

7.1.8 Safe

The desk recognizes safety aspects by being locked both in folded and unfolded state, lockable wheels and having no squeeze points, thereby preventing accidents. With the desk’s middle support underneath, which is attached to the cable tray, it can manage a vertical load without breaking.

7.1.9 Multifunction

The desk’s handle double acts as a hook for the user's personal belongings, which enables the user to bring along all their necessary items but not having the issue of the items being in the way. When the desk is in a folded state it can multifunction as a whiteboard. Resulting in a more creative and flexible workplace and at the same time save space, by not having to have pure whiteboards occupy the space.

7.1.10 Colour

Two colour proposals have been used throughout the result section: black and white. In both cases grey has been used as an accent colour to indicate interaction point, that is, on the handle and the wheels, however, not the push-down-to-open USB hub. The reason being that it can be distracting when the desk is used as a whiteboard. The white colour blends into the traditional, as observed in Sweden, office environment and the black can be seen as a more sophisticated colour that matches with the design cues of Kinnarps. The metal parts, th<at is, the frame is in both cases presented in a glossy finish to express cleanness and quality, the desktop however, has a matte finish to allow for optical mouse and more importantly, not produce glare. One disclaimer has to be done regarding the black desk and the whiteboard; more vibrant whiteboard markers like neon coloured ones have to be used in this case.

7.2 Exploration Phase

The first question to be asked about the exploration phase is, was the problem or seeked solution interpreted in the right way. Within this project the requests from the client were quite defined; to develop a desk that is foldable, mobile, height-adjustable, self-sufficient and adapted for ABW. With such specific demands, it can sometimes narrow the scope of what can be developed, or the user's actual needs can be missed. In this case, the four first demands created a visualisation of what the result should be and what competitors to compare against, which helped gain inspiration for the generation phase. The last one, adapted for ABW, was not as straightforward and easy to understand as it was perceived in the beginning of the project. An acknowledgment described earlier in the report is that the implementations of an ABW can vary depending on the circumstances, which was discovered at the end of the exploration phase. Reason may be a too narrow exploration phase or that the project group was blinded by their own reality and did not consider lack of space as a potential problem.

When realising the fact that the users for this project's orientation were not heard but instead users from a different implementation, it was time to figure out if the collected information could be used anyway. When considering the situation, it was argued that the users that were interviewed still are users of a desk in an office environment, and what sets them apart is Kinnarps's fundamental requirements. Therefore, needs that contradicted Kinnarps's fundamental requirements were deleted and the remaining were viewed as features that delights the user. The result this had on the final product is hard to tell but satisfying these users' needs may ease their future implementation of the desk and thereby, making a more desirable product. If thinking past the specific companies being interviewed, the interviews gave a great deal of information despite being three. The information from one company to the next matched well and a stagnation could be noticed which indicated that the majority of the needs had been discovered.

Some user needs that were discovered stand on the line for what is a feature of the desk versus what is a feature of the office. The clean desk derives from the fact that offices practice desk sharing rules. What is often a scenario when coming to a desk is that the previous user has left rubbish or coffee stains. To prevent this, the idea was to add a spot on the desk that can house cleaning supplies, but this requirement was later removed. However, to have a good desk and a functional ABW environment

this must be solved, but by the office, to not end up with an impractical swiss army knife of a product. The users also mentioned colour coordinate desks, this to get a sense of belonging and to feel secure, which is also mentioned as a problem in the literature. If the desk were to have this feature, the desk would not be compatible with the ABW strategy since the desks are supposed to be shared by everyone and be anonymous. However, the secureness is still something that the office itself needs to address to make the employees feel secure and a part of the group. These and similar “on the line needs” took valuable time to solve and a clearer definition earlier on for what is the scope would have been more efficient.

Last thing in the exploration phase, that raised a few thoughts, where the desktop area tests. These were conducted with a desktop that was only 120 cm wide and not 140 cm that was in the range of possible widths that Kinnarps requested. It is possible that if the tests would have started with the greater dimensions, the result would have turned out differently. Hence, the removed width would probably be recognized as psychologically greater if the starting point was 140 cm instead of the 120 cm. The desktop size tests result was also hard to quantify because of the nonuniform feedback scale. Therefore, to perform these tests with a pre-made chart, for example, with different feelings expressed, could have made an easier comparable and verifiable result, see Figure 75. Still, the tests were viewed as successful because this method generated unique insights due to the nature of open oral questions and answers.

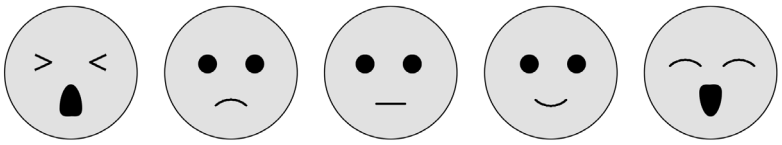


Figure 75: An example of a scale that could have been used

7.3 Generation Phase

The plan was to divide the desk into core components, start with putting focus on the locking mechanism and designed around it, with the actuator and folding joint. Then move on to the wheels and the locking of them, electronics and other features. However, when performing the marked analysis, the observed folding desks had quite a simple folding mechanism and locks that resemble hinges on a door. This gave the impression that the development of the lock would not be that complicated. What was not discovered until a few weeks had passed of the generation phase, was that the desks investigated in the market analysis are not covered by the same regulations as the project’s desk. They lack the height adjustment and therefore, does not include a motor, which regulates the shear and pinch point requirements. Consequently, this resulted in the project group’s internal expertise not being comprehensive enough to develop this more advanced folding joint and lock that complies with the more extensive regulations. More time was, therefore, consumed on external research in quest for inspiration and potential solutions which did not match the project's set time frame. Attempts to gain input on various ways to solve problems were made, workshops with participants with other backgrounds were organized, but due to external circumstances, all except for one minor

workshop, had to be cancelled. However, when new locks had been generated that satisfied the standards, the screening decisions were made in conjunction with more knowledgeable people, therefore, the project group is confident that the lock is the best it can be after the circumstances. But as a result of this more comprehensive development, the locking mechanism consumed 80 percent of the time designated for the concept generation.

