Development of combined guide and soft closing for sliding door systems

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MASTER THESIS

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Abstract

This master thesis includes a product development process focused on incorporating a soft closing system for sliding doors in an existing cabinet at IKEA. A soft closing system prevents the door from slamming into the furniture when closing it. The unit today has what is called guides, holding the cabinet doors in place. The aim is to create a device that possesses all of the crucial qualities of a guide as well as a soft closing to be able to replace the former. The reason for this is to be able to apply a soft closing to the cabinet or similar units to give them the added feeling of luxury that a soft closing provides. The thesis was executed at IKEA Components, a subsidiary company within the IKEA corporate group.

The cabinet today is very simple and this is why a more luxurious feeling was sought after. IKEA Components had part of a solution when the project began that was investigated during this project along with the search for additional ideas. To get a greater understanding of soft closing systems, guides and different kinds of cabinets and storage units, an extensive background study was conducted. This showed that the combination of a soft closing and a guide was not a commonly occurring device at the investigated companies.

A lot of concepts were generated and evaluated and after an extensive iterative process the thesis resulted in two concepts. Both of the ideas consist of encasing the soft closing in a shell that then enables a vertical movement. This was needed to fulfil all of the requirements. The main difference between these concepts is the execution of this movement. The first idea has a kind of snap fitting idea that hold the soft closing in place in the different positions. It is moved by pushing the snap fitting inwards and pushing up or down. The second idea has a more complicated internal design, but is very easy for the user to operate. It is moved by using a “key” and turning it counter clockwise 180 degrees to move it up and by pushing it in and turning it the opposite way, it is moved down.

This thesis resulted in two possible solutions for combining a soft closing system with a guide.

Keywords: Mechanical engineering, IKEA, soft closing, guide, storage unit.

Sammanfattning

Denna rapport innehåller en produktutvecklingsprocess som fokuserar på att integrera ett mjukstängningssystem för skjutdörrar i ett existerande skåp på IKEA. Enheten har idag vad som kallas för guider som håller skåpsdörrarna på plats. Målet är att skapa en enhet som besitter de viktigaste egenskaperna av en guide och av en mjukstängningsmekanism för att kunna ersätta den förstnämnda. Detta görs för att kunna applicera mjukstängningsmekanismen på ett skåp eller annan förvaringsenhet för att ge en lyxigare känsla som en mjukstängningsmekanism ger. Examensarbetet genomfördes på IKEA Components, ett dotterbolag inom IKEA AB.

Skåpet är idag väldigt enkelt och därför eftersöktes en lyxigare känsla. IKEA Components hade delar av en lösning när projektet påbörjades. Denna utvärderades och utvecklades under projektets gång samtidigt som det söktes efter nya idéer. För att få en djupare förståelse för mjukstängningssystem, guider och olika sorters skåp och förvaringsenheter genomfördes en omfattande bakgrundsstudie. Denna visade att kombinationen av en mjukstängningsmekanism och en guide inte är vanligt förekommande på de undersökta företagen.

Många koncept genererades och utvärderades och efter en omfattande iterativ process blev resultatet två koncept. Båda idéerna innebär att mjukstängningskomponenten innesluts av ett skal som möjliggör en vertikal förflyttning. Detta krävdes för att uppfylla kraven. Den huvudsakliga skillnaden mellan de två koncepten ligger i genomförandet av denna rörelse. Det första konceptet har en snäppfästesfunktion som håller mjukstängningsdelen i de olika positionerna. Den förflyttas genom att trycka snäppfästet inåt och uppåt eller nedåt. Det andra konceptet har en mer komplicerad invändig design, men är väldigt lätt för användare att manövrera. Den förflyttas genom att använda en “nyckel” och vrida denna motsols 180 grader för att flytta den uppåt och genom att trycka den inåt och vrida åt motsatt håll förflyttas den nedåt.

Detta examensarbete resulterade i två lösningar för att kombinera ett mjukstängningssystem med en guide.

Nyckelord: Maskinteknik, IKEA, Mjukstängningsmekanism, guide, förvaringsenhet.

Acknowledgments

This master thesis has been performed at the Division of Product Development at Lund's University, Faculty of engineering, together with IKEA Components. There are several people that we would like to thank for all their help and without whom, this thesis would not have been possible.

It has been challenging, incredibly instructive and we are grateful to everyone who have helped us along the way. We would like to give special thanks to our supervisor, Per Lindberg, and our manager, Niclas Persson, at IKEA Components that have supported and guided us through this thrilling journey of writing this thesis. We would also like to thank or supervisor at LTH, Per-Erik Andersson, for always having a quick and positive response and having the answers we needed.

We would also like to thank some other people at IKEA Components for helping us; Christer Petersson, Mikael Reimer, Magnus Månsson, Magnus Svensson, Henrik Lindberg and Peter Weidmert for helping us with their mechanical design expertise and for setting aside their own work when nothing was working with our 3D modelling; Stefan Nilsson for brilliantly abetting us in the choice of materials and for sharing his knowledge of plastic manufacturing; Carl Ervér for guiding us through the jungle of patents; the pattern shop at IKEA of Sweden for printing our many models. To Ida Karlsson, Amanda Dahlberg, Petter Olofsson, Frida Jansson, Malin Larsson and Venetia D'Souza together with all the previously mentioned IKEA workers we would also like to give a big thanks for welcoming us into their wonderful IKEA family and for making us feel at home from the very first day.

Lund, June 2018

Julia Petersson and Vivian Kamel

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1 Introduction

This section contains the introduction of the project, such as information about the design team and the company, delimitations, goals, key people at IKEA and problem description.

1.1 Background

1.1.1 Company background

IKEA Components is a subsidiary company within the IKEA corporate group. IKEA was originally founded in 1943 by the Swedish entrepreneur Ingvar Kamprad at the age of 17. IKEA offers a wide collection of home furnishing products and every piece of furniture is created according to the company's vision: "To create a better everyday life for the many people". Their business idea is "to offer a wide range of well-designed, functional home furnishing product at a price so low that as many people as possible will be able to afford them" [1].

IKEA Group consists of a lot of IKEA companies and IKEA Components is most easily explained as the company that, above all, develops a lot of the mechanisms for the furniture developed by IKEA of Sweden. Mechanisms that, for example, hold the furniture together and enable moving of doors and drawers. Fittings such as hinges, slides, wheels and screws are examples of components developed. As they would say. "Everything that makes the furniture to more than just a pile of wood".

The Master Thesis is conducted in the department at IKEA Components called "Open & Close". They manage just that, everything that in any way opens and closes. Hinges on a kitchen cabinet, the extension rails on a chest of drawers or the wheels on a sliding door are examples of components they have developed.

1.1.2 Team background

The design team consist of Vivian Kamel and Julia Petersson. Two students studying mechanical engineering at the Faculty of Engineering at Lund's

University. The team has during their studies gained knowledge in product development, mechanical engineering and design. A lot of focus during the studies regarded the use of programs such as CAD and FEM analysis which was necessary for the project.

1.2 Problem description

At IKEA, within furniture that have an open and close feature, different extra functions can be added. When looking at the kind of storage unit referred to in this thesis, one with sliding doors, one of the functions that can be added is a soft closing system. A soft closing system prevents the door from slamming into the furniture when closing it. This gives a smoother closing and decreases the tearing of the furniture.

There are different kinds of sliding door furniture at IKEA. In this thesis, a storage unit with an inside standing door, called Mackapär, is investigated. Mackapär is a range of storage unit and the one referred to in this thesis is a shoe cabinet [2]. The doors in this furniture are fitted with wheels on the bottom of the doors and mounted standing inside the cabinet. This means that they are constrained on each side by the cabinet walls. A more detailed description of this is found in the research section. In order for this kind of door to stay in place, two so called guides are needed on each side of the door at the top. The guides are crucial parts of a standing sliding door and prevent the door from falling out of its rail where it slides.

Today, Mackapär does not come with a soft closing. With the design of the soft closing as it is today, the mounting of the doors into the cabinet would not be possible if the soft closing where to be placed according to IKEA Component's wishes. The task in this thesis is to add the soft closing function to these doors by replacing one of the guides on the door with a device that works both as a guide and a soft closing. This will create a component that the design team will call a soft closing guide (SCG). According to the co-workers at IKEA Components, this combination is predicted to give the end user an added sense of luxury when using Mackapär. Moreover, since the soft closing will be integrated in the guide, it will lead to an easy mounting since two pieces are combined into one. IKEA Components have initiated a design for this which has not been developed enough to be fully functional. It is wished that the current solution is evaluated thoroughly alongside other solutions developed during this thesis. Figure 1.1, 1.2 and 1.3 on the next page illustrates how Mackapär, example of a soft closing and example of a guide look today.

Figure 1.1: The cabinet Mackapär as it is today [2].

Figure 1.2: Soft Closing for PAX, an IKEA wardrobe [3].

Figure 1.3: The guide mounted in Mackapär.

1.3 Delimitations

The specification and purpose of the project was given to the team from employees at IKEA Components. The SCG should be able to fit on and between the doors as they are installed today.

The actual mechanism of the soft closing, how the soft closing is performed by the unit, is given and will not be developed. Since this project concerns a cabinet with sliding doors, all investigation such as research and benchmarking was focused on storage units with sliding doors and no other storage categories.

The way of mounting the doors will not be investigated since it was stated that this should not be changed. Therefore, the wheels at the bottom of the doors will not be changed either.

It is predetermined that the SCG should be mounted onto the sliding doors, why mounting it in the cabinet walls will not be an option. Since the soft closing as well as the guide today are made through injection moulding, and it is a method that IKEA is familiar with, other manufacturing methods will not be investigated. It is therefore presumed that the concept developed in this thesis will be injection moulded.

1.4 Goals

The main goal of this project is to create a more luxurious experience for the user while using Mackapär without compromising the simplicity of the mounting and whilst still enabling dismounting. During the thesis this will be done through concept evaluation, development and designing of a combined guide and soft closing for the standing sliding door system. It also includes material choice for the concepts. The concepts should be evaluated through tests and the goal is to finally have a working prototype.

1.5 Key people at IKEA

Name	**Title**	**Project role**
Per Lindberg	Requirement Engineer, Open & Close ICOMP	Supervisor
Niclas Persson	Deputy EQR Development Manager for Open & Close ICOMP	Manager
Christer Petersson	Requirement engineer, Open & Close	Advisor on project (mechanical design)

Carl Ervér	Intellectual Property Leader, Business Navigation Department IoS	Advisor on project (patents)
Stefan Nilsson	Technical Specialist, Category Assembly & Accessories ICOMP	Advisor on project (material and production)
Magnus Svensson	Design Engineer, EQR Assembly and Accessories ICOMP	Advisor on project (CAD)
Gustav Holstein	Simulation Engineer, Consultant at ICOMP from Alvelid Engineering AB	Advisor on project (simulations)
Olaf Diegel	Professor in Product Development at LTH	Advisor on project (3D modelling) and Examiner

2 Methodology

This section describes the methods used during the project, such as the choice of process and the construction of that process, both in its original form and the changes that were made to adapt the process to the project.

2.1 Planning

The thesis was calculated to be performed during 20 weeks and the predicted time plan is shown in the Gantt-schedule in appendix A. The planning was done through discussions together with C. Petersson and P. Lindberg. The time plan shows the activities included in the thesis with their estimated duration shown in weeks. In appendix A there is also an illustration of when and for how long the activities were actually performed, this was updated as the project went along.

2.2 Approach and design process

The book *Product Design and Development* by Karl T. Ulrich and Steven D. Eppinger describes a model for product development that can be used in projects where a complete product development process is intended [4]. Since this thesis regards a lot of evaluation and iterative product development, the methods described in the book suit this project well.

One of the goals was to choose material and make a final prototype. As the final concept was to be made mostly in plastic, the book User's Guide to Plastic by Ulf Bruder [5] was used as a guideline during the process. Moreover, there are a lot of co-workers at IKEA that possess knowledge of plastics, computer aided design (CAD) and finite element method (FEM) analysis which was an important information source.

2.3 Research

Before initiating the design process, some research about IKEA, IKEA Components and the products within the category had to be done. It was done both through walking around in one of IKEA’s stores, investigating different functions of open and close units and through receiving existing CAD-parts with relevant information. This information was being updated continuously throughout the project. Moreover, information with details about the furniture and CAD-files was given by co-workers at IKEA Components. The research section contains analysis of existing parts that will be included in the product or that will affect the design. Different kinds of similar storage units and soft closing systems could be used as an inspiration when generating solutions to the problem. These are found in the benchmarking. Furthermore, the partial solution that IKEA Components had come up with was analysed with FEM during the project in order to find out whether or not this solution was functional.

2.4 Design process used in this Master Thesis

The model that was followed for this project is a modified version of the product development model stated in Product Design and Development by Karl T. Ulrich and Steven D. Eppinger [4]. During the project the model was slightly modified to make it more adapted for this project and the process was iterative. Both the original model and the modified model are divided into seven phases, demonstrated in figures 2.1 and 2.2. The phase “Identify customer needs” was not necessary in this thesis since the project specifications were given from IKEA Components with requirements and purpose clarified. This phase was instead replaced with “research”. During this phase, information about IKEA and products that concern the project was acquired. “Final Downstream Development” was replaced with “Final prototype”, since that was the main goal with the project. Also, “patent search” was added to the activities that are supposed to be done continuously throughout the project. This is something that IKEA work frequently with and is important since these kinds of components can be found in a lot of patents.

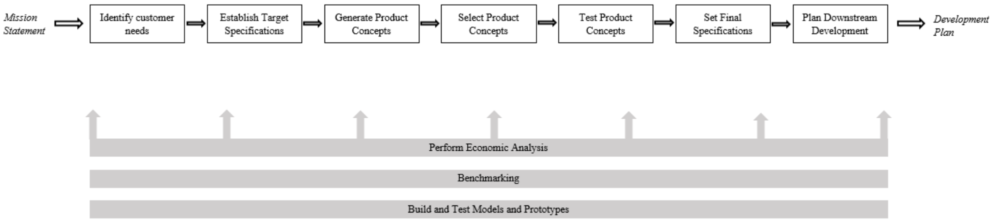

Figure 2.1: The design process according to Ulrich and Eppinger [4, p. 74].

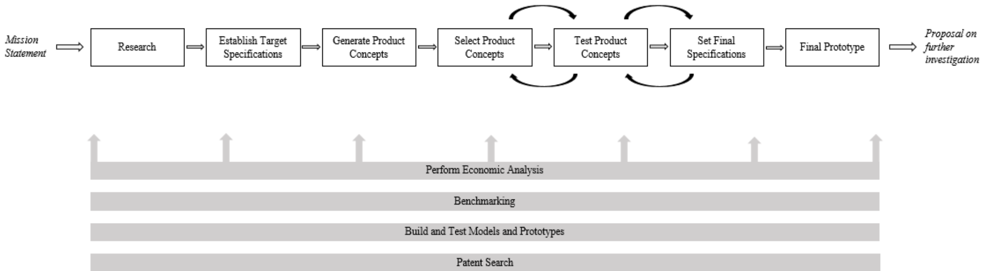

Figure 2.2: The alterations made to the process to adapt it to the project.

3 Research

This section describes the research process during which the information from IKEA was collected and compiled. It will work as a framework throughout the project, describing parts that are concerned and important. The information collected mainly regards the storage unit that the solution is intended to. It also describes how a guide and a soft closing system works. The partial idea that the people at IKEA Components have developed was analysed during the research.

3.1 Definition of directions

When describing the different cabinets and components during the report, to make it as clear as possible, the coordinates displayed in figure 3.1 below is used throughout the report.

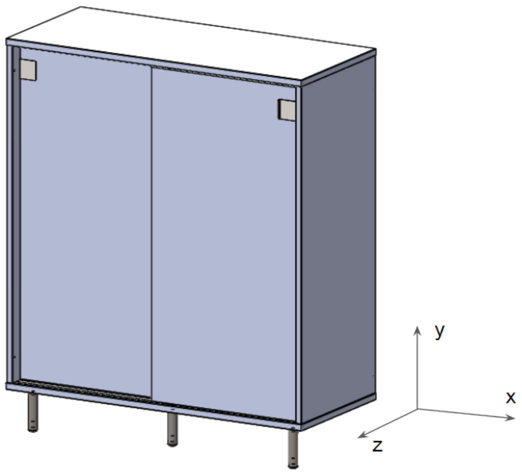

Figure 3.1: Mackapär storage unit with coordinate system defined.

3.2 Storage unit

Within the category of storage units with sliding doors at IKEA there are different varieties regarding installation and function. The concept developed in this thesis is intended to be used in a storage unit with standing sliding doors in IKEA's range called "Mackapär". Figure 3.2 shows what this shoe cabinet looks like.

Figure 3.2: Mackapär cabinet [2].

3.2.1 **Mackapär**

To know as much as possible about the cabinet that was to be used, the research about this furniture was made thoroughly. It is a cabinet with standing sliding doors. It is installed through placing the wheels located at the bottom of the door into the bottom rails of the cabinet, and then fixing the top with guides into the top rails of the cabinet [6]. This is demonstrated in figure 3.3 on the next page.

One of these guides is to be combined with a soft closing. Today, Mackapär is not designed for a soft closing to be included. As can be seen figure 3.3 on the next page, the way of installing the door in Mackapär means that when the wheels have been put in place and the door is tilted into its upstanding position, any protrusive object will hit the roof of the cabinet. This will turn out to be the biggest challenge when wanting to add a soft closing to the top of this storage unit and what needs to be solved in this thesis. This is because when adding a soft closing with its current design at the top of the door, for the soft closing to work during normal use, it has to protrude above the top of the door to reach the rail, making mounting impossible. The design of a soft closing can be seen in figure 3.11 below.

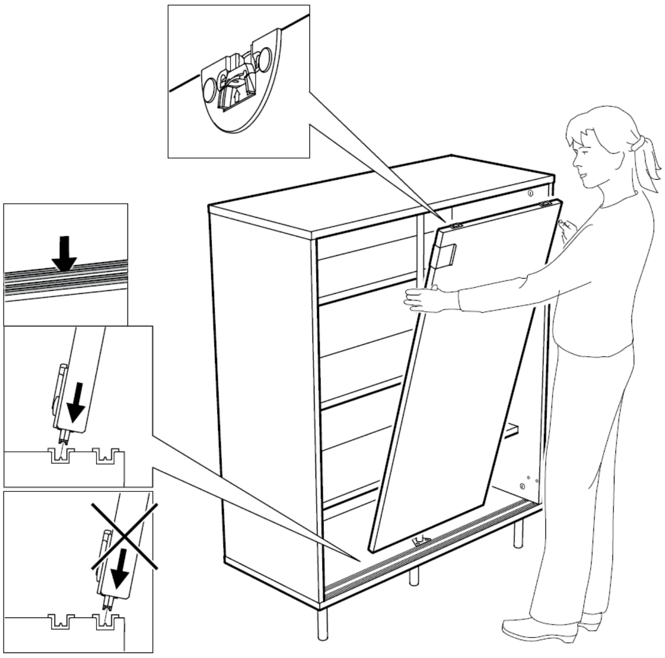

Figure 3.3: Mounting of Mackapär cabinet doors [6].

3.2.1.1 The Guides

As described in section 2, the guides work to prevent the door from falling out of the top rails. The guides are fixed through pushing the lever up into the rails in the y-direction. Figures 3.4, 3.5, 3.6 and 3.7 below show the guide before and after being pushed up. According to N. Persson and P. Lindberg, what is important when designing the guides is that they need to withstand a force of 200 N pushing the door inwards and outwards in its mounted position in the cabinet. This is a safety feature to make sure it can handle both, for example, someone falling on the door from the outside and possible items falling on the door from the inside.

Also, the very tip of the guide, when being in its top position, should be designed to be in contact with the rails without creating too much friction. It should slide smoothly while guiding and with as little noise as possible. According to P. Lindberg, the guides that are being used at IKEA today are made in the plastic material POM for the tip of the guide (A) and a 15% glass fibre reinforced PA6 (PA6 GF15) for the base (the rest). POM is a good material to use when a gliding function is necessary and PA6 suits well when stiffness is needed. If more stiffness is desired, glass fibres can be added [5]. Put in its context, the guides mounted in the unit is shown in figure 3.8 below. The placement of the guides in the doors is displayed in picture 3.9 below.

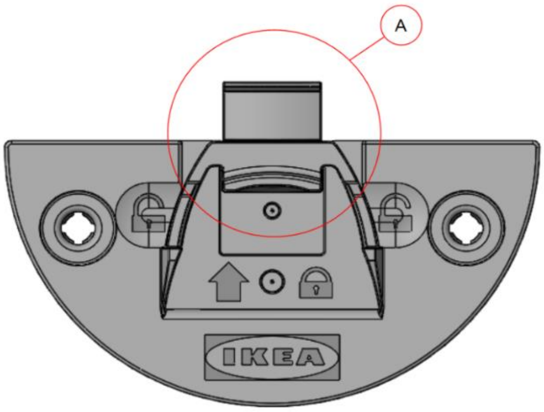

Figure 3.4: Front of the guide with latch pushed up.