The locking mechanism complimented by the handle is the core of the desk, everything else is built around those or with them in mind. They both reached a satisfactory level much because of the time put into developing them but also the extensive research performed on competitors' desks. Being able to try out and get a feel for what actuators and folding mechanisms that work gave an advantage in the development and probably led to an avoidance of malfunctional mechanisms that would not have been discovered until late in the process. One observed detail amongst others is that the desk Foldex's handle leverage is too small because of the design of the internals fulcrum point. The result of this is that users with less hand strength have a hard time actuating the lock. To prevent that, the project's desk has relied on sprints that amplify the power put into the handle and also made a larger handle to fit the whole hand if necessary.

The consequence of having 20% of the time left of the concept generation for all other components after the locking mechanism, led to a lot of design decisions having to be made in a very short amount of time, more or less considered. The aesthetic aspect of the concept is an example of that. The geometrics of the components became a consequence of the function it had rather than a function that meets a form in for example, the consoles. Another example is the utilization of compliant mechanisms and other solutions to minimize the amount of parts could not fully be investigated on the final concept, there is still potential for improvements in that area. Components that were considered as not fundamental or to be explored if time allowed for it, were removed or just added without deeper consideration. Three examples of that, is the side protection of the desktop, the laptop stand and USB-C implementation.

With a locking mechanism and handle that is easy to use, prevents accidents, is durable and joins together well with all other parts, the generation phase is, all and all, considered successful.

7.4 Evaluation Phase

For an extended period of the project, the intention was to have a prototype made and to use it for the evaluation of the final concept. It was however not possible under the current circumstances of Covid-19 which led to that improvised alternative ways of evaluating the final concept had to be performed. The result of that, is that the outcome of the evaluation cannot be confirmed with the same certainty. Foldex was used as a model to compare concepts with, throughout the process, despite that it only fulfils three out of four fundamental requirements, the reason being that the project group had it at their disposal. It can be considered an unequal comparison, but it was great to gain feedback from users regarding the folding and flexibility. CAD was one of the methods used to evaluate the mechanical feasibility of the concepts, though it only was two concepts, this method was far too time and resource consuming. In this case it also did not generate enough information to determine the verdict of the concepts. It was however a good method to discover and solve problems previously not considered. It was

in that phase that the shape of the consoles arose. They were meant as a symbolic illustration of how and where they were to be. This was instead taken as a definitive design by Kinnarps (who liked it). The intended scenario was to evaluate the lock and pay the consoles more attention in a later stage. The moral is that it is treacherous to combine and show different levels of fidelity of a concept in the same presentation. If there would have been a possibility for prototypes both the locks could have been tested and evaluated physically, this may have resulted in another outcome.

For the subjective requirements Kinnarps was used as the decisive decision, they are a stakeholder but not the target group and therefore a questionable determiner. One example of why this is a problem is that they “eat, sleep and breathe” desks, and can therefore have preconception about how to use them or have the function, something a not so indoctrinated user might not. Kinnaprs thought, for example, that the intended use of the handle was obvious (the correct one), something that may be due to that is how the industry orientates their handles. For the non-confirmed requirements further testing will be needed to assure that the product, not only in theory is feasible, but also in practice. Some requirements were not achieved due there being only 20% left of the generation phase and they were all seen as features, therefore not achieving these, does not mean that the project is not achieved. For example, minimizing the wheel marks and preventing hair cumulation in the wheels needs further testing, wireless charging was viewed as outside the scope, one standard height and lowest/highest was viewed as unsafe. The last requirement, pre-settings, was viewed as something that would foster users to implement it in a wrong way therefore, getting a non-ergonomic workstation.

7.5 The Project

The pandemic outbreak, Covid-19, struck early on in the process which resulted in the user studies having to be cut short and some changes to the process had to be made. Still, user needs were found, a concept was designed and was evaluated with methods available. When viewing the final concept and thinking of other potential ones that could have arisen from the process, the final concept is estimated to be successful due to fulfilling the requirement specification and satisfying the client. Especially since the fish trap model shaped the project’s progress in a funnel-like way where problems are solved one by one where alternatives are considered in all steps which gives a steady convergence towards the final concept. As in all projects, there are details that can be improved. In this case, it could be to validate the user needs and put more time on the aesthetic design aspects. One other aspect that was important was working two persons on this project, it made it easier to solve different mechanical issues and combining ideas from different perspectives led to an innovative concept.

7.6 Further Work

To finalize the desk, further development and optimization is needed. The components in the joint and the consoles need to have appropriate manufacturing processes chosen and be optimised accordingly. For a higher volume of units, die casting is probably the best to overcome the labour cost of bending and welding. The lock itself is constructed with a lot of metal to metal surfaces, something that can result in friction and jamming if not greased properly. Therefore, to mitigate the need for maintenance, other solutions have to be considered, for instance bushings of other materials. This is, however, only a hypothesis and needs to be tested with prototypes. A prototype can also serve as a means for determining the amount of material needed and the size of the spring, something that is hard to do elsewise. The amount of material relates to the strength of the lock and folding joint which is set by the standard EN 527-2. The cable tray can also be developed further by reducing the amount of material used, by for example perforating it. However, since it has a structural use, this has to be done with tests. Future works also entails evaluation whether the measurements taken to make the handle express the intended function is enough and also decide if a surface mounted height-adjusting switch is the better choice, as it possibly can be easier accessed when folded.

Another aspect of the desk that needs further work is the wheels. Kinnarps own wheels were pre-selected, with both a diameter of 75 mm and having the anchorable feature. So, there is room for research regarding wheels with similar features to make sure that these wheels are the most optimal wheels to use and to test the requirements *prevent hair cumulation in the wheels* (#47) *and minimize wheel marks* (#56). Also, consider developing cable routing, for example, the cables going from the height-adjusting switch to the electrical control unit, so there are no cables hanging free. Future work concerning validating the user needs are an important factor, seeing if they match with the ABW user of a flexible workstation/room. Furthermore, examining the non-achieved requirements, for example *wireless charging* (#62), which during the project was later seen as outside the scope. Regarding the requirements: *one standard height* (#43), *pre-set settings* (#57) and *lowest/highest* (#59), are at this stage viewed as unsafe or not being ergonomic. This due to having an option to set, for example, a standard height which could cause the desk to inflict injury or collide with other desks if not watched during adjustment. The pre-set settings are, as mentioned in the interviews, something that could be a delighting feature for the user but at the same time cause the user to not adapt the workstation, thereby creating a non-ergonomic workstation. Therefore, these three requirements need further research, to see if these problems can be solved.

The non-confirmed needs, for example, *mobile by one person (*#26) *and foldable by one person (*#30), needs to be tested by the users with a prototype, this to confirm that they are working in reality and not only in theory. An interesting thought would also be to test this prototype on users living in the dense cities in Europe to get more insight into the product, if it is fulfilling their needs and if the handle, for instance, is as intuitive as intended.

7.7 Conclusion

The user of the activity-based workplace with the flexible workstations/rooms implementation is an employee that can work with short tasks or with longer projects, in a group or alone. The employee needs to be able to utilize the space available efficiently, be able to refurnish and adapt the setting and not lose time by doing so. The employee also needs an ergonomic workstation that can house its personal belonging as well as the instruments needed to perform the job. The concept achieves these needs by meeting criteria defined by both the users and Kinnarp;

- Foldable
- Height adjustable
- Mobile
- Self-sufficient
- Stackable
- Having a clutter free and multipurpose desktop that double acts as a whiteboard
- Side protections for long lifespan
- Allow for cleaning between legs
- Communicating the intended function, which decreases the folding time and thereby the refurnishing time

This project resulted in a concept for a workstation able to adapt to the ever-changing needs of the office that is physically restricted regarding space. A tool that will help the ABW user transform the space to fit a wide selection of situations and tasks.

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8.1 Appendix I - Interview material

Customer intro questions:

- What is your daily responsibility?
- Are you working in an ABW environment yourself?
- How long have you worked in the ABW environment and here at this company?

Topic Specific Questions:

ABW in general - opinion

- What do you think of ABW?
- What do others say about ABW?

When you arrive in the morning

- How do you choose your location?
- What are your priorities when choosing a desk?
- What makes you choose a desk that seemed good at first glance
- Which work zone do you prefer? Quiet zone etc

How does the desk look when you them- what do they look like when you get them - policies?

- Cleanliness
- What is left on the desks?
- Wear & tear - textiles - the table surface - what gets worn, why?

Does it happen that you re-furnish to adapt to different situations?

- In what contexts?
- How?
- How frequent?
- Good/bad?
- What do you do with unused desks?

How do you feel at home at today's desk - "safe"?

- Do you feel at home at a new desk?
- If not, how do you make yourself feel at home?
- Seen something that co-workers do to feel at home?

What do you have with you at your desk?

- Do you have room for everything?

How to adapt the workplace for you (chair and table)

- Do you know how to customize it (change settings)?
- Are you sure about the setting? Ex. right height
- Do you get help with understanding the ergonomics? (Ergonomics training)

Product Opportunity Questions:

What requirements do you have when you buy a desk?

- Priceworthy
- Quality
- Environmental
- Sustainability
- Features

Do you have folding tables?

- Have you seen the need / what are they used for?
- What do you think about folding tables?

Do you have tables with wheels?

- Have you seen the need / what are they used for?

What electronic features do you think are important on a desk:

- Socket
- Dock
- Load
- Screen

What practical features do you think are important on a desk:

- Hook
- Box
- Storage
- Mousepad

What have made you like the ABW environment, do you see any potential improvements for the future?

Is there something you dislike about your desks - what could have been improved?

- Have you tried other desks that you have been extra satisfied with?

One day in life:

Show us what an ordinary day would have looked like for you in the office, all details are important, and everything is of interest.

Some situations:

- Find a workplace and send mail
- Go for lunch
- Go home

8.2 Appendix II - PNI of the market analysis

8.2.1 SA-möbler

Snitsa tables

Multifunctional frame desk which makes it very customizable. 23 mm high-pressure laminate (HPL). Slidable desktop is a smart feature that provides one clutter-free workspace with hidden cables. 60-125 cm of height adjustability. Retails at 6 640 SEK.