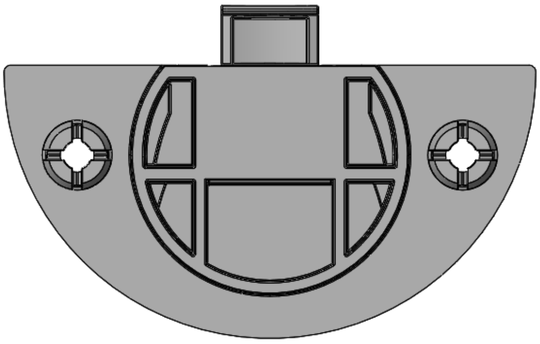

Figure 3.5: Back of the guide with latch pushed up

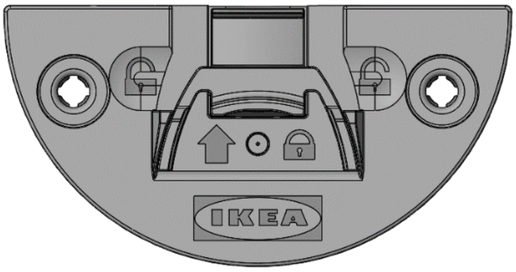

Figure 3.6: Front of the guide with latch down.

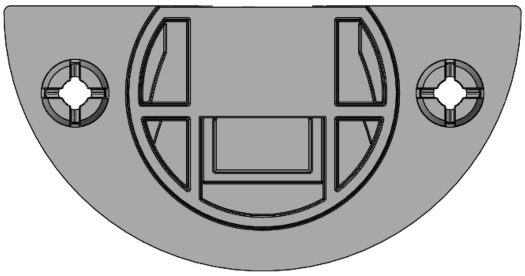

Figure 3.7: Back of the guide with latch down.

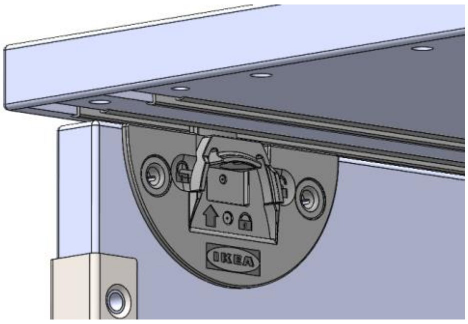

Figure 3.8: Guide positioned in track when mounted.

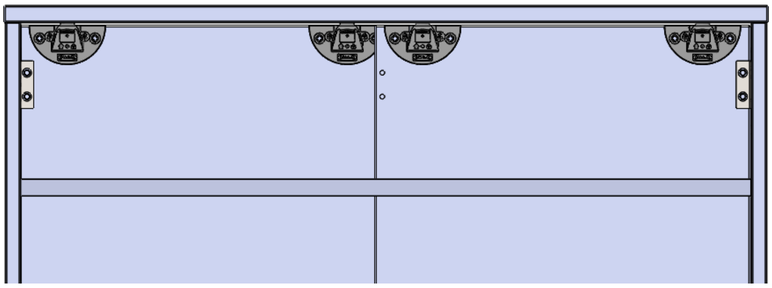

Figure 3.9: Position of the guides on the doors and in the cabinet.

3.2.1.2 The Wheels

At the bottom of the cabinet doors are the wheels that make the sliding of the doors possible. Since the IKEA cabinets are manufactured in such large numbers to then be assembled by the customer, every cabinet might not have the exact dimensions. To counteract this the wheels are adjustable in the y-direction (se figure 3.10 below) to make sure that the doors always can be straight. They have a height adjustment length of 2 mm in each direction, resulting in a total height difference of 4 mm between the top position and the bottom position of the doors. This is something that needs to be taken into consideration when designing the SCG.

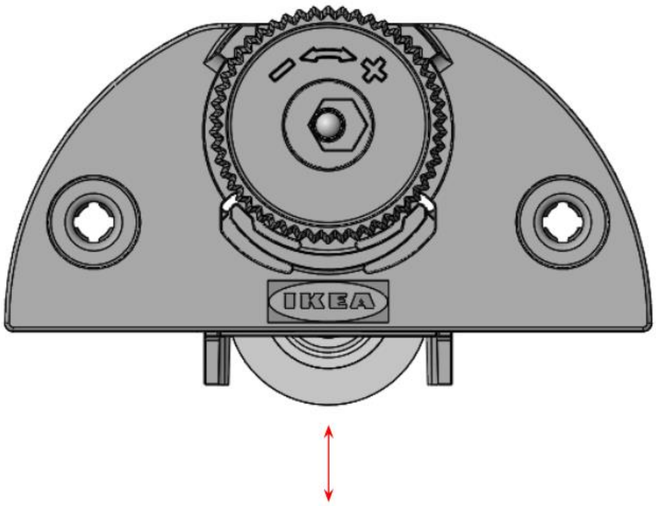

Figure 3.10: The wheels and the possible adjustment.

3.3 Soft closing system

A soft closing system can be added to a storage unit at IKEA when requested that a door or a drawer should be closed softly. The system catches the door when it is closing so that it closes softly, silently and slowly. This is considered to give the user a more luxurious feeling when using the furniture, according to N. Persson. Figure 3.11 below shows a soft closing that is being used in a storage unit at IKEA today, called Malsjö. This thesis and all the concepts will originate from this soft closing. These figures are taken from CAD files.

3.3.1 **Design**

At IKEA, all of the soft closing systems consists of one activator (A in the picture) that catches the door through a hook (B in the picture) and a damper with a pneumatic piston, a pin and a spring (C in the picture).

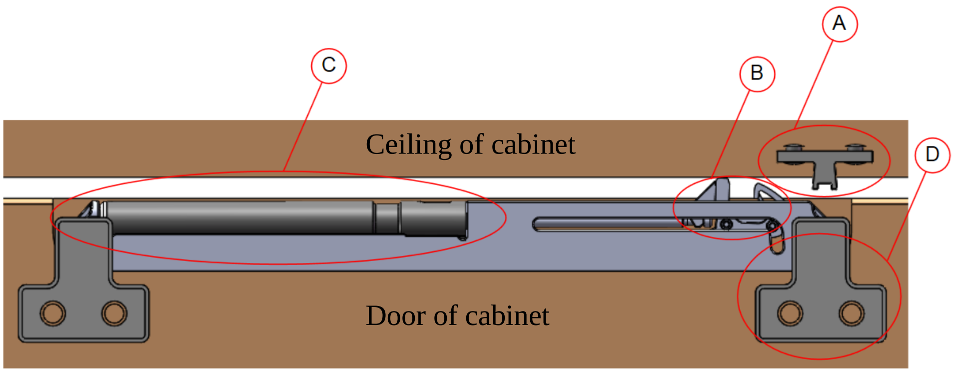

Figure 3.11: The different parts of the soft closing.

As can see in the figure above, the soft closing in Malsjö is today mounted onto the door through two fasteners (D in the picture). It is also mounted on the bottom of the cabinet instead of the top like in this thesis.

3.3.1.1 The hook

The design of the hook can be seen in figure 3.12 on the next page. This hook is designed to work together with the damper part, why it should not change too much.

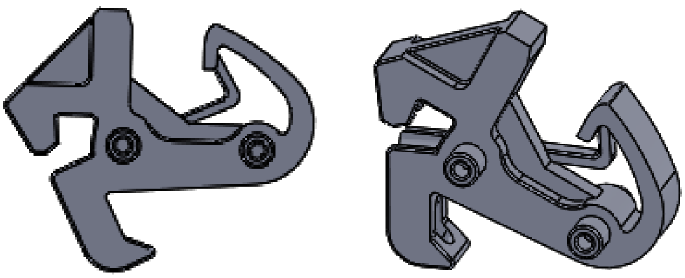

Figure 3.12: The design of the hook.

3.3.2 How it works

The function of the soft closing mechanism occurs in 3 steps (see figure 3.13 below):

1. The user pushes the door (on which the soft closing is attached).
2. The activator hits the hook that is attached on the soft closing base. This leads to the hook attaching to a pin, which can be seen through the tracks in the figure.
3. The activator catches the door before it hits the wall. The damper which is connected to the hook through the pin gives a soft closing. During this, the hook is being dragged backwards by an extension spring.

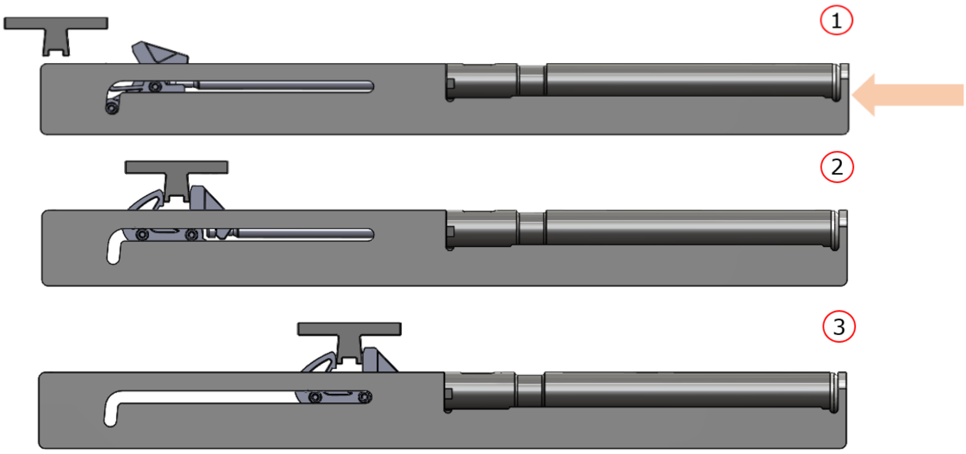

Figure 3.13: Description of how the soft closing works.

Figure 3.14 on the next page shows a transparent view of the soft closing, showing the parts making the actual soft closing mechanism such as the spring, the pin and the hook interact.

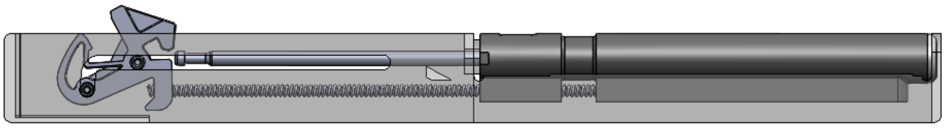

Figure 3.14: Transparent picture of the soft closing system.

Depending on the type and look of the storage unit, different kinds of soft closing systems are used. The soft closing system that is intended to be used in this thesis is one for standing sliding doors and is illustrated in figure 3.13 above. Different parts of the soft closing are made in different materials:

- The housing, which is the blue part in figure 3.11 above, is made in 30% glass fibre reinforced PA6 (PA6 GF30).
- The hook is made in PA6.
- The damper, damper end and the pin is made in POM, this is the part marked with C in figure 3.11.

To get a hint of the price of this product, the team asked J. Niklasson about this. Today, this whole soft closing including all costs is purchased for 0,977 Euro. However, the team assumed that the material cost was more relevant and easier to compare with the final concept. Therefore, S. Nilsson was consulted in order to calculate the material price of the soft closing. A list of densities and material prices that IKEA Components use was given and is shown in table 3.1 below.

Table 3.1: Material cost and density

Material	*Cost/kg (SEK)*	*Density (g/cm^3)*
PA6	25	1,14
PA6 GF15	27	1,23
PA6 GF30	27	1,35
POM	18	1,4
ABS	25	1,04

The density was simply put into the CAD-parts upon which the mass was given in Solidworks. When this is multiplied by the cost/kg, the material cost is given. The delimitations indicates that the part that will change significantly in this thesis is the housing, why the price for this was calculated. The price of the housing for the soft closing showed above is 0.417 SEK. Since the final concept will combine a soft closing and a guide, the price of the guide was also calculated. The price of the guide showed above is 0.379 SEK and the price of the original hook, figure 3.12 is 0.037 SEK. The calculations for this can be seen in appendix D.

3.3.3 **Soft closing system for standing sliding door**

As described in the problem description above, the purpose of this thesis is to combine a soft closing with a guide in a standing sliding door. In order for the soft closing to also act as a guide, it needs to be mounted into the door. Today, a storage unit with a soft closing system mounted into the door in the bottom of the door does exists at IKEA. However, in that unit a soft closing system is not combined with the guide. The conclusion is that a soft closing system that is combined with the guide for a standing sliding door does not exist in any IKEA furniture today.

3.4 Prototype from IKEA Components

As being mentioned before, IKEA Components has been working on a solution for this task which should also be taken into consideration in this thesis. The design is a further development of the soft closing system illustrated in figure 3.13 above, but adaption to the issues needs to be solved for it to work in Mackapär. The basics of this concept are that the hook in the soft closing is slightly redesigned to act as a guide, from here on called a guide-hook. The hook has simply gotten an elongation of the tip of the hook.

In order for the door to be installed, the guide-hook needs to be hidden during installation. This was done by an extra step in the track that the hook glides in. This can be viewed in figure 3.15 on the next page. However, if this concept actually works in reality had not been fully tested and would therefore be further investigated. The guide-hook also needed further development to make sure that it was fully functional as both a hook and a guide.

The design team chose to consider this further development as one concept that should be evaluated when choosing concept. But, the first step was to investigate if this kind of design is even strong enough to withstand the forces of 200 N, which is a demand for the guides. To find out, a FEM-analysis was made by G. Holstein. The detailed design and the result from the FEM-analysis is shown in the sections below.

3.4.1 **Design**

Figure 3.15 on the next page shows the design that an IKEA Components co-worker has been working on. As being mentioned above, this idea originates from the soft closing displayed in figure 3.13. Some smaller changes has been made for this concept. As can be seen, the track where the guide-hook slides is changed. A two-step track has been added for the guide-hook to be completely hidden during installation of the door. This is the function that solves the problem that the hook needs to be hidden for the mounting of the Mackapär doors to be possible. The original hook has been slightly modified in order to work more as a guide-hook. It has not, however, been completely converted into a guide-hook since the top of the hook has not been modified for the purpose of gliding smoothly and silently in the rail. A handle has been added to it so that the user can drag the guide-hook to its hidden position when it is necessary.

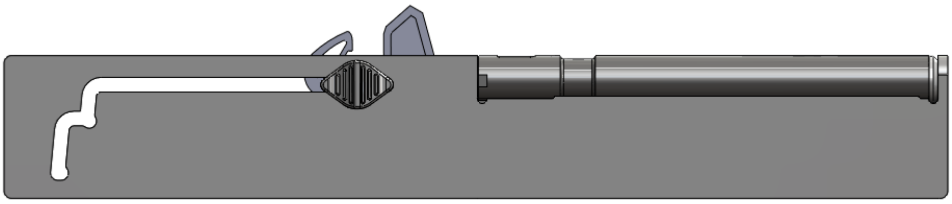

Figure 3.15: The existing idea from IKEA Components.

3.4.2 FEM analysis

As is described above, the guides in Mackapär, as it is designed today, needs to withstand a force of 200 N. To find out whether or not this concept is strong enough for this, a FEM-analysis was done. This was done by Gustav Holstein and through the LS DYNA. According to N. Persson, this kind of analysis is usually done at IKEA Components performing 4 different load cases. These load cases are:

- Pushing the door with 200 N from the **outside** of the cabinet at the top corner, directly under the guide.

- Pushing the door with 200 N from the **inside** of the cabinet at the top corner, directly under the guide.
- Pushing the door with 200 N from the **outside** of the cabinet at the middle of the cabinet, straight below where the guides act
- Pushing the door with 200 N from the **inside** of the cabinet at the middle of the cabinet, straight below where the guides act

The red crosses in figure 3.16 illustrate the top and the middle position on which the load is applied. The analysis was done through investigating these four load cases with the guide-hook being in two different positions: with the hook being tilted (see figure 3.17) and with the hook in the middle of the track (see figure 3.18). This because the hook has to be able to handle the loads both when the door is closed and the hook is up (figure 3.18) and when the door is open and the hook is tilted (figure 3.17) How to perform the analysis was decided through consultation with N. Persson and G. Holstein.

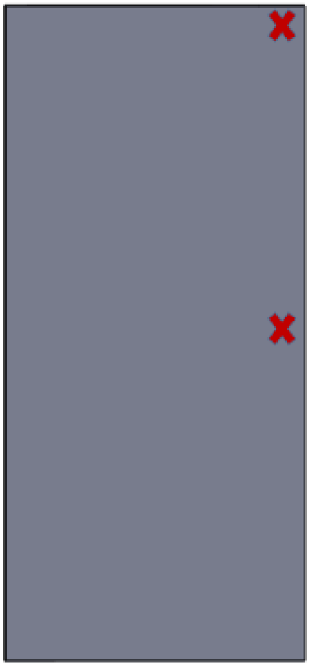

Figure 3.16: The load cases marked out on the door

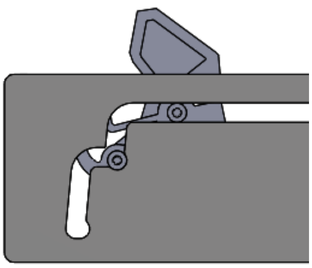

Figure 3.17: The hook when tilted.

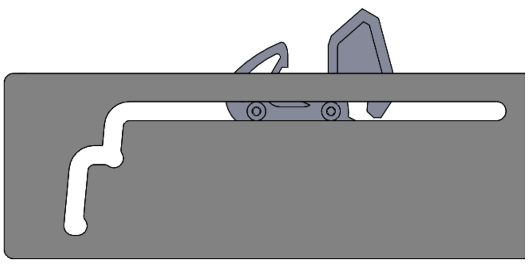

Figure 3.18: The hook when it is in the middle of the track.

Figure 3.19 on the next page show the result from the analysis with the guide-hook in the middle of the track. Figure 3.20 shows the result from the analysis with the guide-hook being tilted. In the figures the coloured images of the hook display the deformation of the hook in millimetres, during the load. The grafts show the forces that the hook is exposed to during the tests. The vertical axis shown the forces in Newton. As can see in both cases, the guide-hook is barely affected by these loads and the maximum force before the guide-hook breaks is almost the double of the requirement. It is safe to say that the design of this guide-hook, with the same material as the original design has, it is strong enough to replace one of the guides in Mackapär.

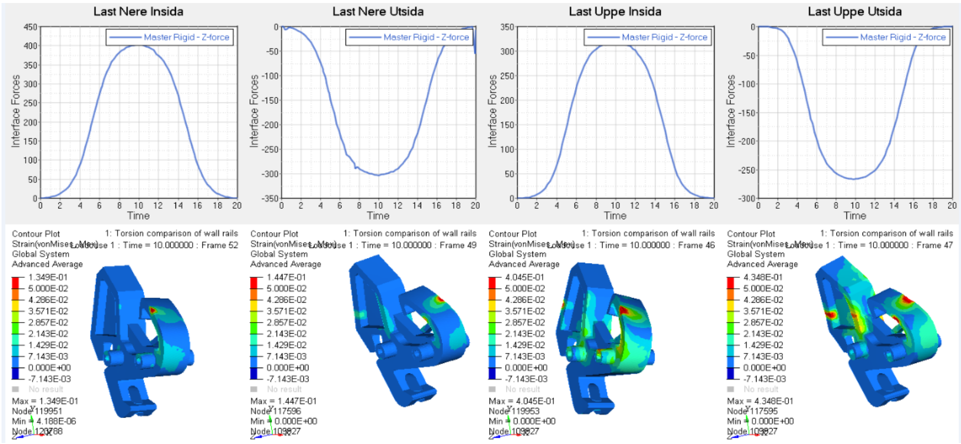

Figure 3.19: FEM results for hook in the middle of tracks.

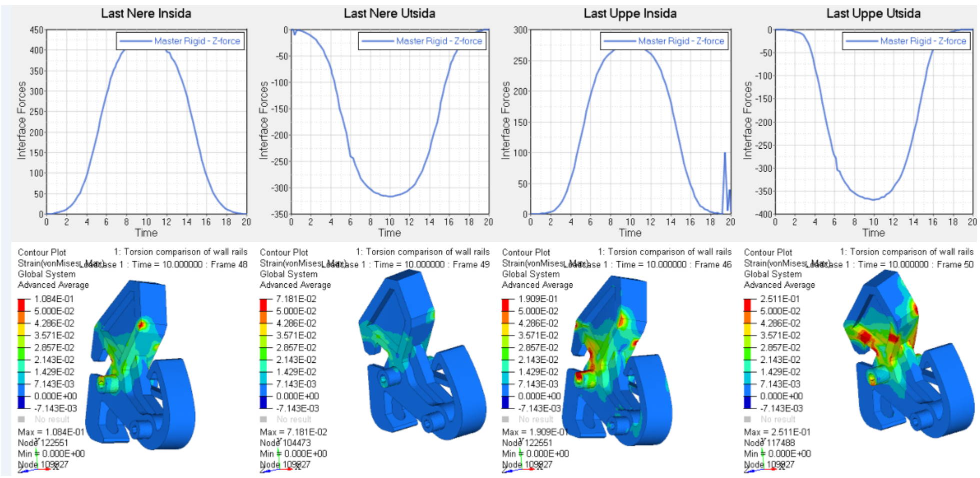

Figure 3.20: FEM results for tilted hook.

3.5 Democratic design

At IKEA, the product development is done through trying to achieve the best of five dimensions: Form, Function, Low Price, Sustainability and Quality [7]. Except for these five, the dimension “safety” is extremely important, it is not included in this model since it is a dimension that has to be fulfilled, always. In this thesis, it is desirable to find a good balance between these dimensions when developing the solution. Figure 3.21 below shows the model.

Figure 3.21: The five dimensions of product development at IKEA [7].

4 Establish target specifications

This section presents the product specifications that were established from the information gathered from IKEA. They were used to make sure that the final product would fulfil the requirements.

4.1 Method

The model of establishing product specifications is stated in Ulrich & Eppinger. Using to that method, the following step were done [4, p. 94]:

1. Prepare a list over qualities
2. Collect information about competitors’ solutions
3. Set ideal and marginal values

The majority of the specifications were collected from IKEA Components in the beginning of the project. Some of them could be used as specifications directly and some of them were demands and wishes interpreted into specifications. Throughout the project, more sufficient specifications were discovered and added by the design team. The importance factors were decided partially through discussions co-workers from IKEA Components but also through estimation by the design team.

4.2 Product specifications

In table 4.1, all the specifications that were given and those that were found throughout the project can be seen. The specifications with the least importance has factor 1 and the ones that are nearly non-negotiable has factor 5. In the cases where values are stated, the values are given from IKEA Components co-workers and pre decided. Some of these specifications are difficult to understand just by looking at this table. Therefore, an explanation for every criteria is listed in appendix C.

Table 4.1: Product specifications

No.	Criteria	Importance factor (1-5)	Unit	Margin value	Ideal value
1	Intuitive for the user	3	Subj.	-	-
2	Easy to install	4	Subj.	-	-
3	Material cost	3	SEK	1	0,825
4	Ergonomic when installing	3	Subj.	-	-
5	Few changes on existing doors	2	No.	Yes	No
6	No loose pieces to assemble	4	Binary	Yes	Yes
7	Few tools needed when installing	1	No.	1	0
8	Easy to dismount	3	Binary	Yes	Yes
9	Symmetric SCG	5	Binary	Yes	Yes
10	Safety	5	Subj.	-	-
11	Robustness	2	Subj.	-	-
12	Total cost	3	SEK	9,770	<9,770
13	Manage height adjustment	5	mm	±2	±2
14	Material choice – gliding noise	4	Binary	Low noise	No noise
15	Act as guide and soft closing	5	Binary	Yes	Yes
16	Depth limitations	5	mm	12	<12
17	Slam shut test	5	No. cycles	10 times 4 kg	10 times 4 kg
18	Durability	5	No. cycles	20000	20000
19	Made in plastic	2	Binary	No	Yes
20	Pressure force from outside	5	N	200	200
21	Pressure force from inside	5	N	200	200
22	Intuitive for user	3	Subj.	-	-
23	Not visible in normal use	5	Binary	Yes	Yes
24	Dismountable	5	Binary	Yes	Yes

5 Generate product concepts

This section contains the concept development phase during which the ideas for solutions were generated. Brainstorming, benchmarking and decompositions of the main problem is presented.

5.1 Method

All of the steps in this section were performed in parallel, since one step could lead to another step being developed or to a step having to be remade. For example, the benchmarking could give new ideas for a new brainstorming session. The concept generation was done through several brainstorming sessions and division of the problem into subproblems in parallel with patent search and benchmarking.

5.1.1 **Brainstorming**

The first brainstorming session was made separately by the members of the design team, without affecting one another. All of the ideas found were taken into consideration without putting any opinion on whether or not they seemed realistic. While performing the first idea generating process, the partial solutions provided by IKEA Components were first disregarded to not restrict the process. The design team made that decision so that the existing solution would not limit the creative thinking during the brainstorming.

After the separate brainstorming, the team got together, presented the ideas and from that a second brainstorming session was made. The second session was performed together in the team and more detailed concepts were brought forward. Those concepts and ideas were presented to C. Petersson and P. Lindberg. Together with them, the concepts were developed and new ideas were added. Some of the ideas were also ruled out for different reasons. All the ideas and the reasons for discarding some of them can be seen in the table in appendix B. The following brainstorming sessions were done in a more structured manner after the problem had been clarified through division of sub problems.

5.1.2 Division into subproblems

After some brainstorming sessions, it was made clear that the problem actually contains several smaller problems depending on each other. In order to simplify the concept generation phase, the main problem was established and divided into subproblems for further clarification. The division into subproblems was a way of clarifying the many small functions that need to be a part of the big solution. This approach was made only for clarification of the problem and its challenges, not for solving one sub problem at a time. The reason for this is that many sub problems are connected, and therefore difficult to solve individually. Within the categories, parts of the project were divided up and the problems/relations between them was defined. Section 5.2 describe the subproblems and what requirements that have to be fulfilled between the parts. Since the division into subproblems gave a deeper understanding of the problem, it facilitated the following brainstorming sessions.

5.1.3 Benchmarking

The benchmarking was done both internally within IKEA and IKEA Components and externally when searching through competitors' solutions.

The internal benchmarking began with walking around in an IKEA warehouse. During this, different types of storage units and soft closings were found and investigated. In order to gain understanding in the installation of Mackapär, the team actually bought one and installed it. Continuously, having contact with IKEA Components co-workers gave information about other products or solutions that might be relevant to investigate. The information received was mainly CAD-files of the products and solutions.

The external benchmarking was made through internet searching in order to find other storage units that has a soft closing and/or guides. Different installing videos and manuals were investigated in order to find similar solutions. Moreover, a benchmarking session was made where the team walked around in different furniture stores which were considered to be competitors. During this session, different storage units with their soft closing or guides were investigated.

5.1.4 Patent search

The patent search is a big part of the product development at IKEA Components according to N. Persson and was therefore important to do while choosing concept. As the patent search should be based on the concepts and ideas, this was made after generating ideas.

Through consultation with Carl Ervér, an intellectual property leader at IKEA, the way of doing the patent search was established. The design team presented the different ideas and concepts that had been developed to C. Ervér in order to find the most suitable way for the patent search to be done. There were different kinds of approaches that could be used; using search words or using citations. In patent applications, citations are used as reference to previous patents. Since this thesis regards a product that is commonly produced by many different actors, C. Ervér predicted that search words would be difficult for unexperienced patent searchers. Moreover, there is already a patent for the solution that IKEA had come up with. Therefore, it was decided to work from the existing patent of the prototype and work through its citations to find related patents.

A proper patent search that firmly concludes if a new product infringes on an existing patent or not, is usually very complex and done by experts. The result of the search in this thesis will therefore only be suggestions of patents that might be relevant to investigate further. Those suggestion are patents that may have similar attributes to any parts of the concept ideas or are relevant in other manners. Finally, according to C. Ervér, the design team should not make any conclusive statements in whether or not the concept suggestions are infringing on the presented patents. This because those kinds of statements can only be made by a patent office.

5.2 Establish the problem

Before starting the development process, it was important to establish the actual problem. The research phase gave a lot of information, but to be able to start the process of coming up with solutions, the problem had to be clarified further and divided into subproblems. The problem was summarised into a general main problem: to replace one of the guides on the inside standing door with a device that works both as a guide and a soft closing, whilst still allowing for easy mounting, dismounting and without loss of stability. This meant that the qualities of both the guide today and the existing soft closing had to be integrated into the new device.

5.2.1 Subproblems

The problem was divided into subproblems to make it as clear as possible. The subproblems were also sorted after which device they related to, the guide or the soft closing. The subproblems occurred during the brainstorming why the definition of the subproblems was made by the design team. Table 5.1 on the next page shows the interaction between parts and where problems could arise.

Table 5.1: Table showing the different subproblems.

Guide	Part 1	Part 2
Subproblem 1	Guide	Rail
Soft closing		
Subproblem 2	Hook	Piston
Subproblem 3	Hook	Spring
Subproblem 4	Hook	Handle
Subproblem 5	Hook	Track
Subproblem 6	Soft closing base	Cabinet door
Subproblem 7	Activator	Hook

5.2.2 Subproblem 1 – Force, noise and height adjustment

As shown in the Research section, the existing guide is placed in the rail in the top of the cabinet when mounted (see figure 5.1 below). When wanting to replace one of the guides with a soft closing, some problems arise.

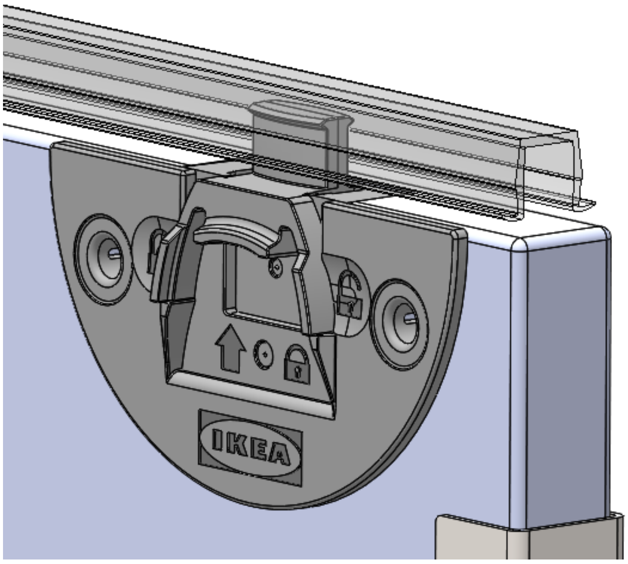

Figure 5.1: Guide mounted in the cabinet

The guide that is used today is designed to glide smoothly in the top rail and cause as little noise as possible when doing so. This means that the new solution has to comply with those conditions too. It is also designed to handle the forces from pushing the door in both the inward and outward direction (z-direction). These are qualities that the new solution must also possess.

As described in section 3.2.1.2, the wheels are adjustable in the y-direction. This means that the new device has to be able to handle a possible height change of two millimetres in both directions. If it does not, the guide would leave the rail and the door would fall out when the wheels are in their lowest position and the guide would hit the roof of the rail when it is in its highest position.

5.2.3 **Subproblem 2 – Pin movement**

When wanting to hide the new device completely to enable the mounting, a problem with the piston pin presents itself. To be able to tilt the hook today, when the activator is released from the hook, the pin and hook is designed so that when the hook is tilted, it simply tilts away from the pin, leaving it in place. The hook in both positions are shown in figures 5.2 and 5.3. For the new solution the device has to disappear completely to enable the mounting/dismounting, like the guide does today, leading to a lot bigger movement. Since the pin cannot be bent, it then has to be disconnected all together from the hook before it can be moved in a more extensive way. If a solution can be found where the hook moves but still allows the pin to stay it its place it would also work.

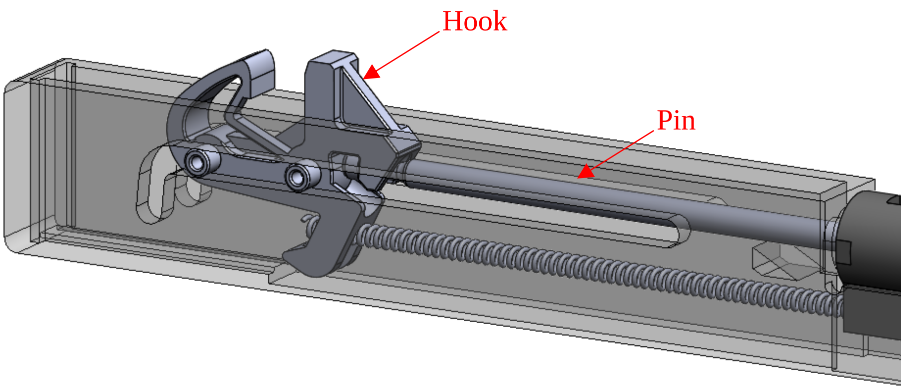

Figure 5.2: The hook in its horizontal position

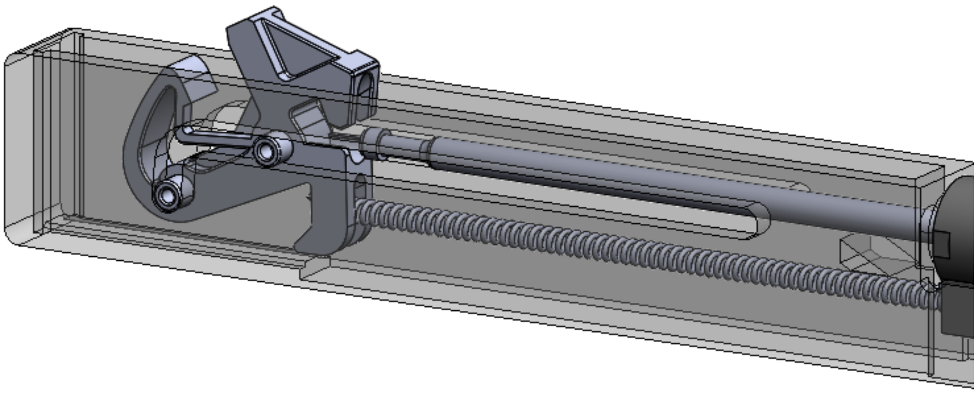

Figure 5.3: The hook in its tilted position

5.2.4 **Subproblem 3 – Spring movement**

The spring also creates problems for a larger movement of the hook. Its placement today is shown in figure 5.4 below. Depending on how the hook will be moved, it could also be an obstruction. The good news about the spring however is that it is, clearly, flexible. Meaning that as long as it is not in the way of actual material, it is a little more forgiving of movement than the piston pin.

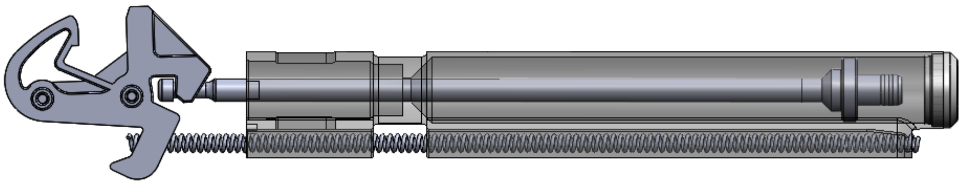

Figure 5.4: The connection between piston, hook and spring

5.2.5 **Subproblem 4 – Moving hook**

This is a problem that comes from the demand that the new solution has to have a mounting/dismounting feature. When looking at the concept given from IKEA Components, the user should move the hook out of the way for when the door is mounted/dismounted. In order to move the hook manually, some kind of handle must be created to perform the movement of the hook. This handle has to be constructed in a way that it can accomplish three things. First, that it is ergonomic and easy to handle for the user. Second, that it has to be strong enough so that the user can pull the hook even though it is being pulled in the other direction by the spring. And lastly that whilst fulfilling the first two conditions it still cannot be too big since the two doors have to be able to pass by each other without complications. In figure 5.5 below it can be view where this handle would have to be fastened to be able to move the hook.

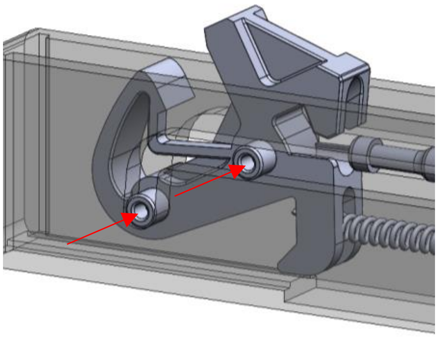

Figure 5.5: Where the handle could be placed

5.2.6 **Subproblem 5 – Track design**

This is a problem that changes a bit depending of if the guide is included in the hook or not. In the original soft closing, with the guide not included, the hook is guided by the tracks on the sides of the soft closing. The importance of the track is that it has to be easy for the user to move the hook along it. The construction of the tracks depend entirely on the ideas of the new solutions. The original tracks in the existing version is shown in figure 5.2 above, amongst others.

5.2.7 **Subproblem 6 - Installation**

This subproblem concerns the installation of the entire soft closing system onto the door. For this problem there are two important factors. First, the soft closing has to be mounted in a way that it can withstand all of the forces that arise during the product testing. Second, that it cannot be visible when the cabinet is fully assembled. How the base is fastened can vary depending on the new solutions. For more detailed picture of how the soft closing today is mounted in Malsjö, view figure 3.11 in section 3.3.1 above.

5.2.8 **Subproblem 7 – Activator design**

The last subproblem concerns the activator that catches the hook/is caught by the hook, depending on which soft closing solution is used. When the door approaches the edge of the cabinet, this is what activates the soft closing. For the combination of the soft closing and the guide it is important that the activator still works in regards of the soft closing mechanism, as well as not being a hindrance for the guide. The problem of the actual appearance of the activator was deemed to have less significance during the initial concept development, since the concepts were not fully developed. It was therefore decided that the design of activator was to be determined during the further development. For a closer look at how the activator in Malsjö works today, view figure 3.13 in section 3.3.2 above.

5.3 Benchmarking

Benchmarking has been done both within IKEA, IKEA Components and other solutions provided by competitors for similar products. Since this project concerns sliding doors, it has been decided to focus the benchmarking amongst the storage units that has sliding doors in their design. From the benchmarking, no solution for a combined guide and soft closing was found. However, the benchmarking was in some case used as inspiration for the concept generation.

5.3.1 **Internal benchmarking**

The internal benchmarking aimed to find products at IKEA that are similar to Mackapär and the mechanisms within it.

5.3.1.1 Storage units

IKEA produce many storage units with slightly different solutions [8]. In this thesis, the design team decided to categorize these after how the doors are mounted into the cabinets/wardrobes. The installation and the soft closing mechanisms are affected by this, why this categorization seemed relevant. The most relevant storage units, according to the design team, were investigated further and are presented in the sections below.

The different kinds of storage units relevant to this thesis that IKEA provides are:

- Standing sliding doors in which the doors are covered by the cabinet on each side of the door. They are standing in the cabinet on wheels, mounted through placing the wheels on the bottom first, and then tilting the doors into their upright position in the cabinet before fastening it with guides. This is, as described in section 3, the kind that Mackapär is and also Malsjö which is described further on.

- Doors that are mounted through “hanging” the doors on top of the roof of the cabinet on which it slides on wheels. The most common one that is Pax, which is described further in the next section.
- Sliding doors that are hanging on a rail on the inside of the cabinet in which it slides on wheels. The most common one is Galant which is described further in section 5.3.1.3 [9, 10].

5.3.1.2 Pax

Pax is a storage unit with hanging sliding doors, which are mounted through hanging the door onto the cabinet through hooks [11]. Figure 5.6 below shows how the doors are installed.

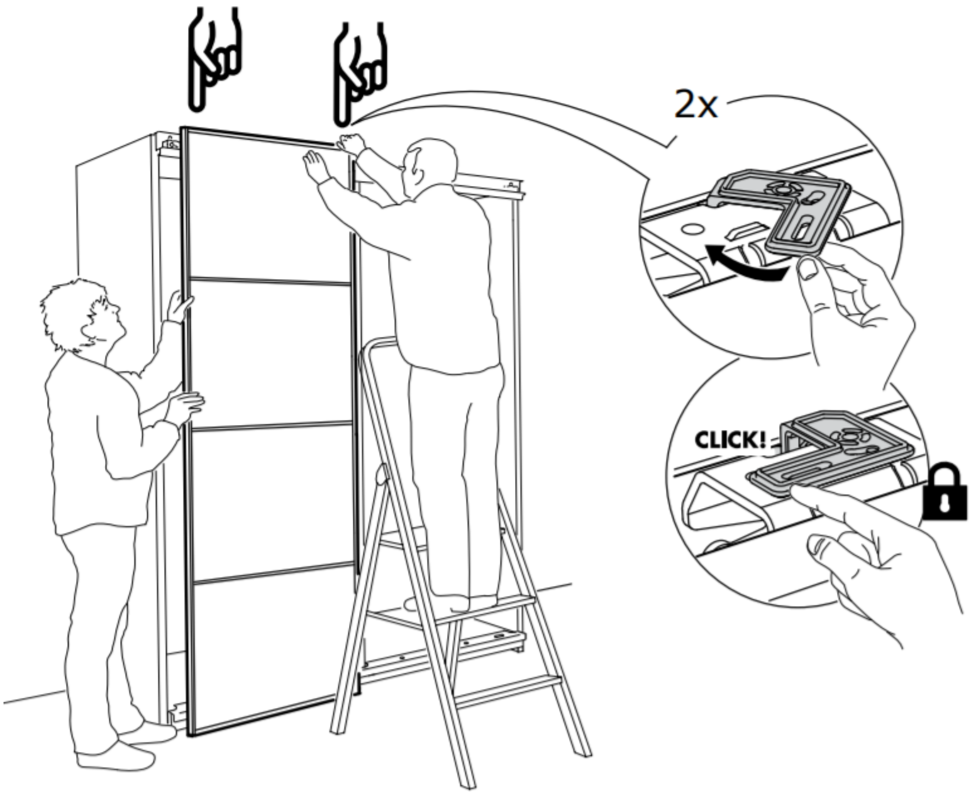

Figure 5.6: How doors in Pax are installed [11].

5.3.1.2.1 Soft closing in Pax

A soft closing system is not included in Pax but can be bought separately. In Pax, a soft closing system is designed to be mounted on the inside of the cabinet roof, "lying down" [12]. That means that it is installed into the cabinet and not the door as is the thought for the solution in this thesis. Figure 5.7 below shows the design of the soft closing that can be added to Pax.

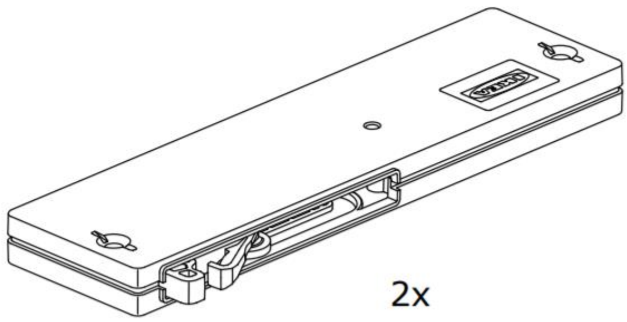

Figure 5.7: The soft closing used in Pax [12].

Since this soft closing system is installed on the inside of the cabinet's roof and the doors are hanging, it does not have the problems, during installation, that need to be solved in this thesis and is therefore difficult to apply.

5.3.1.3 Galant

Galant is a storage unit with hanging doors, which are mounted inside of the cabinet, hanging on top of a rail [13]. In figure 5.8 on the next page it is shown how the doors on Galant look like and how they are installed.