+

Multiple desktops to choose from
Multiple legs to choose from
Height adjustable
Slidable desktop

-

Arguably not appealing is the standard appearance
Not foldable
Not easily movable (No wheels)

♫

Similar to Kinnarps range
A lot of accessories like panels and cabinets
Adapted for the international market with its regulations
Utilizing standard rails which enables the flexibility and scaling

8.2.2 Balzar Beskow

Mobil

Standard bent tubing as the frame. Foldable desk by pulling the locking lever beneath and then tilting the desk. Big wheels for transporting the desk easily when not in use and stackable.

+

Large wheels that can clear obstacles
No spring
Stackable when not in use

-

Poorly designed locking lever, hard to pull out to initiate folding
Badly balanced when folded, due to unbalanced centre of gravity
Not height-adjustable

♫

Rounded edges
Distinct clicking feedback sound when locking

8.2.3 String

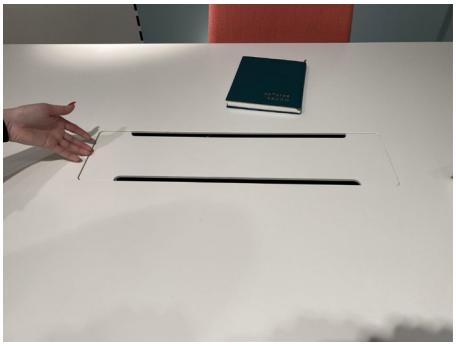
Works

Veneered MDF with clear lacquer desktop. Powder-coated sturdy steel legs. Integrated cable tray. Retails at 14400 SEK. 71,5-118,5 cm of height adjustability. W180 x d90 of desktop area. The loading capacity is 60 kg.

+
Good cable management
-
Not foldable
Heavy
Not easily movable (no wheels)
Bulky
♫
Eye-catching colour scheme
Easy acquirable shelf parts and material.

8.2.4 Pedrali

ARKI-TABLE



The desk is height-adjustable and ranges from 740-1140 mm, it also includes an electrical outlet in the centre, with cover. Powder-coated aluminium legs and laminate desk. The electrical outlet has a cover. Underneath the desk, there are chamfered edges that encapsulate the undercarriage and the electrical package

+

Height adjustable
Electrical outlet easily accessible behind a board in the centre of the table
Intuitive operating switch

-

Not foldable
Not easily movable (no wheels)
Reinforcement underneath the board

♫

The edges underneath
Arguably, the chamfer gives an aesthetically pleasing look and touch

8.2.5 Icons of Denmark

Woodstock Flip Top Table

Combining a solid oak column with a fixed cast-aluminium leg. The desktop has a lacquer veneer. The dimensions are 160 x 74 x 80 cm. Retails at 30 000 + SEK

+

Movable
Foldable

-

Not height adjustable
Fiddly two-hand operation to fold the table

♫

Only front wheels have a locking mechanism
Interesting combination of natural material and steel

8.2.6 ISKU

The desk can be stacked together, the electrical outlets are covered.

+

Interlocking desks together but not flexible
Electrical outlet easily accessible behind a board on the right side of the table

-

Not height adjustable
Not easily movable (no wheels)
Not foldable

♫

The interlocking mechanism, though it does not make it flexible. The shared frame can then be used for mounting panels
Felt covered compartment

8.2.7 Wilkhahn

Confair

A conference table and not a desk but an interesting design. An office desk within the same product line, that was not available at this exhibition, has similar attributes and can also be turned into a whiteboard. Legs in diecast aluminium and a veneer desktop. There was also a side table on display.

+

Possibility to interlock desks
The side table had the easiest folding lock to unlock, due to its finger support
The legs go together and take up less space than conventional folding tables
Easy to be folded by one person
Side protection

-

A spring-loaded folding mechanism that fatigues over time and has an own amount of power when folded which can cause the desk to slam together, creating noise and a security hazard
Consists of many intricate parts

♫

Interesting and novel folding design

8.2.8 Fantoni

Woods desk

Desk size is 160 x 80 / 180 x 80 cm. Constructed of oak veneer, powder-coated steel frame with solid oak legs.

+

Height-adjustable

-

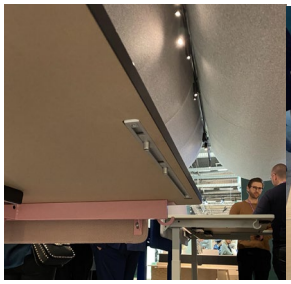
Not easily movable (no wheels)
Not foldable
Legs moving along the floor when height adjusted causing friction and a crab walk
The leg design prohibits conventional folding design.

♫

Clean and uncluttered design
Peculiar legs and actuator

8.2.9 Ragnars

L-station



+

Movable panels, positive aspects of a cubical but still open
Height-adjustable
Hooks placed underneath on the side of the desk, not interfering with the user
Possibility to attach cabinets underneath the desk

-

Not easily movable (no wheels)
Not foldable

♫

Smart solution for the elbow placement
Movable panels that can be placed on the table
Original colour scheme

8.2.10 Kinnarps

Foldex

Kinnarps's own line up for a flexible ABW. The desk is not high-adjustable and thereby not designed for long duration of individual work, rather for group or creative sessions. When the meeting is done, it folds and stacks, transforming a tight space into an open place.