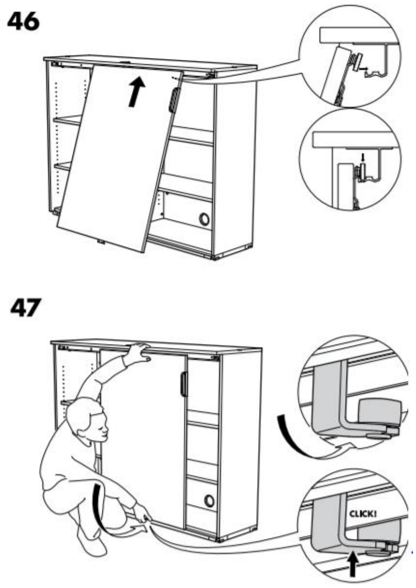

Figure 5.8: How the doors in Galant are installed [13].

As can be seen, Galant is mounted in the reversed way compared to Mackapär that is through placing the top first. Even though it is mounted on the inside of the cabinet, it is guided by the wheels on which the doors are hanging. This also makes it unimportant for solving the main problem in this thesis.

5.3.1.3.1 Soft closing in Galant

In Galant, a soft closing system mounted behind the top rails, "standing", is used [13]. For this furniture a soft closing system is included when purchasing it. Figure 5.9 below shows the design of a soft closing in Galant.

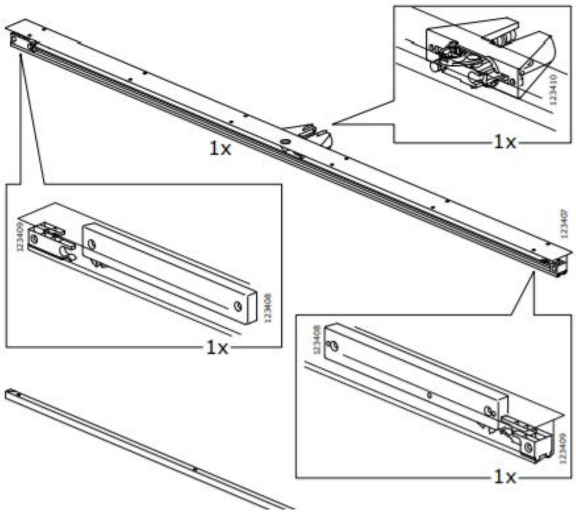

Figure 5.9: Soft closing used in Galant [13].

Figure 5.10 below shows the placement and the design of the activator in Galant [13]. The activator is placed on the door and the soft closing base is placed in the cabinet, which also makes these solutions non-applicable in the solution needed for this thesis.

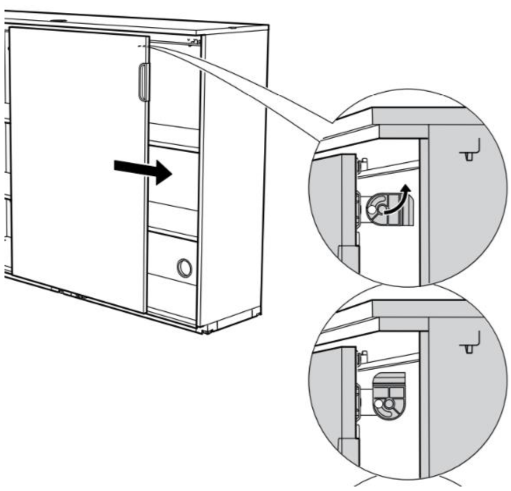

Figure 5.10: The activator in Galant [13].

5.3.1.4 Malsjö

Malsjö is a storage unit with standing sliding doors, similar to Mackapär. The doors in Malsjö are also installed through placing the wheels at the bottom and then pushing guides up into the top rail (see figure 5.11 below) [14]. The difference is that Malsjö today has a soft closing system included, placed at the bottom of the doors, and therefore has no problem being mounted with the soft closing installed.

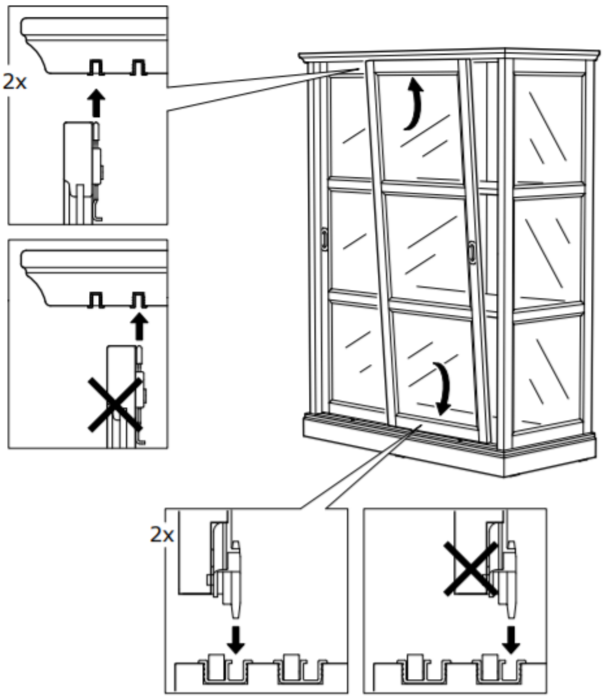

Figure 5.11: Installation of doors in Malsjö [14].

5.3.1.4.1 Soft closing in Malsjö

It is the soft closing used in Malsjö that is used as a reference model for the solution in this thesis. It is, as described above, installed at the bottom of the doors which is why the hook does not need to be hidden (see figure 5.12 on the next page) [14]. Since this thesis regards a soft closing being combined with a guide in Mackapär, which is placed at the top of the cabinet, this way of installing the soft closing is not an option.

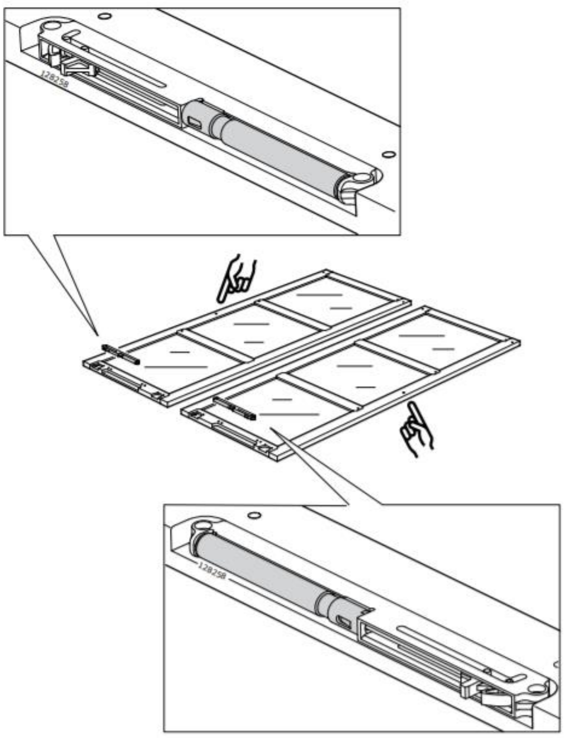

Figure 5.12: Soft closing in Malsjö. [14]

5.3.2 External benchmarking

5.3.2.1 Competitors

IKEA is not alone with providing storing solutions nor is IKEA Components the only company working with these kinds of mechanisms and fittings. Therefore, it was necessary to investigate how other furniture companies solves the same problems. Mio, JYSK, KVIK and Häfele are companies that were considered to be competitors to IKEA and IKEA Components and might have similar solutions. Mio, JYSK and KVIK are companies providing complete furniture solutions. These companies had storage units with sliding doors and soft closing systems in their range [15, 16, 17]. There is a possibility that they use subcontractors for their fittings and soft closing systems just like IKEA does with IKEA Components. Nevertheless, the design team could not find information about this and therefore will these companies continue to be considered as the competitors in this thesis.

Other companies were also investigated, but no relevant information was found and will therefore not be presented.

The Internet search gave some results, in those cases where the installation of different storage unit was thoroughly explained, that may be useful in this thesis. In general it was quite easy to find how other companies using sliding doors have made their solutions, at least the design of the soft closing. This was found through looking in their installation manuals. However, there are not that many companies that combines the guides with the soft closing and in those cases where they did, the mounting of the doors was done differently. Nevertheless, this still resulted in generation of ideas that could be useful in this project. In some cases, it also gave the insight that some of the ideas were not possible for different reasons.

During the visits to the stores, it was noticed that none of these companies, in the products that were available in stores, are using "inside standing sliding doors". Either the sliding doors were hanging on a rail or the "inside" solutions where hinge doors. Since the doors were in some way installed differently in all of the storage units found during the benchmarking, no solution where the guide is combined with the soft closing was found. The examples presented below are the storage units that were closest to the solution in this thesis.

5.3.2.1.1 Mio

Mio was one of the physical stores that was visited and the design team estimate them to be the largest Swedish competitor to IKEA. During the visit to Mio, no storage units with standing sliding doors was found. All of their sliding doors were hanging doors. Figure 5.14 on the next page shows how the doors are mounted and figure 5.13 to the right shows their version of a guide. As can be seen, the doors are mounted in similar way as Mackapär, with the bottom of the door being place first and then it is tilted in, but Mio's version hangs on wheels, the same principle as Galant. The guides are placed on top of the doors, which is not possible in Mackapär since the cabinet is in the way. Furthermore, the soft closing is placed in the cabinet and not on the door [18]. The solution used in Mio is therefore not applicable on Mackapär.

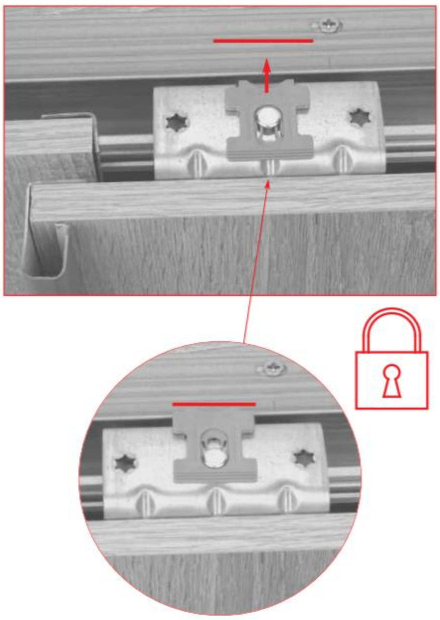

Figure 5.13: Soft closing on a unit at Mio [18].

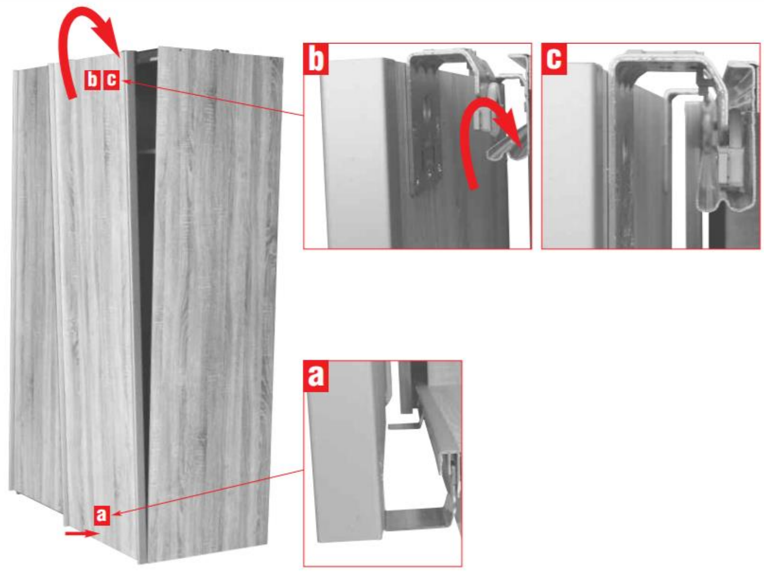

Figure 5.14: The mounting of the doors for a Mio cabinet.

5.3.2.1.2 Jysk

At Jysk, there were sliding hanging doors very similar to the ones at Mio and they are therefore not described further. There were also storage units with standing sliding doors, similar to Mackapär. One of them is shown in figure 5.15 above and is installed the exact same way as Mackapär but with a slightly different guide. This one does not come with a soft closing and therefore has no solution that can be used in this thesis [19, 20].

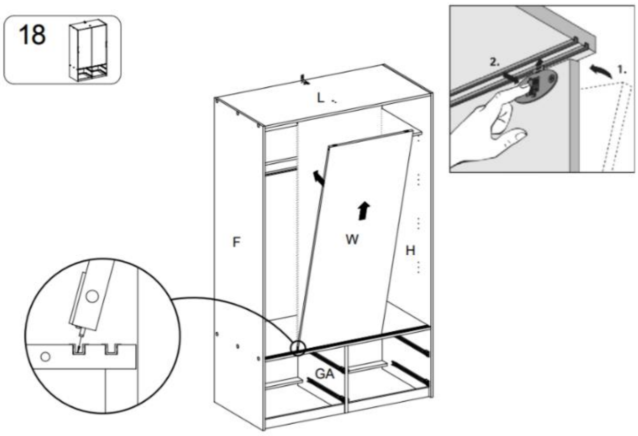

Figure 5.15: How doors in a unit at Jysk is installed [20].

5.3.2.1.3 Kvik

Kvik have a few solutions for sliding doors. The solution with a standing sliding door is presented in figure 5.16 below. As it can be seen in the picture, it is installed by placing the top of the door first and then placing the bottom, similar to Galant, but it is a standing sliding door just like Malsjö and Mackapär. After this the height of the door is adjusted by tightening or loosening, see figure 5.17. The door is held at its place by the support rails in which the door is placed [21]. The way of mounting the doors is different to Mackapär and therefore not useful in this thesis.

Figure 5.16: How a door in a unit at Kvik is installed [21].

Figure 5.17: Fastening the door [21].

5.3.2.1.4 Häfele

Häfele is a company which is similar to IKEA Components since they specialize in furniture fittings. There are different kinds of solutions for soft closing that Häfele provides. In figure 5.18 to the right, is a soft closing that works in a similar way to the one at IKEA apart from the base, more specifically the track where the hook moves, that looks slightly different [22].

Figure 5.18: A soft closing made by Häfele [22].

5.4 Generation of ideas

A summary of all the ideas that were brought out from the brainstorming sessions as well as idea that where discovered during later further developments can be found in appendix B. Idea 1.1, called "two-step" is the given to the team from IKEA Components and it is described in research section 3.4 above. Shortly after the brainstorming a primary screening session was held where the ideas that could be discarded right away were removed. This session was held by the design team together with C. Petersson and Lindberg. The ideas were evaluated based on intuition and pros and cons to restrict the amount of ideas and limit the final evaluation the most relevant and realistic ideas. Which ideas that were discarded and why can also be found in appendix B.

5.4.1 **Promising ideas**

The ideas that were deemed to be suitable for further development are shown in this section. The generated ideas showed a clear pattern of three categories in which the ideas could be divided. The division is shown in table 5.2 and in the explanatory sections further on in the report (5.4.1.1-5.4.1.3). This categorisations facilitated the comparison and evaluation of concepts that are similar.

The table displays the discarded ideas as well as the promising to show which category they fall under. But for the explanatory sections, only the promising ideas are explained further. None of the ideas are fully functional solutions, they need to be combined in order to create a full concept. Each category from 1-8 (with subcategories like 1.1, 2.1…) represent a different kind of solution. Compilations of these ideas can be found in section 5.4.2 below.

Table 5.2: Categorisation of the ideas.

Guide included in the hook	**External guide integrated in the soft closing**	**Moving the actual soft closing base**
	Promising ideas	
1.1 Two-step	4.1 Separate Guide 1	8.1 Movable Base 1
1.2 Guide-hook	4.4 Separate Guide 4	8.3 Movable Base 3
1.3 Side-hook	4.5 Separate Guide 5	8.4 Movable Base 4
2.1 U-track		8.5 Movable Base 5
9.1 First Handle		
	Discarded ideas	
3.1 Inside Track	4.2 Separate Guide 2	8.2 Movable Base 2
5.1 Foldable Hook 1	4.3 Separate Guide 3	
5.2 Foldable Hook 2	4.6 Separate Guide 6	
	7.1 Snap Guide Base 1	
	7.2 Snap Guide Base 2	
	7.3 Snap Guide 1	
	7.4 Snap Guide 2	

5.4.1.1 Guide included in the hook

These ideas have been categorised together because their solutions all consist of combining the guide part of the device and the hook. Making the guide and the hook the same component.

5.4.1.1.1 Two-step (1.1)

This concept is described in research section 3.4.

5.4.1.1.2 Guide-hook (1.2)

This is a solution that merges the already existing hook with the guide in the simplest way possible. It does not include a solution for the hiding of the guide-hook and will therefore have to be combined with a solution for that. The tip of the existing hook is simply redesigned to be able to run in the top rails with a similar tip that the guide has today. The solution can be viewed in figure 5.19 on the next page.

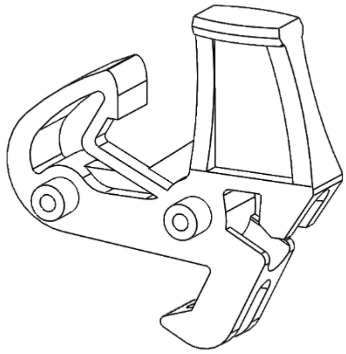

Figure 5.19: The Guide-hook solution

5.4.1.1.3 Side-hook (1.3)

This idea was created when the idea of a separate guide came up. Some of the separate guides relies on the fact that the hook is moved out of the way of the track. This has to be done since if the separate guide is placed in the same rail as the hook, the activator that is placed in the same rail will collide with the separate guide. This is the idea that was created to solve this problem. The idea is that the base is extended a little at the top and thereby hiding the hook. Half the hook has also been moved to the outside of the base. The part that holds the spring and rod is still placed on the inside of the base put the part that acts as the “hook” part, the part that catches the activator, is placed on the outside. This idea is shown in figure 5.20 and 5.21.

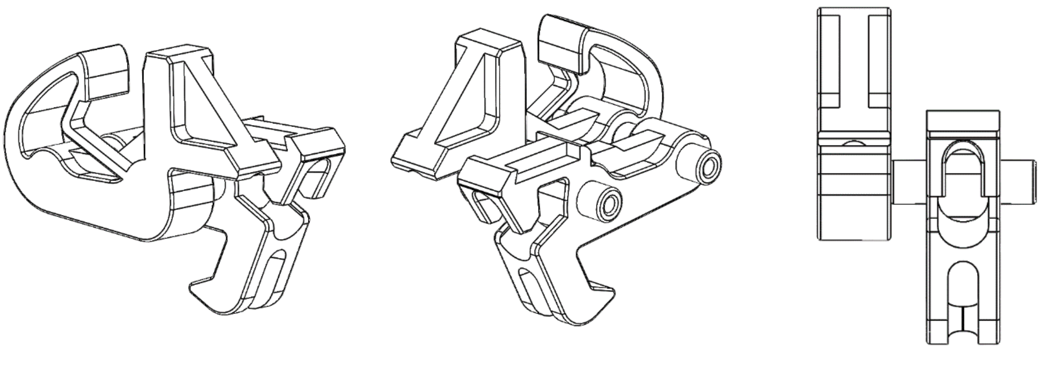

Figure 5.20: The Side-hook solution

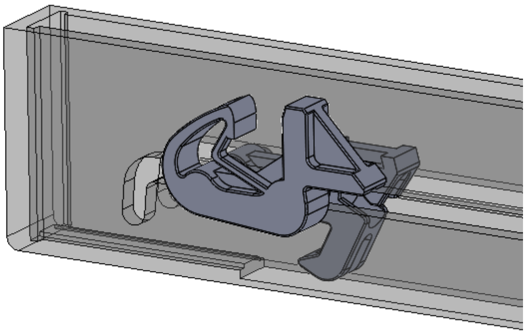

Figure 5.21: The side-hook in the tracks.

5.4.1.1.4 U-track (2.1)

This solution incorporates a way for the hook to be hidden. It does not, however, include the physical appearance of the hook/guide and is therefore a suitable combination for the guide-hook described in section 5.4.1.1.2 above. This solution is shown in figure 5.22 and 5.23.

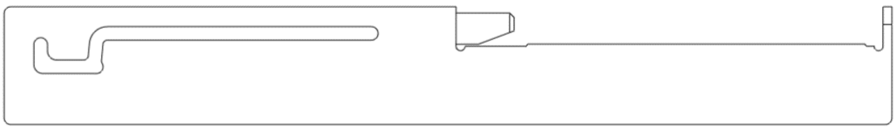

Figure 5.22: U-track solution.

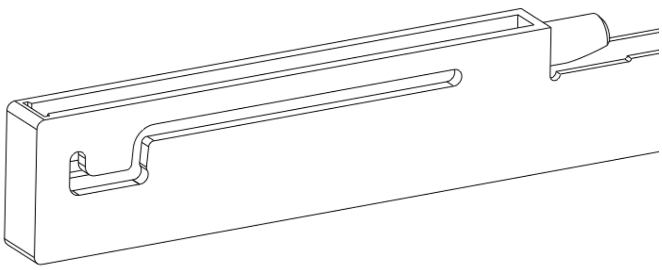

Figure 5.23: Close up on U-track.

5.4.1.1.5 First handle (9.1)

This handle was first created to have a handle that could be used for the testing of the concepts (see figure 5.24 below). The handle was considered to be less significant and the more detailed design was therefore postponed to the further development of the concepts. The handle was categorised in this section since the concepts that would be needing handles was the ideas with the guide included in the hook.

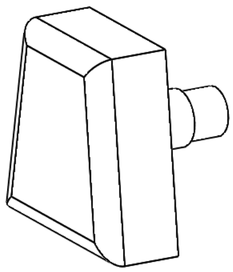

Figure 5.24: The first handle.

5.4.1.2 External guide integrated in the soft closing

These solutions are summarised by the idea that the guide is included in the soft closing in the sense that they are included in the same part and are mounted in one piece. However, the part that performs the tasks of the hook and the part that performs the tasks of the guide are not the same component on the soft closing. All of these solution also requires a solution for the hook to be hidden or otherwise moved out of the way for the mounting and dismounting. Some of them include this and some do not.

5.4.1.2.1 Separate Guide 1 (4.1)

This idea is a cylindrical guide which can be hidden by pinching the guide together at the bottom, making the clutches retract and the guide can be pulled down into its socket, hiding it during mounting and dismounting (see figure 5.25 and 5.26 below). The clutches then keep the guide in place when it is in the top position. The position of the guide on the soft closing is shown in figure 5.27 below.

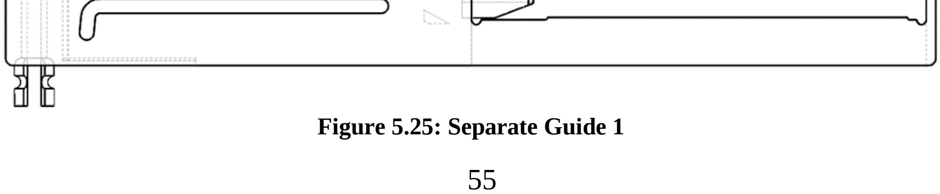

Figure 5.25: Separate Guide 1

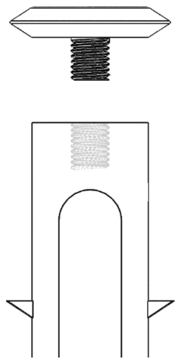

Figure 5.26: The attachment of the head of the guide.

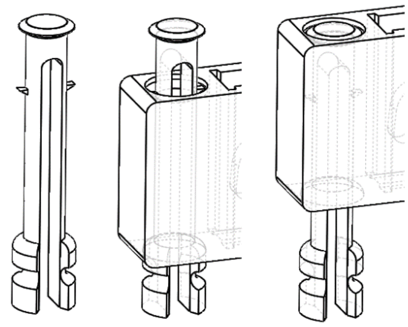

Figure 5.27: The guide part of the mechanism. Alone, extended and retracted.

5.4.1.2.2 Separate Guide 4 (4.4)

This solution uses a kind of snap fitting and the elastic ability of the plastic. It is a separate guide that is extended up into to rail. The placement on the entire soft closing is shown in figure 5.28 on the next page. Figure 5.29 shows how the guide is held in place on the inside of the soft closing and its position. For this solution the hook and the activator is placed away from the track. This so that the guide will not interfere with the activator that would otherwise have to be placed in the track. This part of the solution has not yet been solved but is meant to be solved in a further development if this idea was to be chosen.

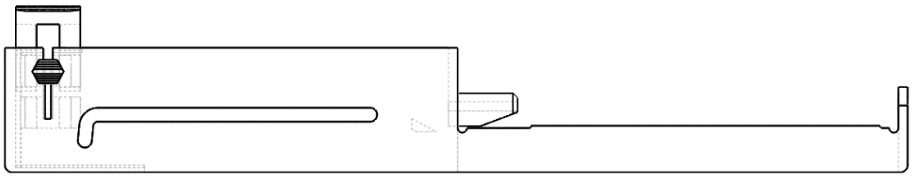

Figure 5.28: Separate Guide 4.

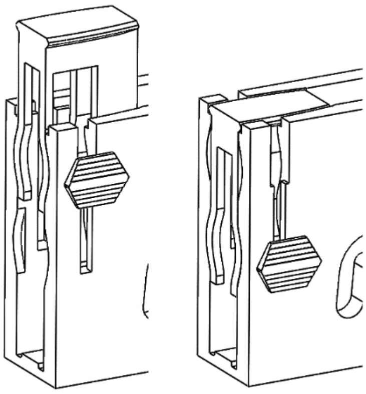

Figure 5.29: The guide parts positions with a section view.

5.4.1.2.3 Separate Guide 5 (4.5)

This solution is a similar to Separate Guide 4, but with the difference that the "legs" keeping the guide in its place is positioned on the outside of the soft closing instead of the inside (see figure 5.30 and 5.31). There are also just "legs" on one side. This solution work under the same assumption that the hook and the activator has been removed from the track and will, like solution 4.4 above, be solved in an eventual further development.

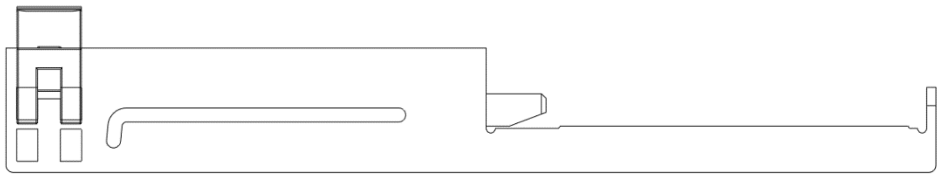

Figure 5.30: Separate Guide 5.

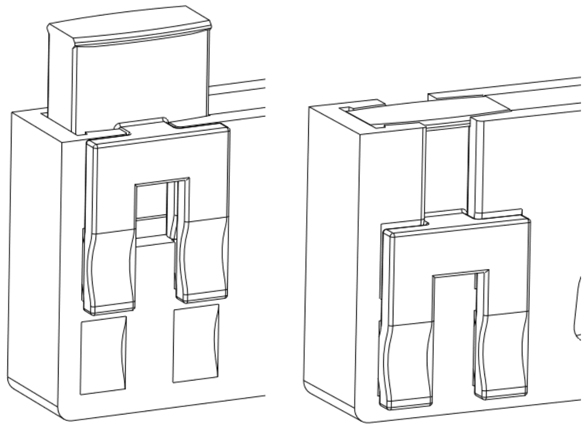

Figure 5.31: The guide parts positions in extended and retracted position.

5.4.1.3 Moving the actual soft closing base

These ideas have been gathered under the same category due to the fact that they all consist of moving the entire SCG for the hiding of the guide/hook, in some way. They are also similar in the way that none of them include any screws or other separate fastening for attaching them to the door. That is all included in the SCG.

5.4.1.3.1 Movable base 1 (8.1)

These ideas consist on the whole soft closing being moved when the hook needs to be moved out of the way. This means that everything on the soft closing can look the same apart from the part the keeps the soft closing base in place. This idea does however not include the solution for the hook to also function as a guide and would therefore have to be combined with, for example, solution 1.2 above. The solution also requires a little bit more complicated and specific milling of the door for it to work with the SCG. This solution can be viewed in figure 5.32 and 5.33 below and on the next page.

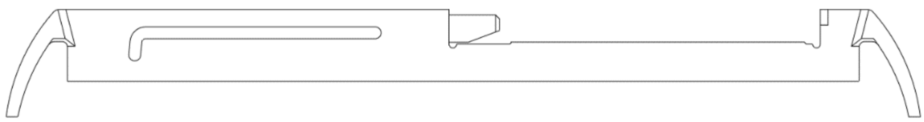

Figure 5.32: Movable base 1.

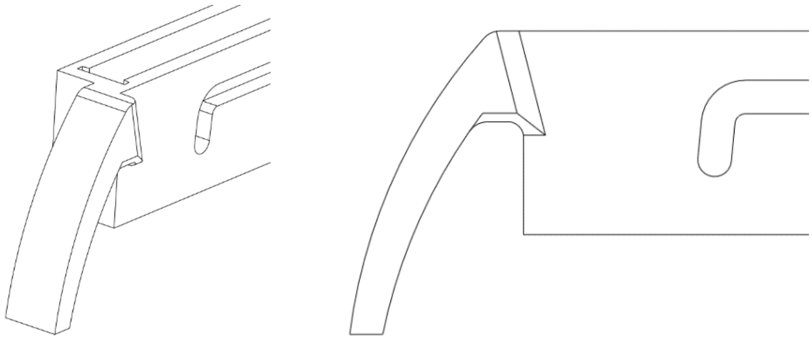

Figure 5.33: Close up in the snap fitting.

5.4.1.3.2 Movable base 3 (8.3)

This solution uses the kind of tracks that are displayed in figure 5.34 below. The figure shows an example and not the actual idea, this to clarify the mechanism and make it easier to understand the explanation of the idea that is made further on. The structure of the mechanism on the SCG base is shown in figure 5.35. This idea is based on the concept that the soft closing is placed in the tracks to then be able to be locked in two different positions in the vertical direction. The first being low enough that the hook is not in the way during the positioning of the door, it is then pushed up to a higher position, placing the hook in the track. To push the SCG upwards, the mechanism in figure 5.36 and 5.37 is used. It consist of two legs that have a hinge in the middle of the legs and the ends that are attached to the SCG base are also hinged. As shown in figure 5.36 the handles on the snap fitting is pushed together making the whole SCG base move upwards. When it is in the top position the snap fitting locks the SCG in place. To unlock them the handles are push in the

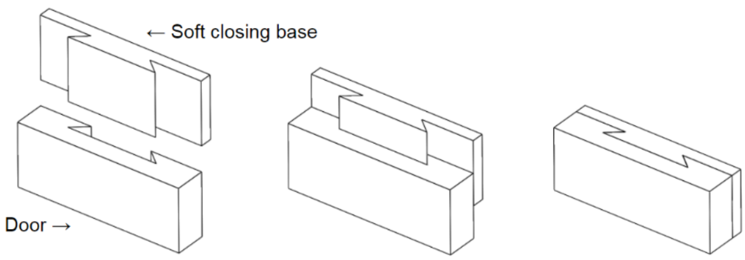

Figure 5.34: Example of the kind of fitting used for this solution and what parts that represent an example of the real parts.

opposite direction, unlocking the snap fitting. Like solution 8.1 above, this idea does not include the solution for the guide/hook.

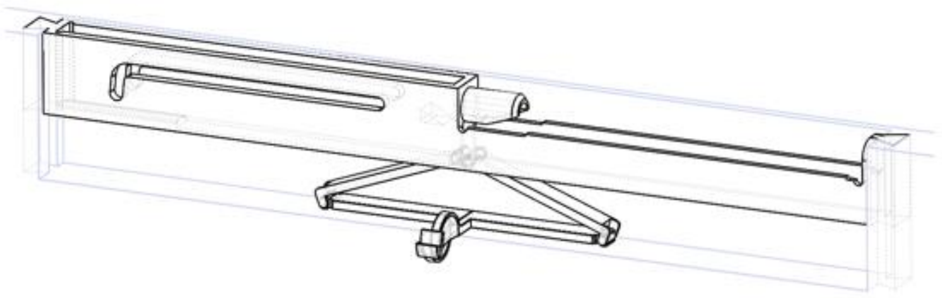

Figure 5.35: Movable base 3.

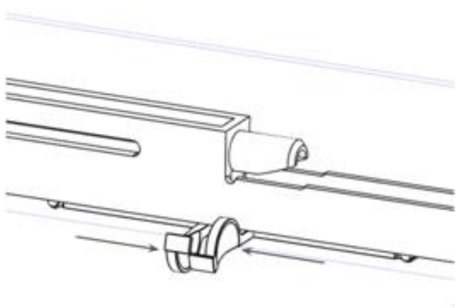

Figure 5.36: Close up on snap fitting when in hidden mode.

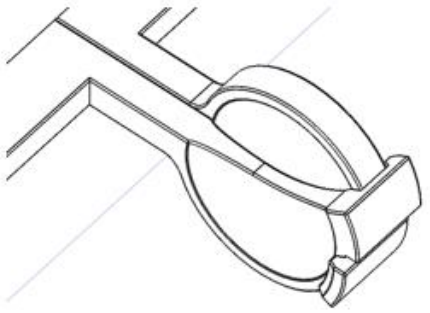

Figure 5.37: Close up of the actual snap fitting and its design.

5.4.1.3.3 Movable base 4 (8.4)

This solution is very similar to solution 8.3 but with a different locking mechanism for keeping the SCG in place. In this case the SCG is locked in place by two legs that automatically unfold when the SCG is lifted (se figure 5.38). The legs are fitted in the SCG base with a hinge. The hinges are designed so that the legs can be moved within a 90 degrees angle. The positions of the legs are shown in figures 5.39 and 5.40 on the next page. Like solutions 8.1 and 8.3 above, this idea does not include the solution for the guide/hook.

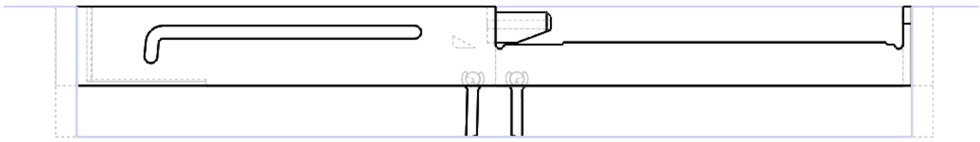

Figure 5.38: Movable base 4.

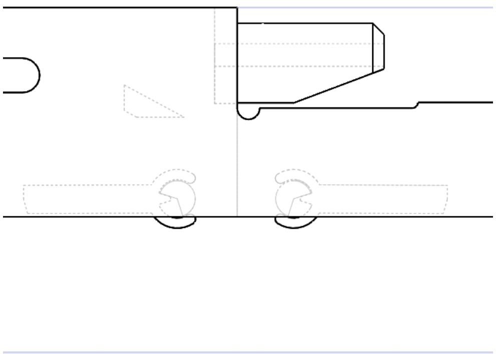

Figure 5.39: Close up, hidden mode.

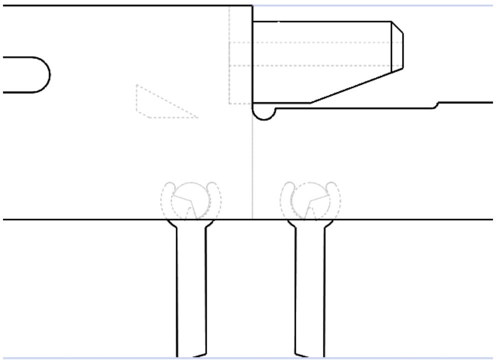

Figure 5.40: Close up, extended mode.

5.4.1.3.4 Movable base 5 (8.5)

This idea is SCG being fasted in a sort of case that is first fastened to the door and then the SCG is clicked in place. In one end the SCG is fastened with a snap fitting which it then rotates around. In the other end the soft closing can be fastened in two positions. Hidden and not hidden. To change position the lever is pushed in and the soft closing can be moved up or down. The idea is showed in figure 5.41 to the right and figures 5.42 and 5.43 below and on the next page.

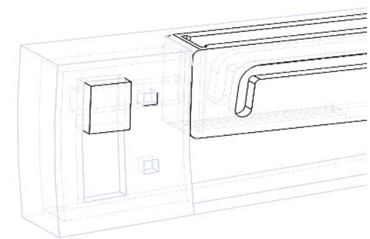

Figure 5.41: Movable base 5, close up.

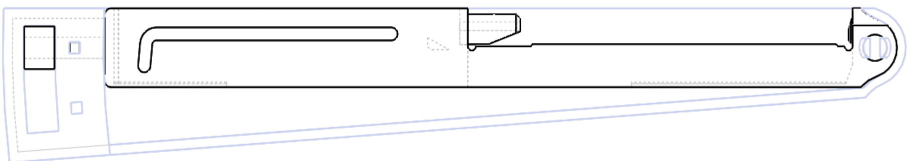

Figure 5.42: Movable base 5 in when none hidden.

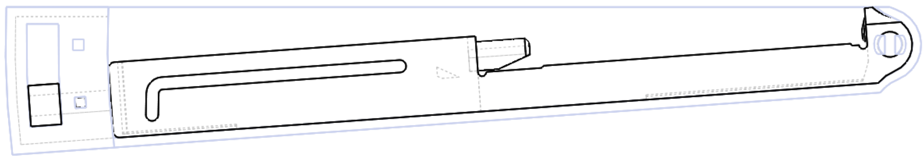

Figure 5.43: Movable base 5 when hidden.

5.4.2 Compilation of final concepts

The promising ideas presented above are in many cases separate ideas that need to work together in order to become a full concept. The ideas in section 5.4.1 where therefore merged to create full concepts that solve as many of the subproblems as possible. These can be seen below and the names of the concept is simply the alphabet in order.

5.4.2.1 Concept A

The first concept is the concept that was given to the team from IKEA in the beginning of the project together with idea 1.2. It is the two step solution combined with the Guide-hook. This concept is shown in figure 5.44 below.

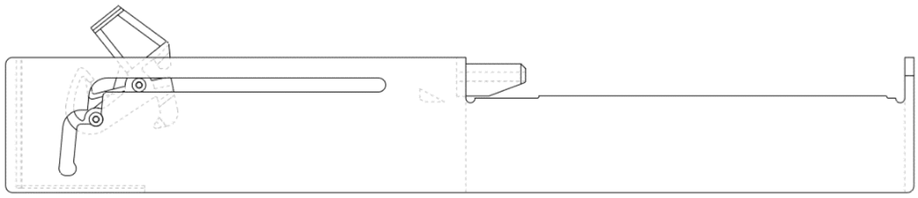

Figure 5.44: Concept A.

5.4.2.2 Concept B

Ideas 1.2, 2.1 and 9.1 were combined to create concept B, see figure 5.45 on the next page. For this concept the hook works as a guide and the track in the soft closing base is used to hide the hook during the assembly of the door. The handle is attached to the hook to be able to hide and unhide the hook when needed.

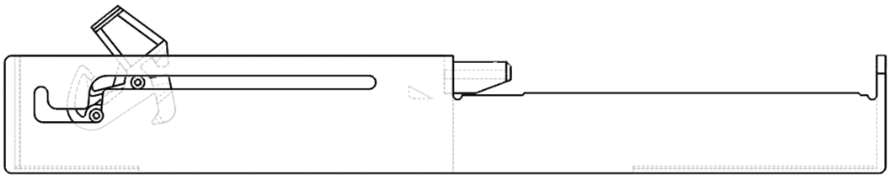

Figure 5.45: Concept B.

5.4.2.3 Concept C

Ideas 1.3 and 4.1 were combined to create concept C. This is shown in figure 5.46 to the right and figure 5.47 below.

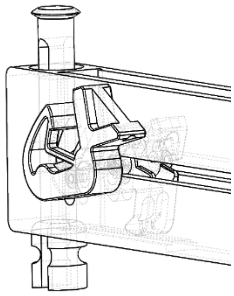

Figure 5.46: Concept C, close up.

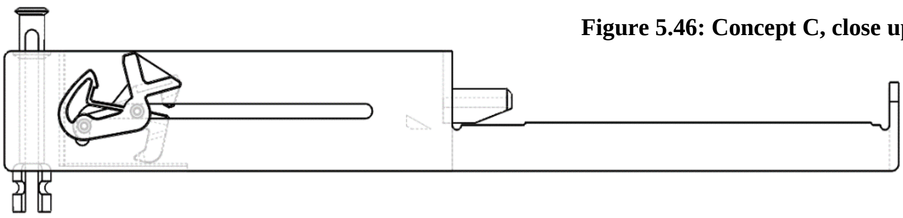

Figure 5.47: Concept C.

5.4.2.4 Concept D

For concept D, solutions 1.3 and 4.4 was combined. The two idea put together is shown in figure 5.48 to the right and figure 5.49 on the next page.

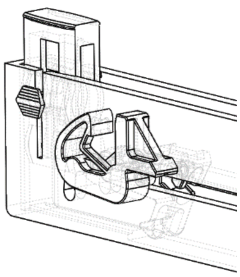

Figure 5.48: Concept D, close up

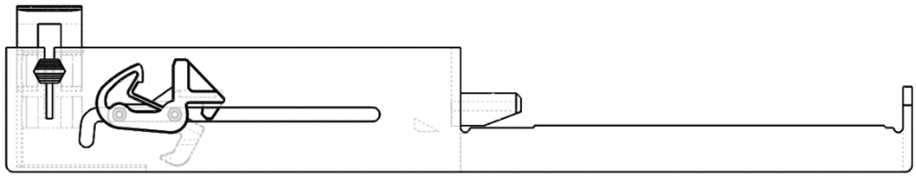

Figure 5.49: Concept D.

5.4.2.5 *Concept E*

Concept E consist of solution 1.3 and 4.5. As solution 4.5 is very similar to solution 4.4 and since they are both placed in the same position on the guide, these two concept are very similar. Making the guide the dividing factor. The concept can be viewed in figure 5.50 to the right and figure 5.51 below.

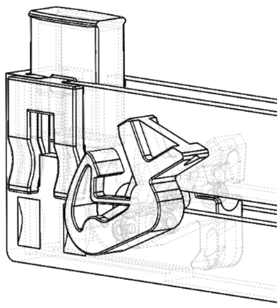

Figure 5.50: Concept E, close

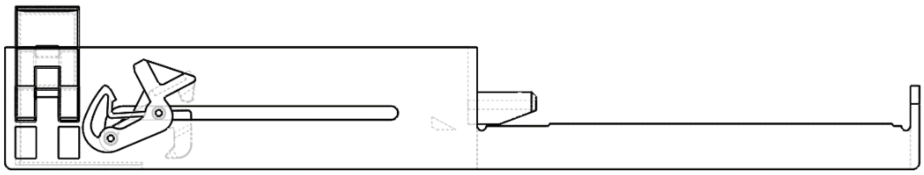

Figure 5.51: Concept E.