+

It is smooth and soundless when folding.
Easy to use locking for the wheels.

-

The folding mechanism makes the desktop flex while resting forearms on it.
It takes two hands and a knee to fold and unfold it and you need to be somewhat strong and when pulling the locking mechanism towards you the whole table slides towards you on the floor.
There is no auditory feedback, like a click sound, when locking the desktop.
Not easy to understand how to use the lock.
Locks on only two wheels is not enough to prevent the desk from moving.
The visuals of the desktop locking lever do not correspond with its haptic feedback.

8.2.11 Kinnarps

OBERON

Kinnarps's conventional office desk.

+

Very customizable to fit everyone's taste and need

The divider / panel has an inbuilt screen holder that clears up desktop space

-

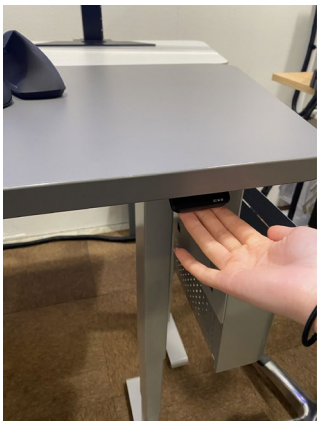
Not foldable

Not flexible (no wheels)

♫

One of the desktops has a stained ash board that stands out from the

8.2.12 Various interesting acknowledgments



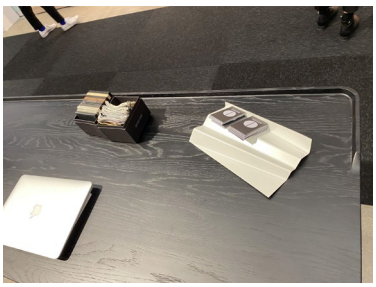
An intuitive way of operating the height switch, which is easy to understand and lets you operate without having to look.

- Intuitive operating switch

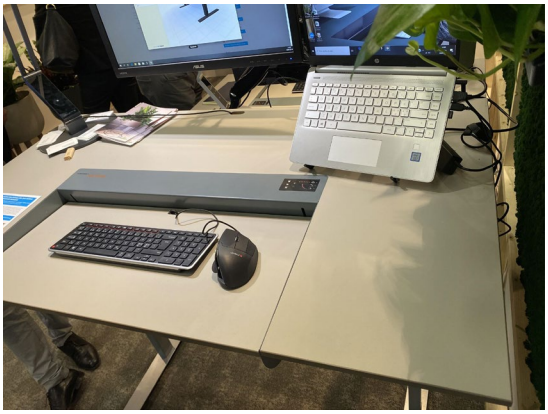
Smooth leg shape, shelf on top of the electrical outlets

Felt-covered compartment for exclusive expression.

Smooth chamfered edges underneath



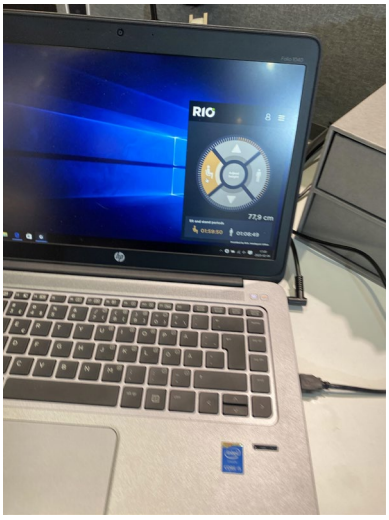
An edge for the end of the desk preventing thing from falling of



Selective tiltable desk area for high arm ergonomics

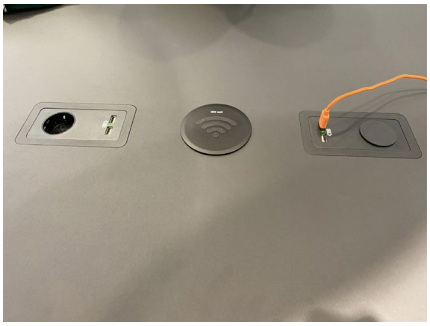
An interesting design of legs that enables easier stacking

Rubber protective frame, both underneath legs and on the side to protect the tables when stacked. Rubber frames around the table which provide an impact-resilient profile.