5.4.2.6 Concept F

This Concept is compiled of ideas 1.2 and 8.1. This is shown in figures 5.52 and 5.53 on the next page.

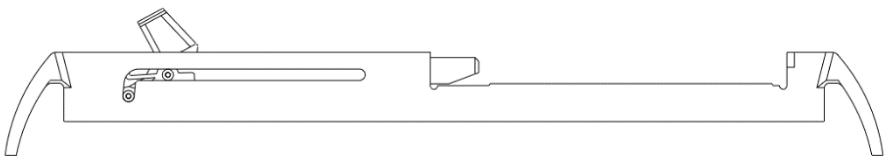

Figure 5.52: Concept F.

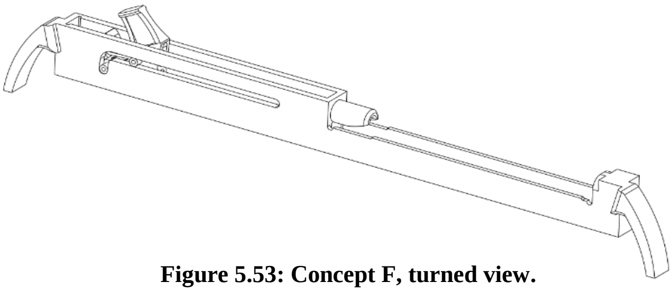

Figure 5.53: Concept F, turned view.

5.4.2.7 Concept G

Concept G is made up of solution 1.2 and solution 8.3 which is shown in figure 5.54 below.

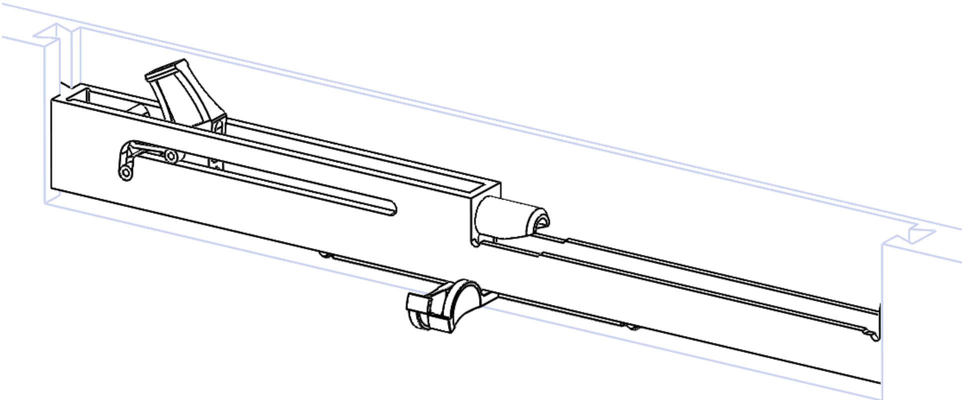

Figure 5.54: Concept G.

5.4.2.8 Concept H

Concept H is made up by idea 1.2 and idea 8.4. The concept is shown in figure 5.55 below.

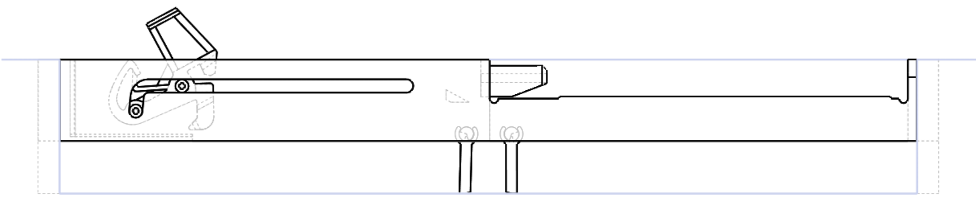

Figure 5.55: Concept H.

5.4.2.9 Concept I

Concept I consist of ideas 1.2 and 8.5. The final concept is shown in figure 5.56 below.

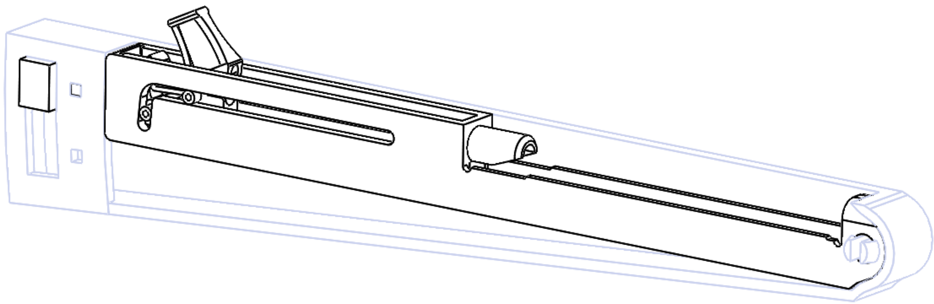

Figure 5.56: Concept I.

5.5 Patent search

When going through the citations of the patents related to the first idea presented by IKEA, the design team made a judgement if a patent might be relevant or not. The patent search showed that there are a large amount of solutions for soft closings or guides, but very few solutions for a combination of them. The only patent that was found for a combined guide and soft closing was a solution where the whole soft closing was movable when installing. Below, the patent numbers followed by their issue year of the investigated patents are presented.

- EP2700778 (A1) – 2014 [23]
- EP3056647 (A1) – 2016 [24]
- WO2012124706 – 2012 [25]
- WO2016106434 – 2016 [26]
- WO2010043334 – 2010 [27]
- WO2017018890 – 2017 [28]
- CN104739054 – 2015 [29]
- US2014026357 – 2014 [30]
- GB2496864 – 2013 [31]
- EP2619392 – 2013 [32]

The patent search was performed trough the web page Espacenet [33].

6 Concept selection

In this section, the way of choosing concept is covered. The different steps in screening the generated ideas are described. The section contains the screening, further development, scoring and selection of the concepts.

6.1 Method

The methodology used for selecting concepts to move forward with is inspired by Ulrich & Eppinger. In Ulrich & Eppinger, a two-stage concept selection methodology is presented. These are concept screening and concept scoring. Both of these stages follow a five-step process [4, p. 143]:

1. Prepare the selection matrix
2. Rate the concepts
3. Rank the concepts
4. Combine and improve the concepts
5. Select one or more concepts

In this thesis, as described in section 5.4, the team chose to use intuition to do a first screening where some ideas were discarded. The ideas discarded can be found in appendix B.

From the concepts presented in section 5.4.2, the two-stage methodology of Ulrich & Eppinger was used for choosing concept. The methodology was slightly modified after consultation with IKEA co-workers. In parallel with the five-step process, prototypes were built and tested in order to gain a deeper understanding and visualization of the concepts.

The concept selection began with a concept screening, where some concepts were eliminated. From the remaining concepts, some were further developed and then tested together with the other ones passing the screening. In order to make the concepts actually work, the testing and the further development was done in parallel with some of the concepts. The test was to try to install and dismount a prototype of a SCG, because those were two important criteria. The testing gave an important understanding of the ease or difficulty of using the concept. The concepts passing the screening and the tests went in to a concept scoring matrix. The concept getting the highest score in this matrix was finally chosen for a more thoroughly evaluation and a more detailed design.

6.2 Concept screening

6.2.1 **Prepare matrix, rate and rank the concepts**

The concept screening was done through comparing and rating the concepts to a reference concept. This reference should be a well-developed concept that the team members know well [4]. When the concept was better than the reference at the given criteria it received a (+), when it was equal it received a (0) and when it was worse it received a (-).

The given concept from IKEA Components was chosen as a reference, since some of the ideas had been developed from it and some were completely different. The criteria that were used in the selection matrix were picked out from the product specifications in table 4.1 in section 4. The team decided which of the criteria that were relevant to use and easy to use as a comparison between the concepts. Some of the specifications are pure demands given from IKEA Components which the product has to have. These are therefore already in the concepts, why they are not a part of the selection- matrix. Some of the criteria are difficult to evaluate without trying the actual concept in real life.

The ranking of the concepts was done based on intuition and consultation with IKEA co-workers. Table 6.1 below shows the result from the concept screening and the columns marked with green are the one moving forward.

Table 6.1: Concept screening

Selection criteria	A (Ref.)	B	C	D	E	F	G	H	I
Ease of installation	0	0	+	+	+	+	+	+	+
Material cost	0	+	-	-	-	0	0	0	-
Changes on doors	0	+	-	+	+	-	-	-	-
Few loose pieces	0	0	-	0	0	0	+	+	+

Table 6.1 cont.

Few tools needed	0	0	0	0	0	+	+	+	+
Ease of dismounting	0	-	+	+	+	0	+	+	+
Symmetric SCG	0	0	0	0	0	-	0	0	-
Robustness	0	0	-	+	+	0	-	-	+
Sum +'s	0	2	2	4	4	2	4	4	5
Sum 0's	8	5	2	3	3	4	2	2	0
Sum –'s	0	1	4	1	1	2	2	2	3
Net score	0	1	-2	3	3	0	2	2	2
Rank	4	3	5	1	1	4	2	2	2
Continue	Yes	Yes	No	Yes	No*	No	Yes	No *	Yes

* The concept is too similar to another concept, therefore a choice was made to only move forward with one of them. The choice was made by the design team, and chose the concept that seemed most realistic using intuition

As can be seen the table 6.1 above, concept D and E got the best ranking mainly due to their simplicity and robustness. However, as described in the table, the team decided to only move forward with one of them because they are very alike. The judgement was made that concept D was more developed, demanded less material and easier to use, why concept E was not investigated further.

The second best concepts according to the screening matrix is concept G, H and I. Their simple design gave high scores in the specifications regarding the involvement of the user. G and H are very similar, but the design team decided that concept G was slightly more robust and likely to work in real life, why concept H was not investigated further. Moreover A and B will be investigated further, since the team feel that these concepts should be tested with a prototype to get a fair idea of how they work. Concept C, E and F and H is therefore discarded, mainly because of an uncertainty in the function and unsymmetrical design.

6.2.2 Further Development

After the concept screening, some concepts were 3D-printed and evaluated and in some cases the need of further development was obvious. In the further development, ideas for the activator was brought forward. The scope of concept was very wide up until this point, why the design of the activator was difficult to determine.

It is important to have in mind that the further development and the prototype testing was performed in parallel, even though the sections is presented after each other when reading below.

6.2.2.1 Concept J (Spin-off on concept B)

Concept B was not classified in the concept screening as being in need of revision. However, during the evaluation of the concept the team realised that the U-track idea could be simplified a bit further. This to possibly make it easier and more intuitive for the moving of the hook during the mounting and dismounting. The problem that laid the foundation for this ideas was the fact that the team realised that to move the hook, both in the U-track and in the two-step solution, would require movement in several directions.

6.2.2.1.1 The solution

The idea that arose was to change the end of the U-track from having a corner to a smooth transition instead. This so that the Guide-hook will just glide in the track when the hook is pushed to the side, instead of the hook having to be navigated around the corner. This solution is shown in figure 6.1 below.

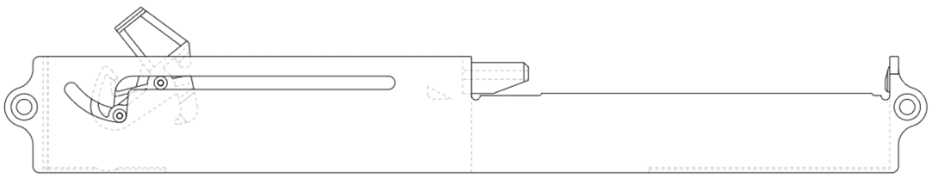

Figure 6.1: Concept J.

6.2.2.2 Concept D+

From the prototype testing, it was concluded that the hook designed to make Concept D work was too complicated to produce. Therefore a further development was made to remove the necessity for using this hook, hereby called Concept D+.

6.2.2.2.1 The solution

As is described in section 6.3 below, some problems were found with using the side hook. The reason for the side hook was to move the activator and the hook away from the top rails to avoid collision with the guide. Therefore, a solution to avoid the activator being in the way of the guide while still using the original hook was necessary. To solve this, the whole soft closing part of the SCG was turned upside down, but the guide was left in the upwards direction. By doing this, no activator in the rail was needed, instead this was place further down. This idea is shown in figure 6.2 below. The guide was also developed further after the prototype testing showed that it was a bit too small. This is described in section 6.3 below. The development of concept D is called D+.

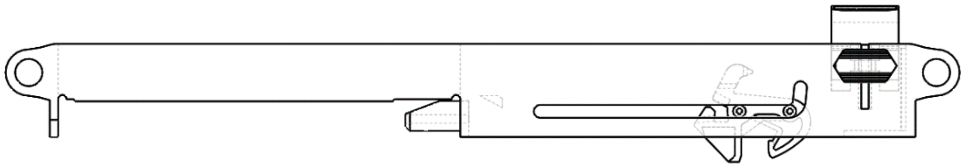

Figure 6.2: The new concept D+.

6.2.2.3 Activator

Up until this point, there were no development of the activator which triggers the soft closing mechanism. The team chose to postpone this until there were full concepts to proceed from. From the concepts that has gone through the scoring, it can be concluded that two different activators need to be developed: one where the hook runs in the rails and one where the hook does not. Two ideas for these can be seen in figure 6.3 and 6.4 below. The one that designed for the hook that does not run in the rail is supposed to be fastened in the top part of the cabined and hit the hook from the side. The other one simply looks like the one used in Malsjö today.

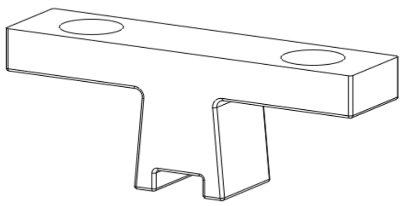

Figure 6.3: Activator for hook that runs in the rail.

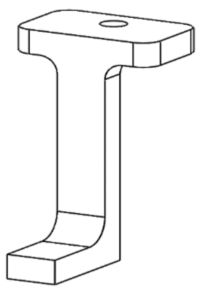

Figure 6.4: Activator for hook that does not run in the rail.

6.3 Prototype testing

Since some of the most important criteria are subjective and this thesis strives to create an easy installation for the user, prototypes had to be done and tested. The prototypes were 3D-printed, simplified models of the remaining concepts, made at IKEA pattern shop. They were printed in 1:1 scale and tested through performing the same steps that the user would have to go through whilst installing and dismounting the doors. As has been declared above, the prototype testing and the further development was made iterative, since these sections are depending on each other.

6.3.1 **Result**

6.3.1.1 Concept A, B and J

The result of these prototype tests are presented together as they are very similar in the design and are therefore comparable. These concept differed a little in the ease of dismounting due to the difference in the tracks. The test with these was to try to drag the hook to the end position, where it should be hidden. As has been described before, this is crucial in order to dismount the door.

While doing this, it was made very clear that the spring was too stiff for this movement to be done smoothly in all three of the concepts. The design that allowed the smoothest way of dismounting was design A, but this was still considered non-user friendly. Concept B and concept J were extremely difficult to pull. When considering the position that the end user will pull it in, it was foreseen to be nearly impossible to dismount this kind of SCG.

Moreover, during the testing of the prototypes another risk was discovered. The team realised that if the user mounted the SCG with the hook in its tensed position, there is a risk that the SCG is placed on the wrong side of the activator. That leads to the soft closing mechanism being unusable.

After trying these concepts it is concluded that these concepts have too many risk factors both when installing and dismounting the door. Since intuitiveness and user friendliness is important for IKEA, this is a good enough reason for discarding these concepts. Therefore, concept A, B and J will not move forward to the concept scoring. Photos of the concepts can be seen in figures 6.5, 6.6 and 6.7 on the next page.

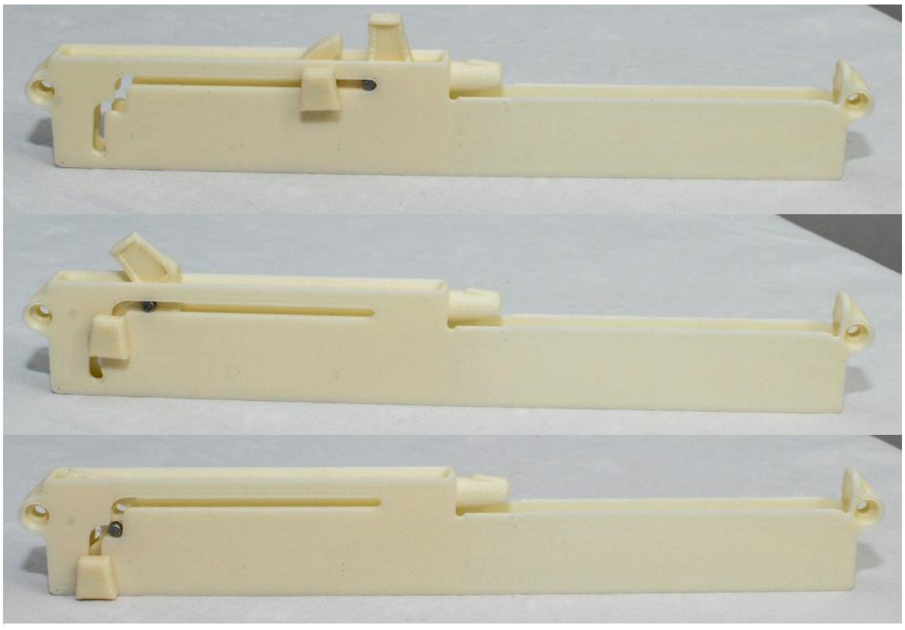

Figure 6.5: Photos of prototypes of concept A.

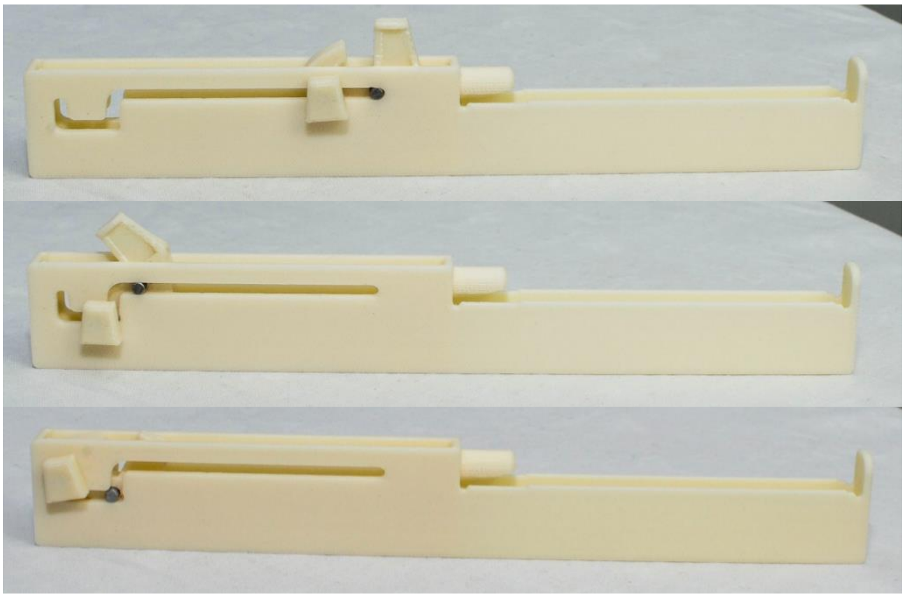

Figure 6.6: Photos of prototype of concept B.

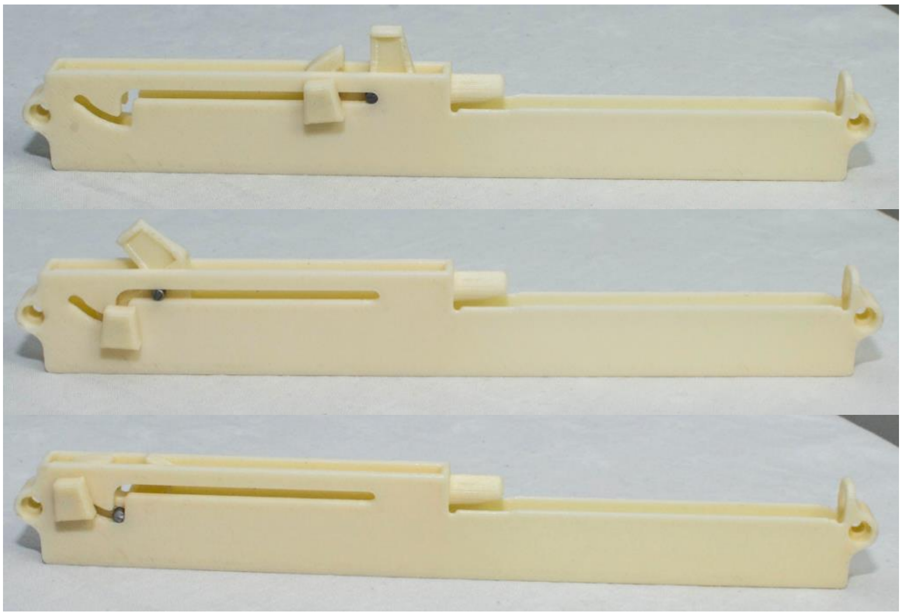

Figure 6.7: Photos of prototype of concept J.

6.3.1.2 Concept D

When 3D-printing concept D, it was quickly concluded that the dimensions of the guide and its handle was too small. The overall concept worked, but it had some room for improvement. Also, with the side-hook in hand, it was made clear how difficult it would be to produce and to make it strong enough. The connection between the both hook parts seemed to week and with the small area around them, the team felt the need of coming up with a new solution for this. This is presented in section 6.2.2 above, and from this prototype testing, concept D+ was born. Concept D+ was the concept that was move forward to the concept scoring. The original, concept D can be seen figures 6.8 and 6.9 below and on the next page.