A PC application that saves the height settings for continuous ergonomic seating

A cut out made for easier cable management

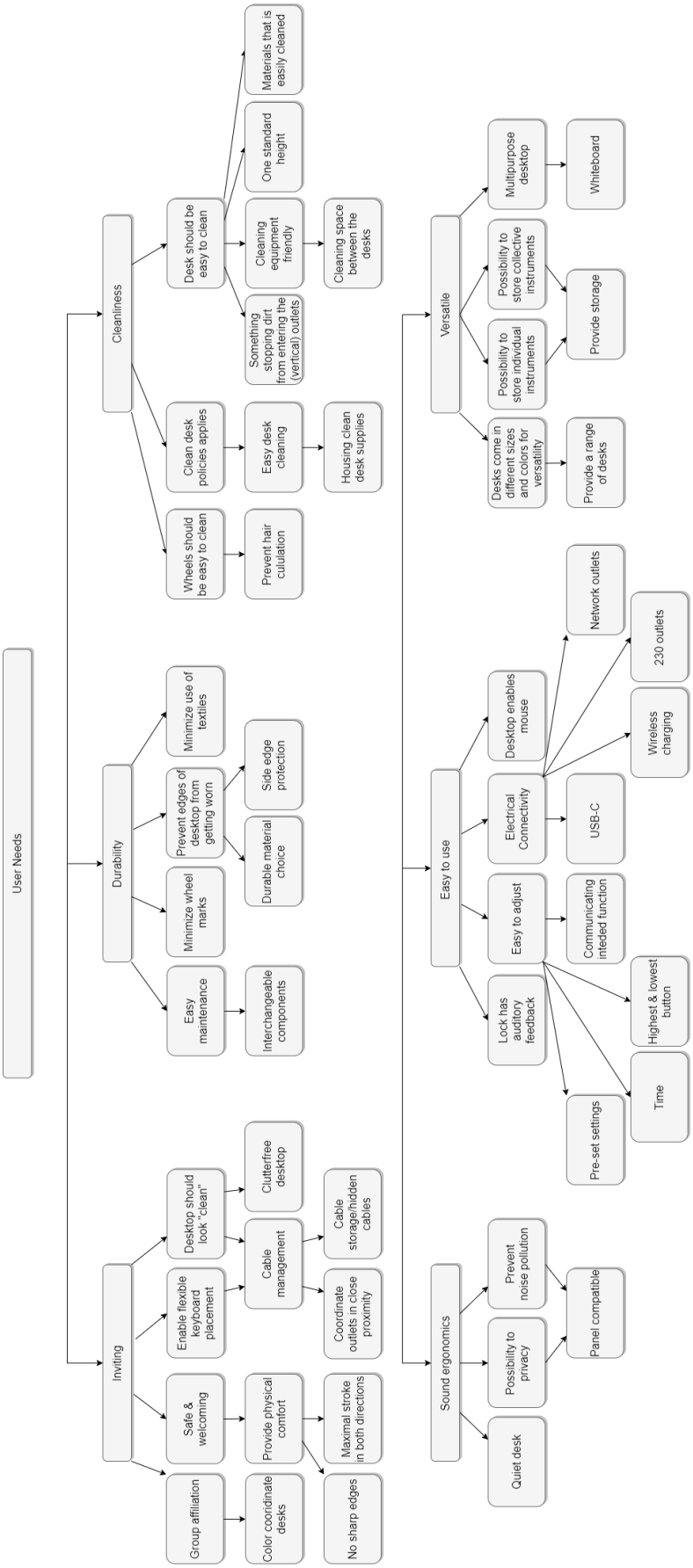


Electrical outlets & cordless charging for phone

Simple to manufacture but still original leg design

The cut-out supports the user's arms when working in a standing position, by letting the user stand closer or in a sitting position and not having a chair with armrests.

8.3 Appendix III – Objective three



8.4 Appendix IV - SWOT

8.4.1 Motion of the actuator

Push

S: Non complicated mechanism, No precise hand movement
W: Demanding motion, **Desk gets pushed away**
O: If visible; intuitive, potentially does not need to be adapted after the locking mechanism,
T: Lack of knowledge may lead to rejection

Press down

S: Fool proof, Non complicated mechanism
W: Complex motion; Hard to understand, **Goes against the direction of folding**
O: New on the market; few competitors, potentially does not need to be adapted after the locking mechanism,
T: Can interfere with knee clearance,

Press up

S: Simple motion; intuitive. Same direction as the desk movement
W:
O: Can be used as a hook, potentially does not need to be adapted after the locking mechanism,
T: Accidentally triggered, interferes with knee clearance, **Squeeze point can appear**

Pull

S: A comfortable motion, Fool proof
W: Shifts the desk
O: Potentially good in combination with a counter stay, potentially does not need to be adapted after the locking mechanism,
T: Could be hard to pull if much power is needed, can potentially jam

Combination

S: Fool proof
W: Complicated mechanism
O: New on the market; few competitors
T: Lack of knowledge may lead to rejection

8.4.2 Number of interaction points

Single

S: Quick, Requires one hand
W: Requires additional parts to connect to other side due to locking
O:
T: Similar to the competitors, **Not fool proof**

Double

S: Fool proof (redundant)
W: Require two hands, cannot be used for long desks
O:
T: Too troublesome to fold

Combined

S: One lock actuator handles both locks
W: Only fool proof in some directions, requires additional parts
O: Requires one hand
T: Similar competitors, Can potentially pinch if badly designed