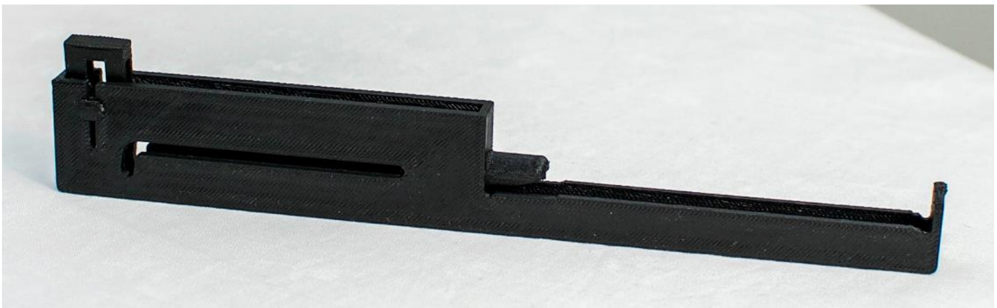

Figure 6.8: Photo of prototype of concept D.

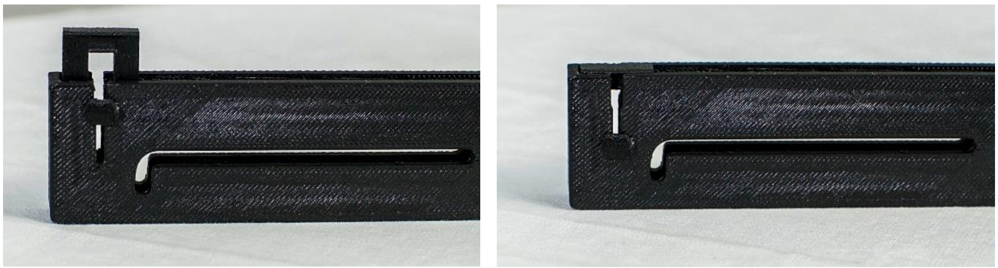

Figure 6.9: Photo of concept D when the guide is extended (left) and when the guide is hidden (right).

6.4 Concept Scoring

The concept scoring was, as described above, done with the five-step process described in Ulrich & Eppinger [4, p. 154]. Some modifications has been made regarding the criteria compared to the screening. When being this far gone in the development process, the team started to consider manufacturability when discussing the concepts. Even though this was not a demand from IKEA to consider, the team felt that it was important in order to present a realistic product. Also, throughout the scoring process it was made clear that all concepts had the exact same ranking in the criteria “few loose pieces”, “few tools needed” and “symmetric SCG”. Therefore, these three criteria were replaced by “Ease of manufacturing”. This criteria mainly regards the possibility of using injection moulding as manufacture method and creating an easy mould.

The way of ranking the concepts was also made differently from the screening. In the concept scoring, a reference was chosen for each individual criteria. Depending on the criteria, different concept acted as a reference, this can be seen in the table 7 below where the rating is presented in bold. The reference for each criteria was chosen by the design team.

From this reference, the rest of the concepts were scored according to table 6.2 on the next page. When rating, the design team had the prototype testing in mind together with intuition to make a judgement. The result from the concept scoring is presented in table 6.3, where the reference criteria is written in bold and the columns marked in green are the one moving forward. Table 6.2 shows the scale for the scoring.

Table 6.2: The scale when scoring the concepts [4, p. 155]

Relative Performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Table 6.3: Result of concept scoring

Selection criteria	Weight	Concept D+		Concept G		Concept I	
		Rating	Weighted score	Rating	Weighted score	Rating	Weighted score
Ease of installation	25%	4	1	2	0.5	**3**	0,75
Material cost	15%	**3**	0,45	4	0,6	2	0,3
Changes on doors	10%	**3**	0,3	3	0,3	3	0,3
Ease of manufacturing	15%	**3**	0,45	2	0,3	4	0,6
Ease of dismounting	20%	3	0,6	**3**	0,6	3	0,6
Robustness	15%	**3**	0,45	2	0,3	5	0,75
	Total score	19	3,25	16	2,6	20	3,3
	Rank	2		3		1	
	Continue?	Yes		No		Yes	

From the concept scoring, concept D+ and concept I received the highest score and will be investigated further. Concept D+ was predicted to be superior in its ease of installation. The user simply has to push the liver up and it is done in a similar way as the current guide. Concept I was considered to be the easiest one to manufacture, since it has a quite uncomplicated design. Concept I was also the most robust concept, since the shell gives a thicker SCG. Concept G got the lowest score based on its uncertainty with the “legs” and how easy it would be to install. Concept G will therefore no longer be considered for the final design.

6.5 Concept evaluation

From the concept scoring, concept D+ and concept I was chosen as the final concepts to investigate and/or develop further. As being mentioned before and as can be seen in the product specifications; patent search, safety and user friendliness are important for IKEA. The team decided to consult with P. Lindberg and C. Ervér about these final concepts to get a hint if they see any risks in moving forward with them.

6.5.1 **Concept D+**

Concept D+ is according to the evaluation methods the best solution for this problem; it is by far the easiest and most intuitive to mount and dismount, the soft closing works just as today and the design is not too complicated. When consulting with P. Lindberg however, a safety concern was brought up. It was stated that there was a risk for the activator to be harmful when a user reaches in for something in the closet. There is a risk for the activator to be in the way and therefore the user to hurt its arm. Also, the small area where the attachment of the SCG is designed may be too small in order for it to withstand forces both from slamming the door but also tension from the bolts. The design team could not find any existing patents where there was a risk for infringement.

The conclusion is that there is too big of a risk of the user getting hurt with the placement of the activator. The design team felt that a lot of time has been put on concept D and concept D+ to solve all the subproblems and a choice had to be made. After giving it some consideration together with P. Lindberg it was decided to drop this concept and move forward with developing concept I.

6.5.2 **Concept I**

The design team found this concept the smoothest one; the activator can be located in the rails, the mounting is easy, it is quite similar to the solution today and it is intuitive for the user. Since concept D+ seemed to be too big of a hazard, this concept was the clear choice for the final concept. Nevertheless, the team wanted to investigate it deeper before suggesting it to IKEA. One part of this was to speak with C. Ervér to investigate the risk of this concept to infringe on another patent. The team had found a patent that they felt had some features that were similar to concept I and needed help from Ervér to learn how to read and interpret the claims in a patent. The patent that was investigated was patent EP 2619392 [32].

That patent concerns a soft closing integrated with a guide. This is movable and moves through being pivoted in a joint. After briefly learning how to read the claims in an understandable way, the design team made the judgement that concept I ran a great risk of infringing on the patent. Even though the design itself had some differences, the functions described in the claims seemed too similar. To be completely sure, a real patenting firm would have to do an investigation, which takes a lot of money and time and could therefore not be done for this project. Because of this, the design team had to make a decision whether or not to move forward with this concept despite this risk. During this discussion, where P. Lindberg also participated, it was decided to try to change some of the functions in the concept in order to move away from the patent.

Still, concept I is a very good candidate and an easy solution to the problem in this thesis why it still is something that IKEA should consider. The concept should be further investigated by patent experts at IKEA who can dig deeper into whether or not it infringes and then decide how to move forward with it. If it turns out to be too similar to the patent existing, there are still ways for IKEA to use it; by getting a license from the owner of the patent or by having they produced it [34].

After this conclusion, the design team worked on further developing concept I.

6.6 Further development on concept I

Since a movable SCG is, according to the concept evaluations, the smoothest solution to the problem, the design team with a consultation from P. Lindberg decided to change the way of moving the SCG. This mechanism was an important part of the existing patent and is in accordance with the delimitations in this thesis, the only function that is changeable at this moment. Therefore, the moving mechanism seemed like a reasonable function to modify. During the further development on concept I, new solutions of moving the SCG was brought forward in an attempt to move away from the patent. The result from this is shown further on and these concept will be called I+ and I++.

Both concept I+ and I++ include the actual soft closing mechanism, the one being called SCG and a shell in which the whole system will move up and down and also is the part being mounted in the door. The concepts differs in the way of being moved up and down.

6.6.1 **Concept I+**

Concept I+ is built up by two separate parts: the SCG and a shell. Instead of one side of the SCG moves up and down through being pivoted like concept I, this concept is based on the whole SCG being moved. It is moved through a snap fitting that has two positions: one for the upwards position and one where it needs to be hidden. The moving mechanism is simple: the user pushes the snap fitting in, moving the SCG up, release the snap fitting. The same guide-hook as in concept I is being used. The concept with and without the shell can be viewed in figure 6.10 and 6.11 below.

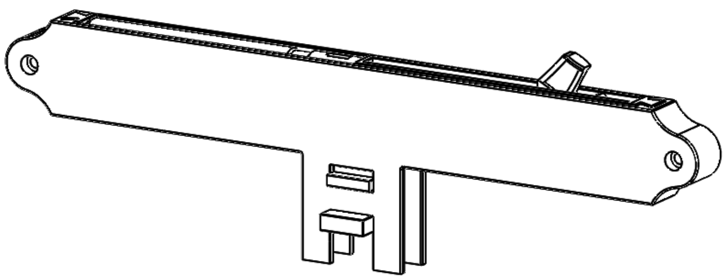

Figure 6.10: Shell + SCG.

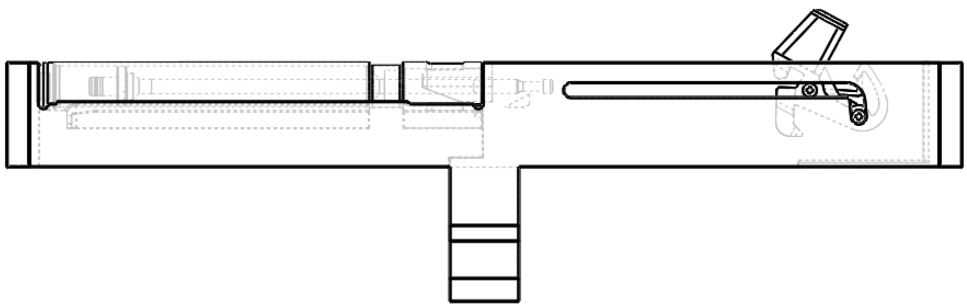

Figure 6.11: The SCG.

6.6.2 **Concept I++**

This concept is similar to concept I+ but has some differences in the way of moving the SCG. Concept I++ moves through a more complicated design having a locking mechanism controlling the two positions. For the user, the way of moving the SCG will be similar to using a key; when you turn it counter clockwise, it will move up and when you turn it clockwise it will move down again. It is controlled by a twisting mechanism connected to an arm, this is described more detailed in section 8.3 later on in the report. Figure 6.12 shows the design of the concept assembled without the shell. Figure 6.13 shows it with the shell mounted on.

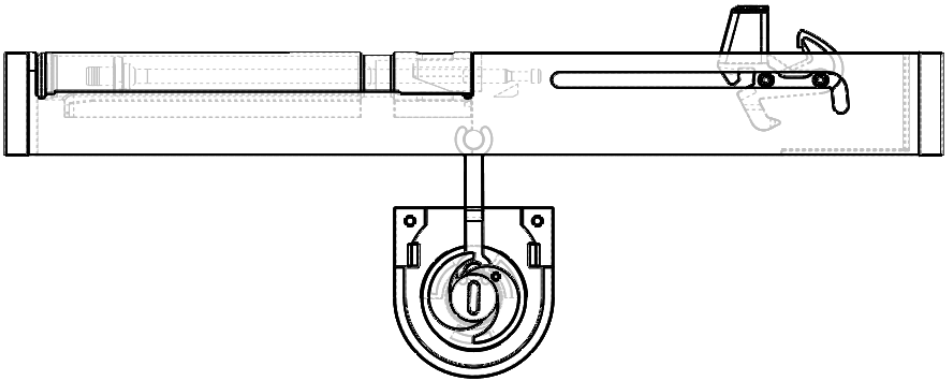

Figure 6.12: The SCG.

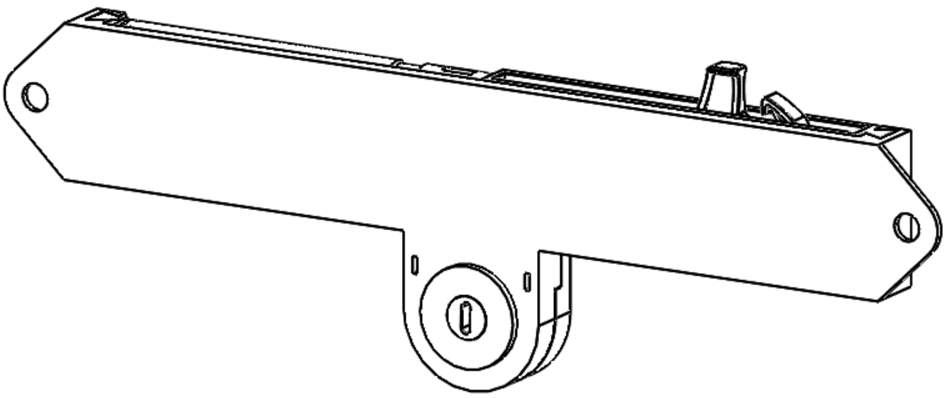

Figure 6.13: Shell + SCG

6.7 Final concept selection

Due to lack of time, whether or not concept I+ and I++ might infringe on a patent cannot be presented but should be further investigated. The design team believe that the new concepts have functions that distances them from the previously looked upon patent, but this needs to be confirmed. After consulting with P. Lindberg, the design team felt that it was difficult to discard one of these concepts since they differ significantly in complexity. Discarding either would mean the loss of a possible working concept and that the decision was more suited for IKEA Components to make if they decide to move forward. It was therefore decided to move forward with both of them. Further evaluation through tests with prototypes and simulation will be done with both of them. By using intuition the design team felt that concept I+ may be easier to manufacture and have a simpler design and is fairly intuitive for the user. Concept I++ however, is predicted to be the absolute easiest for the user during mounting and dismounting but has a more complex design. Therefore, the design team decided that these two concepts will both be presented as final concepts and the decision of which one to use will be up to IKEA Components.

7 Concept testing

This section contains the tests that were made on the final concept and the results from these tests.

7.1 Prototype

Prototypes were printed at the 3D printing lab at LTH to get as exact models as possible. To test with the right materials was, clearly, not possible since moulds would have to be made. The material in the machines at LTH is not similar to the materials that would be used if the concepts where to be produced for real, but the machines are more exact than the ones at IKEA and therefore gave prototypes that were closer to working as the real thing. Mainly, the friction between the pieces was higher due to the roughness of the material at LTH, but this was considered during the testing and it was noted that for a part with real materials it would have less friction. Figure 7.1 below shows the prototype of concept I+ and figure 7.2 on the next page shows the prototype of concept I++.

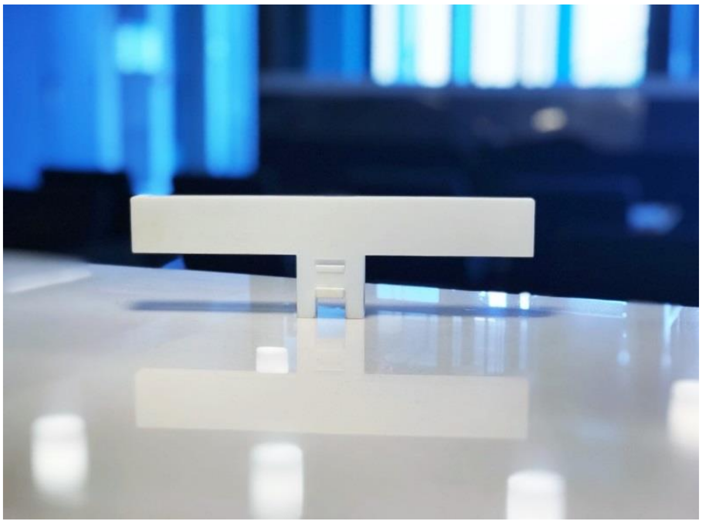

Figure 7.1: Prototype of concept I+.

Figure 7.2: Prototype of concept I++. From the front (to the left) and the back (to the right).

7.2 FEM-tests

Since the concepts are very similar when it comes to the parts that have to handle forces during FEM test and due to the lack of time, it was decided that the FEM analysis would be done on one of the concepts. The FEM-analysis was made on concept I+. This would give a sufficient indication on whether or not it could handle the forces. The analysis was performed by G. Holstein.

From the FEM-analysis that was made in the research, it was made clear that the critical part of the design of the SCG is the hook. The hook was the part taking the most of the load. Therefore, the analysis was based on whether or not the hook could handle the 200 N force. Figure 7.3 on the next page shows which parts of the concept that were given different materials. The first test was made with the hook having the material POM and the base in PA6. It quickly showed that the hook needed to be made stronger. So the analysis was therefore interrupted and the top of the hook was made wider and a strengthening rib was added. The analysis was then restarted.

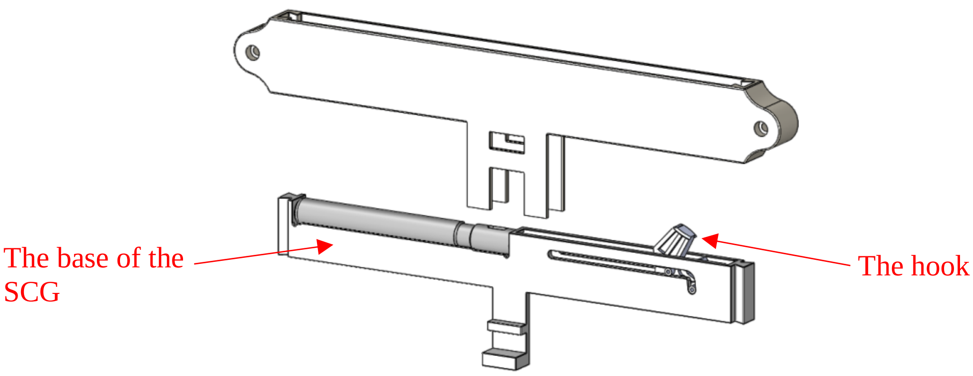

Figure 7.3: Concept I+ in an exploded view

The result for the first analysis is shown in figure 7.3 below.

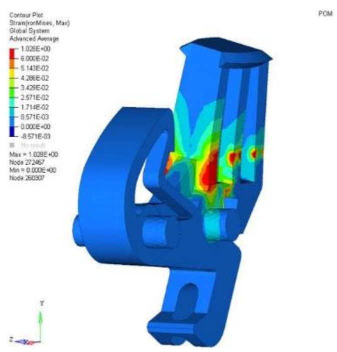

Figure 7.4: FEM-analysis with the hook made in POM

The image shows the deformation of the hook and it is measured in millimetres. This was not a good result and the hook was too weak for the 200-N load. This is shown by the red areas. This led to a second analysis having to be made, with new materials. According to S. Nilsson and G. Holstein, two parts that slide against each other should not both be made in POM due to the properties of the material. Therefore, the hook and the SCG-base could not both be made in POM. In the second analysis, the hook was given the material PA6 GF30 and the base was given POM. This was advised by G. Holstein. The result from this is shown in figure 7.5 on the next page. With this material, the hook and the design of the SCG is strong enough to act as a guide. This figure also shows the deformation of the hook in millimetres.

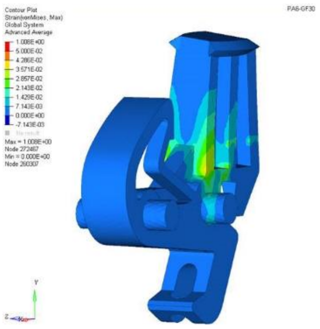

Figure 7.5: FEM-analysis with the hook made in PA6 GF30

7.3 Conclusions from tests

7.3.1 **Risks**

A risk with the concepts that occurred to the team during discussions with P. Lindberg was the risk of “sticky drawer effect”. This is the same problem that can occur on, for example, and older wooden chest of drawers. It is what happens when the drawer is pulled out unevenly. This results in the drawer being tilted in the dresser and the drawer gets stuck, an example of this can be seen in figure 7.6 below, where the edges are in an uneven height. The team tried to find if there was a known, simple, solution for avoiding this problem by researching the issue. However, due to lack of information online and the fact that no engineer at IKEA could be found that had knowledge about the issue, the team made the decision to create a solution for each concept that would fix this. These can be viewed below. Since the problem could not be tested in real life to actually see if they worked, these ideas were, nonetheless, left behind at this stage. They were created to be used if the problem

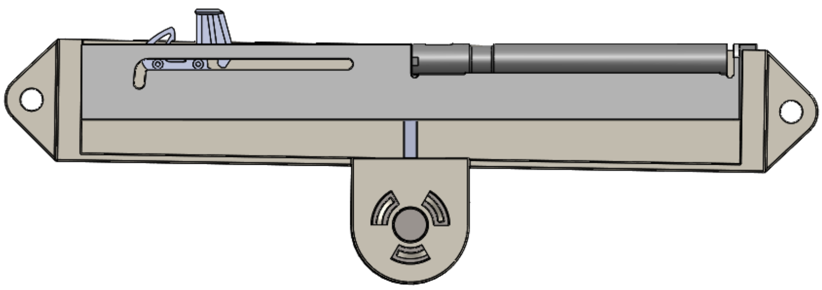

Figure 7.6: Example of sticky drawer effect

were to come up during at a later stage, if IKEA Components decided to move on with the ideas.