8.4.3 Location

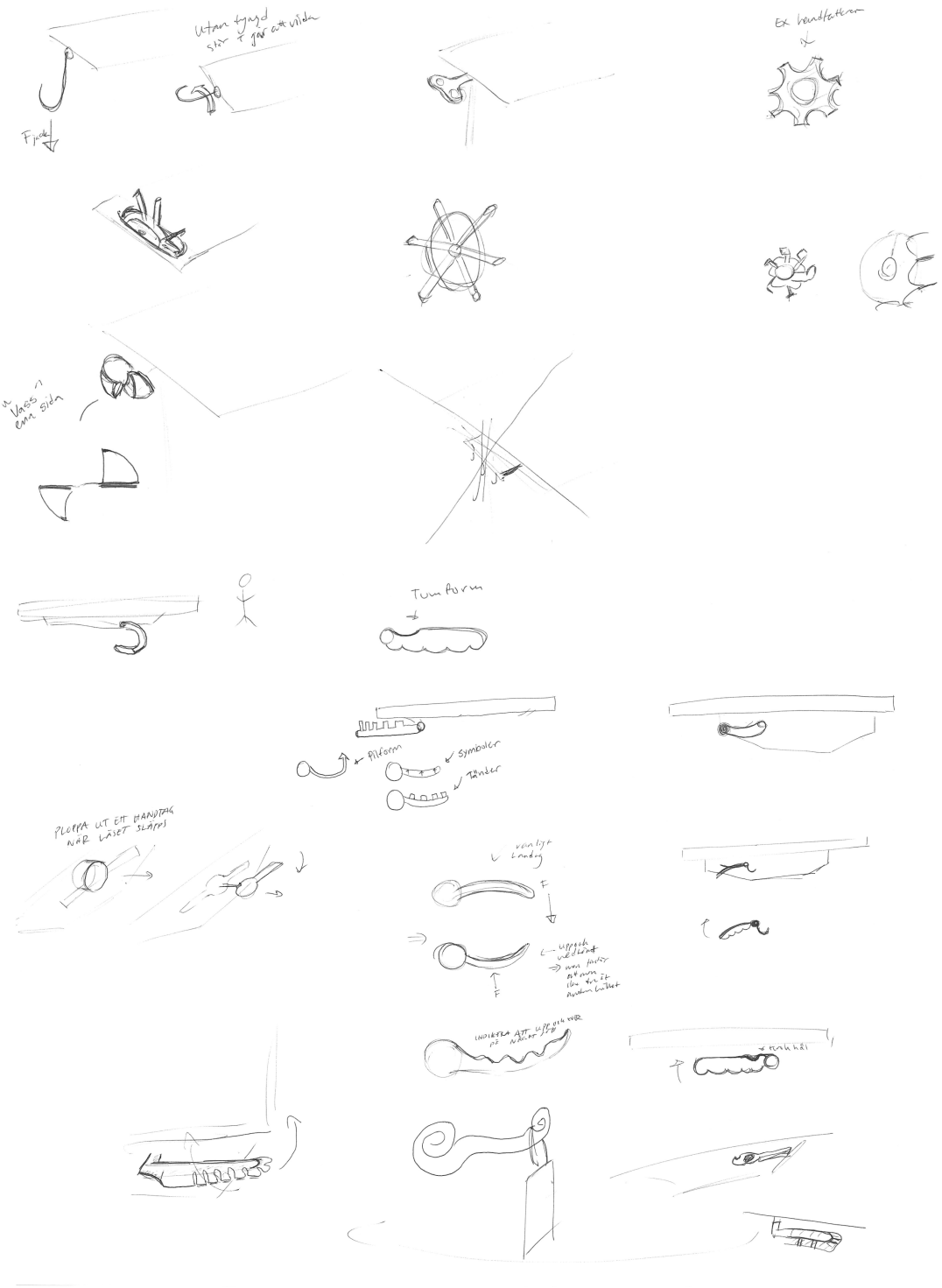
Front

S: Easily accessible from the normal working location,
W:
O:
T: Can introduce accidental actuations, not fool proof in some cases depending on the lock actuator, interferes with knee clearance and leg width

Side

S: Fool proof
W:
O: Potentially more intuitive if located near folding location
T: Not accessible when desks are lined up tight together

8.5 Appendix V - Lock actuator

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8.6 Appendix VI - Requirement specification 2

nr	categories	sub-categories	definition of requirement	sub definition	value / range	optimal value	unit	source	date	comments	
1	Standards	Dimensions	Height of the work surface	Sit/stand	650-1250	618-1306	mm	EN 527-1:2011	2011		✓
2			Max. desk top thickness	At the front	55		mm	EN 527-1:2011	2011	klass D	✓
3				At 500 mm from the front edge	80		mm				✓
4			Min. height of knee clearance for standing position only	Applies only to tables with a height more than 850 mm	700		mm	EN 527-1:2011	2011		✓
5			Min. depth of clearance for standing position only	knee	80		mm	EN 527-1:2011	2011		✓
6				foot	150		mm				✓
7			Min. height of min. foot clearance	Sitting only and sit/stand From 600 mm to 800 mm from the front edge	120		mm	EN 527-1:2011	2011		✓
8				Standing only from front edge to 150 mm	120		mm				✓
9			Minimum legroom depth	Sitting only and sit/stand	800		mm	EN 527-1:2011	2011		✓
10			Minimum desktop depth		800		mm	EN 527-1:2011	2011		X
11			Minimum legroom width	Sitting only and sit/stand	1200		mm	EN 527-1:2011	2011		✓
12				Standing	790		mm				✓
13		Safety requirements	All edges and corners are free from burrs and rounded or chamfered.		Pass		Pass / Fail	EN 527-2:2016	2018		✓
14			Edges/corners of top surfaces are	Chamfered	>1		mm	EN 527-2:2016	2018		✓
15				Rounded	>2		mm				✓
16			Ends of feet and hollow components are capped or closed.		Pass		Pass / Fail	EN 527-2:2016	2018		✓
17			Movable & adjustable parts designed so injuries avoided.		Pass		Pass / Fail	EN 527-2:2016	2018		✓
18			Not possible any load bearing part to come loose unintentionally.		Pass		Pass / Fail	EN 527-2:2016	2018		✓
19			All lubricated parts designed to protect users from stains.		Pass		Pass / Fail	EN 527-2:2016	2018		✓
20		Shear and squeeze points	During setting up & folding - S&S points created are acceptable (unless 21 or 22 are applicable).		Pass		Pass / Fail	EN 527-2:2016	2018		✓
21			Powered mechanisms – no S&S points which close to <25mm unless always <7mm.		Pass		Pass / Fail	EN 527-2:2016	2018		✓
22			During use – no S&S points close <25mm unless always <7mm.		Pass		Pass / Fail	EN 527-2:2016	2018		✓
23		Stability requirements	Stability under vertical load		Pass		Pass / Fail	EN 527-2:2016	2018		---
24			Stability for work tables extension elements		Pass		Pass / Fail	EN 527-2:2016	2018		---
25	Kinnarps	Client Requirements	Mobile	Mobile	Pass		Pass / Fail	Brief	21-1	Can easily be transported	✓
26				By one person	Pass		Pass / Fail	Brief	21-1		---
27			Lockable	When folded	Pass		Pass / Fail	Brief	21-1	Can not be folded/unfolded without intention	✓
28				When unfolded	Pass		Pass / Fail	Brief	21-1		✓
29			Foldable	Foldable	Pass		Pass / Fail	Brief	21-1	With two hands maximum	✓
30				By one person	Pass		Pass / Fail	Brief	21-1		---
31				Quickly		≤3,5	Seconds	Brief	21-1		---
32			Stackable	Stackable	Pass		Pass / Fail	Brief	21-1	With two hands maximum	✓
33				By one person	Pass		Pass / Fail	Brief	21-1		---
34			Aesthetically Pleasing		Yes		Subj	Brief	21-1	Evaluated by Kinnarps	✓
35			Provide electrical power		65	>65	Wh	Brief	21-1	Derived from "provide charging ability" For computer, cellphone, monitor, desk.	✓
36			Desktop width		1100		mm	Brief/test	21-1		✓
37			Desktop depth		700		mm	Brief/test	21-1		✓
38			Production cost			5000	SEK	Brief	21-1		✓
39			Height-adjustable		Pass		Pass / Fail	Brief	21-1		✓
40			Clear standards threshold	Ground clearance	30		mm	Brief/test	21-1		✓
41				Wheel diameter	75	>75	mm	Brief/test	21-1		✓
42			Anchorable	Lockable wheels	Pass		Pass /	Brief	21-1		✓

43	User needs and market analysis	Cleanliness	One standard height			Pass	Pass / Fail	Interview 3	w.8	To make the cleaning easier for the cleaners	X
44			Protection for the vertical outlets	Hinder dirt from entering the		Pass	Pass / Fail	Interview 3	w.8		✓
45			Cleaning space between the desks			>100	mm	Interview 3	w.8		✓
46			Material that is easy to clean			Pass	Pass / Fail	Interview 3	w.8		✓
47			Prevent hair cumulation in the wheels			Pass	Pass / Fail	Interview 3	w.8		X
48		Durability	Interchangeable parts	Legs	Pass		Pass / Fail	Market analysis			✓
49				Wheels	Pass		Pass / Fail				✓
50				Desktop	Pass		Pass / Fail				✓
51				Electronics	Pass		Pass / Fail				✓
52			Durable material			Pass	Pass / Fail	Interview 3	w.8	Collision. have inte mind (not glass etc)	✓
53			Side/lateral edge protection	Folded	Pass		Pass / Fail	Market analysis			✓
54				Unfolded	Pass		Pass / Fail				✓
55			Minimize use of textiles	On wear surfaces		0	mm^2	Interview 1	w.7		✓
56			Minimize wheel marks			Pass	Pass / Fail	Interview 1	w.7	On carpets	X
57		Easy to use	Easy to adjust	Pre-set settings		Pass	Pass / Fail	Interview 3	w.8		X
58				Velocity		3,6	m/s	Interview 2	w.8	konkurent vs kinnarps reference	---
59				Lowest/highest		Pass	Pass / Fail	Interview 3	w.8	Button	X
60				Communicating the intended function		Yes	Subjective	Literature study	2019		✓
61			Lock with auditory feedback		Pass		Pass / Fail	Market analysis			---
62			Connectivity	Wireless charging		Pass	Pass / Fail	Interview 1,2,3	w.7-8		X
63				USB-C	Pass		Pass / Fail	Interview 3/Brief	w.8		\
64			Desktop enables use of mouse			Pass	Pass / Fail	Interview 1	w.7		✓
65		Inviting	Maximal stroke in both directions	Provide physical comfort		Pass	Pass / Fail	Interview 1,2,3	w.7-8		✓
66			Clutter free desktop			Yes	Subjective	Interview 1,2,3	w.7-8		✓
67			Cable mangement	Coordinate outlets with close proximity / same side		Pass	Pass / Fail	Interview 2	w.8	In case of multiple outlets and dock	✓
68				Cable storage/hidden cables		Pass	Pass / Fail	Interview 1,2,3	w.7-8	Look clean and no cables interfering the cleaning	✓
69		Sound ergonomics	Quiet desk	Minimize mechanical noise		Yes	Subjective	Interview 1	w.7	Konkurent referens. testat utan vetskap	---
70			Panel compatible			Pass	Pass / Fail	Interview 1,2,3	w.7-8	Accepts Kinnarps panels	✓
71		Versatile	Provide a range of desks	Different colors and sizes		Pass	Pass / Fail	Interview 1	w.7		✓
72			Provide storage	Individual instruments		Pass	Pass / Fail	Interview 1,2,3	w.7-8		✓
73				Stand for laptop		Pass	Pass / Fail	Interview 1,2,3	w.7-8		\
74			Multipurpose desktop	Whiteboard		Pass	Pass / Fail	Interview 1 & 3	w.7-8		✓

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