7.3.1.1 Suggestions for possible solutions

7.3.1.1.1 Concept I+

For this concept, the solution for the "sticky drawer effect", in case it would later prove to be a problem surrounds snap fitting of the shell. If the snap fitting only can move straight up this will also be true for the rest of the soft closing base and there would be no sticky drawer effect. So for this, the opening for the snap fitting at the bottom of the shell could be fitted with what you could call guiding blocks. If these are fitted on horizontally elongated hole on the right and left side of the opening, they could then be positioned as close to the snap fitting handle as possible and fixed so that the snap fitting only can move straight. Since the opening cannot be guaranteed to be 100% straight on every component because of the extensive costs it would mean to have zero tolerances, this could be a solution for avoiding it.

7.3.1.1.2 Concept I++

For this idea, the solution would be similar to the solution for concept I+ but since there is no part that can be guided to move in a straight line, this would be added. The thought was to have a vertically elongated hole on the front of the shell that goes from the top and is as long as the vertical movement that the soft closing base. On the sides of the track there would be the same kinds of guiding blocks as on concept I+. On the soft closing base there would be a protruding rectangular feature that could glide in the track on the base.

7.3.2 **Materials**

With the design of the concepts, they are strong enough when the hook is made in PA6 GF30, the base in POM and the shell in PA6 GF15.

8 Detailed design

This chapter contains the detailed design of the two chosen concepts. The structure of all of the included parts, material choice, manufacturing etc. will be presented.

8.1 Method

The parts of both of the chosen concepts were created simultaneously to insure that they all work together. For the material choice of the components the material expert, Stefan Nilsson, at IKEA Components was consulted. In order to know whether or not these concept are possible to injection mould, an undercut evaluation tool in SolidWorks was used. Some small adjustments to make it easier to manufacture was made in SolidWorks.

8.2 Concept I+

Concept I+ is built up by two parts: a base and a shell. Those assembled can be seen in figure 8.1 below.

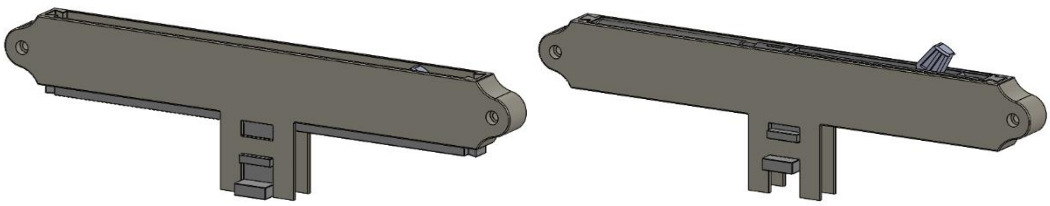

Figure 8.1: Concept I+ in its top and hidden positions.

8.2.1 **Mechanical design**

8.2.1.1 The base

The main difference for the base of the SCG for concept I+ from the original soft closing is how it is fastened. As shown previously in the report, the original soft closing is held in place by two fasteners that are placed in the holes on the soft closing base and then screwed on to the door. To be able to achieve the moving of the soft closing, this was replaced by vertical profiles on the sides with a triangular shape (see figure 8.2 and 8.3 below). This allows the base to slide in the tracks on the shell, tracks matching the shape of the profiles.

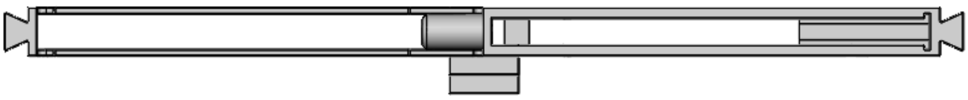

Figure 8.2: The base from above, showing the shape of the profiles on the side.

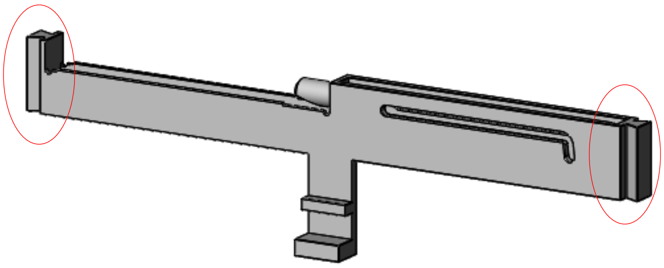

Figure 8.3: The base from side with profiles marked.

8.2.1.2 The shell

The tracks that the soft closing is placed in are located on the shell that was created for concept I+. The shell is meant to work as the support for the base, enabling the vertical movement, and to work as the connection between the SCG and the door.

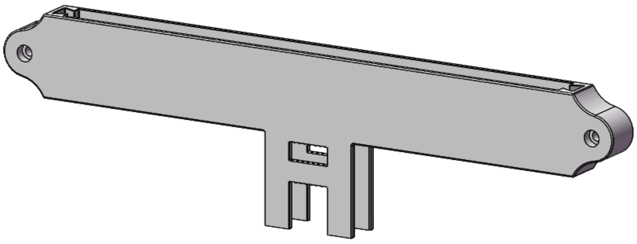

Figure 8.4: The design of the shell.

Naturally, the track have the same shape as the profiles on the SCG making it possible for the SCG to slide from a hidden to a non-hidden position. The design of the shell is shown in figure 8.4 on the previous page.

8.2.1.3 The snap fitting

To be able to lock the SCG in the different position, a snap fitting is used. The SCG and the shell comes mounted as shown in figure 8.5 below, in its hidden position. When it is fastened to the door and the door has been put in position, the bigger bottom lever is pushed in, resulting in the smaller top lever being pushed in as well. When the bottom lever has been push in far enough so that the smaller lever can pass by the barrier of the shell, the whole SCG base is pushed up. When the SCG has been pushed up to its non-hidden position, the bottom lever hits the top of the lower gap that it is in and it can be let go. The SCG is then locked in its top position. This position can be viewed in figure 8.6 below.

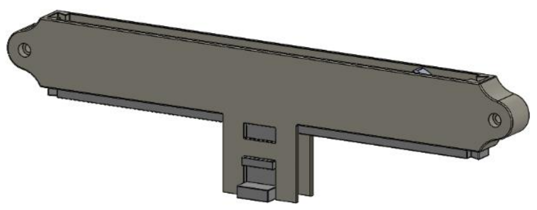

Figure 8.5: SCG + Shell, with SCG in hidden position.

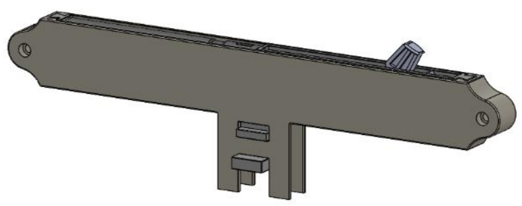

Figure 8.6: SCG + shell, with SCG in non-hidden position.

8.2.1.4 The fasteners

To fasten the SCG to the door, two fasteners are used (see figure 8.7). These are very similar to the fastenings that are used on the existing soft closing today. The fasteners are placed in the holes on the SCG, the whole unit is placed in the cavity of the door and the fasteners are then screw on to the door with two screws each. Figure 8.8 below show the whole soft closing mounted with the fasteners.

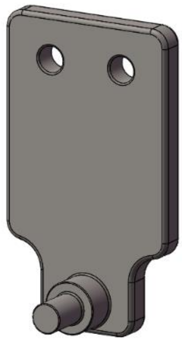

Figure 8.7: A fastener.

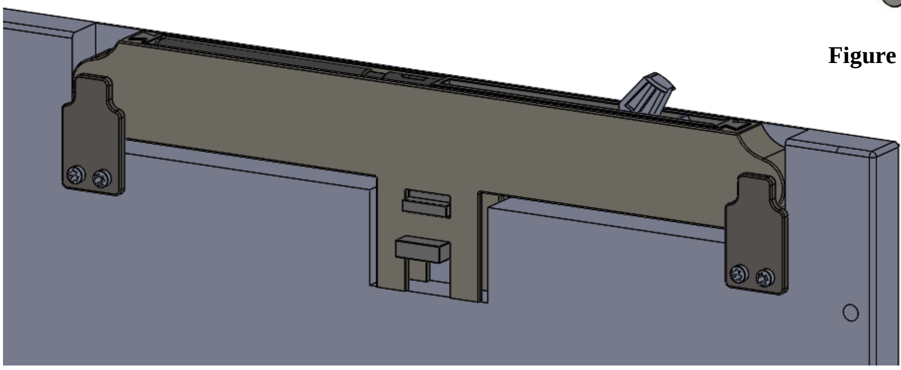

Figure 8.8: The SCG + shell fastened to the door.

8.2.1.5 The doors

Figure 8.9 below shows how the door needs to be milled in order for the SCG of concept I+ to fit.

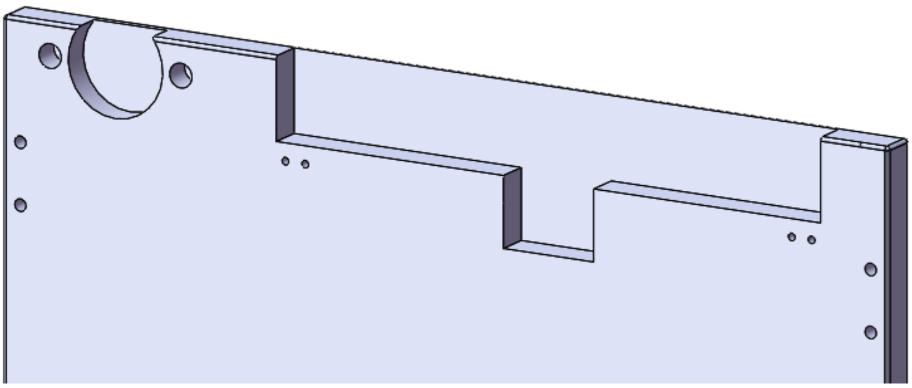

Figure 8.9: Milled tracks on the door.

8.2.1.6 The hook

The hook has the same design for the bottom parts as the original hook. The design of these parts have been done in this way to be able to perform special functions and they were therefore left as is. The top part of the hook was changed to make sure that it would work as both a hook and a guide. The top has been lengthened and the very top has been given a similar design to the top of the guide. The guide was specially designed so that it would glide smoothly and silently in the rails and the same appearance was therefore used to get the same qualities. The design of the hook can be seen in figure 8.10 below.

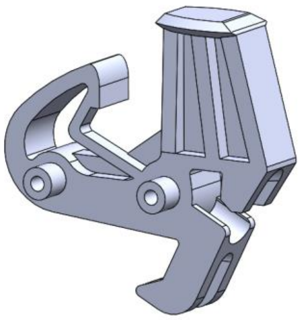

Figure 8.10: Detailed design of the hook.

8.2.1.7 Exploded view

An exploded view for the whole product can be seen in figure 8.11 below.

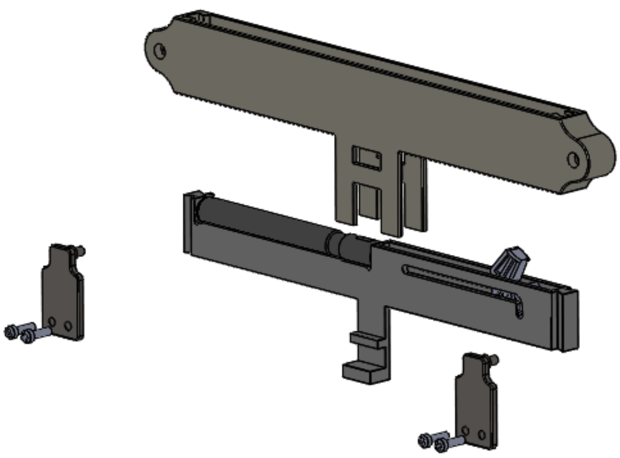

Figure 8.11: Exploded view of concept I+.

8.2.2 **Material choice**

The material choice was made through consulting with Stefan Nilsson. The choice was based on the function of the part, the load applied on the part and which materials that are common to use at IKEA.

8.2.2.1 The base

The base is, as mentioned in the research section, originally is made in PA6 GF30. For the material of the base in concept I+, a flexible material is necessary for the snap fitting to work. It also needs to be able to glide easily in the tracks of the shell. When consulting with S. Nilsson and G. Holstein it was decided to use POM for the base. According to S. Nilsson, it is a material that suits well for gliding products that needs to have a flexible quality. POM has a low friction coefficient which is good when it is sliding through the tracks and it is easy to injection mould [35]. Also, it made the whole design strong enough in the FEM-analysis.

8.2.2.2 The shell

Since the base is gliding in the tracks of the shell it is important to think about how the materials act when being rubbed against each other. According to S. Nilsson, it is known that POM makes squeaking noises when being rubbed against itself. Therefore, having POM as the material for the shell is not an option. Also, now that the base is going to be made in POM, the stiffness is a lot less than in the original base. That is compensated through having a stiffer material for the shell. So it is decided to use the same material as the original base; PA6 GF15 This makes sure that the SCG can handle the demands and it should not be a problem when the materials are being rubbed against each other.

8.2.2.3 The hook

The FEM-analysis showed that the hook needs to be very stiff in order to handle the load cases. The analysis gave the result that the hook should be made in PA6 GF30.

8.2.2.4 The fasteners

Similar design of the fasteners is today being used to fasten the soft closing in Malsjö. Therefore, the same material as them will be used for these fasteners: PA6 GF30.

8.2.3 **Design for manufacturing**

As is described in the delimitations, injection moulding was since before chosen as the manufacturing method. Since all of the parts are to be made in plastic and since they are meant to be produced on a larger scale, this was deemed appropriate. Since the base is made this way today, the team assumed that the design of the previous mould and included sliders can be used similarly on this concept. The additions that have been made on the base was concluded to be a relatively simple addition to the existing mould. For the shell, the same manufacturing method was chosen. An undercut analysis was made in Solidworks to illustrate how the mould should look like. The results from this is shown in the sections 8.2.3.1 and 8.2.3.2 further on.

8.2.3.1 The base

The arrows in figure 8.12 below show the direction from which the two halves of the mould are opened and closed. The red area shows occluded areas, where a core should be placed during the injection moulding. Since the inside of the base has not been changed, the appearance of the core is assumed to be very similar to the core that is used to make it today. It is therefore not investigate further since the knowledge is already available.

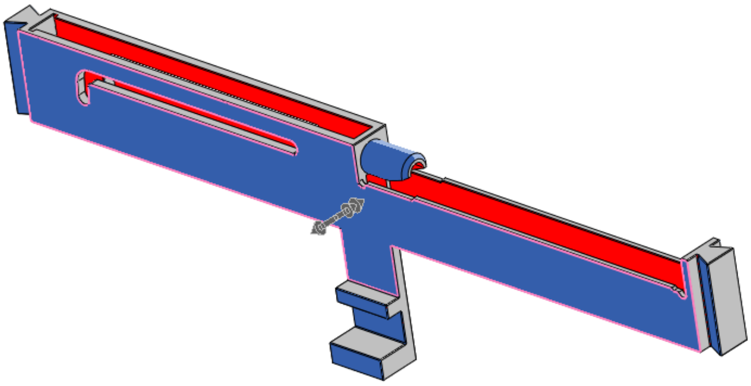

Figure 8.12: An undercut analysis of the base

8.2.3.2 The shell

The shell is made in a similar way to the base but it is simpler. The only core that is needed is one that goes straight through the middle, since the shape is the same all the way through. The undercut analysis can be seen in figure 8.13 below.

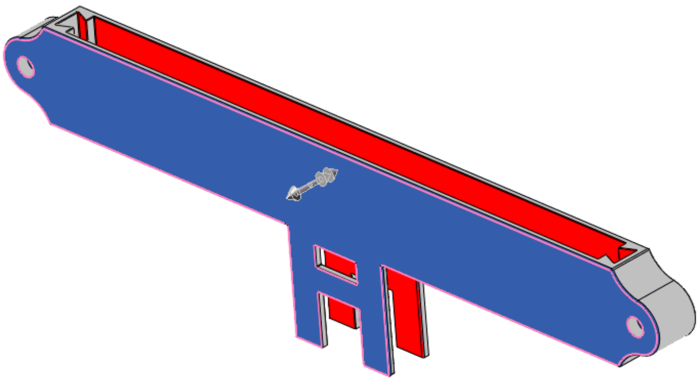

Figure 8.13: An undercut analysis of the shell

8.2.3.3 The hook

The hook would also require sliders for the mould, but as it is made this way today, this should not be a problem. The undercut analysis can be seen in figure 8.14 on the next page.

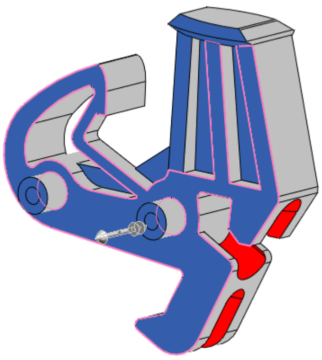

Figure 8.14: Undercut analysis for the hook.

8.3 Concept I++

Concept I++ is, according to the design team, a user friendly and easy concept. It consists of four parts: the SCG, a shell, a twisting mechanism (crankshaft) and a steering/linking arm. However, for the user it will only be one coherent product, since it will be delivered with all these parts assembled. The user simply has to attach the product to the door for the installation to be finished. Figure 8.15 and 8.16 below show how the product is delivered to the user.

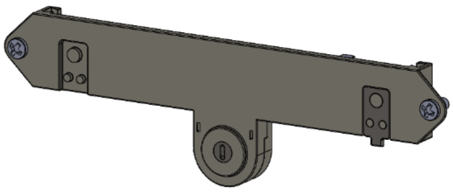

Figure 8.15: The product in its delivered form seen from the front side

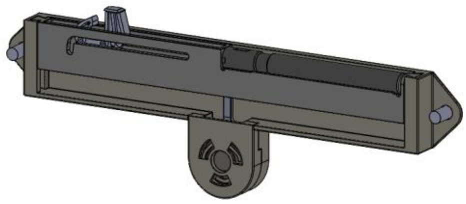

Figure 8.16: The product in its delivered form seen from the back side

The product is fastened onto the door with screws. Figure 8.17 illustrate how the SCG is placed in the door. When the door is in its place in the cabinet, the user simply takes the key, puts it in the keyhole and turns it. By doing that, the whole SCG will move upwards, placing the guide-hook in its correct position where it works as the original guide. When/if the door needs to be demounted, the user takes the key, puts it in the keyhole again and pushes it in followed by turning it clockwise. This lowers the SCG to its hidden position. So, for installing: the key is turned clockwise and for demounting: the key is pushed in and turned counter clockwise. The red arrows in figure 8.18 on the next page show where to put the key and how it is turned. The original guide on the left side in the figure is pushed up in the same way as it has always been done. Figure 8.17 and 8.18 show concept I++ mounted on the door.

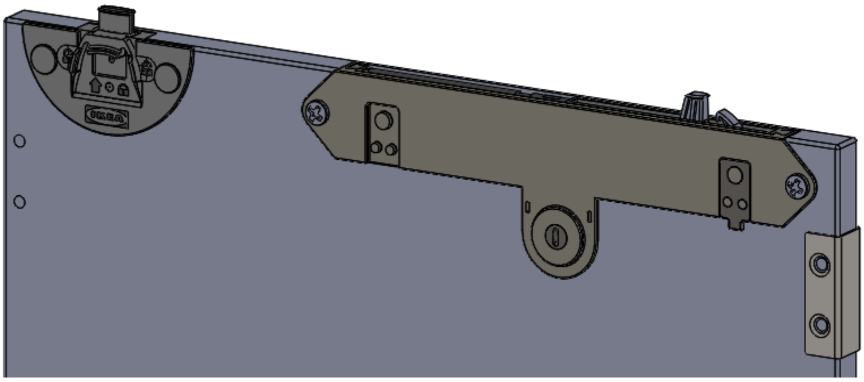

Figure 8.17: The SCG mounted onto the door with the guide-hook in its non-hidden position

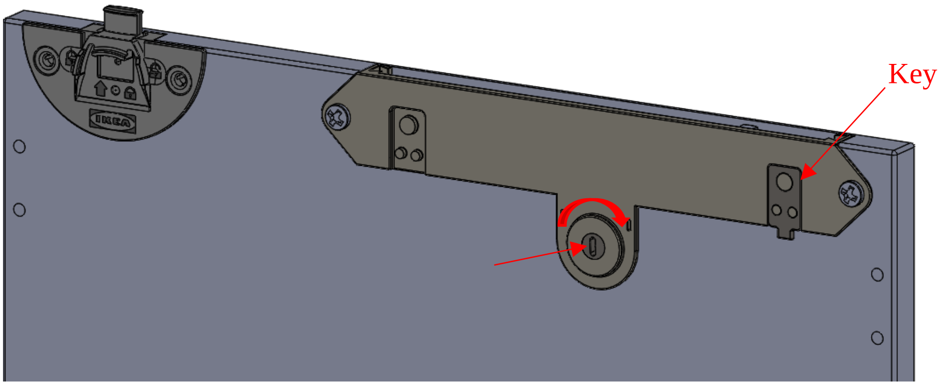

Figure 8.18: The SCG mounted onto the door with the guide-hook hidden

In the following sections, every part in this concept are thoroughly described separately.

8.3.1 **Mechanical design**

8.3.1.1 The base

The design of the base is very similar to the one in I+. It can be viewed in figure 8.19 below. The difference is that I++ does not have the part that snaps into the shell. Instead it has a cylindrical pin at the bottom on which an arm that controls the twisting mechanism is supposed to be fastened. This pin is illustrated with the red circle in figure 8.20 below.

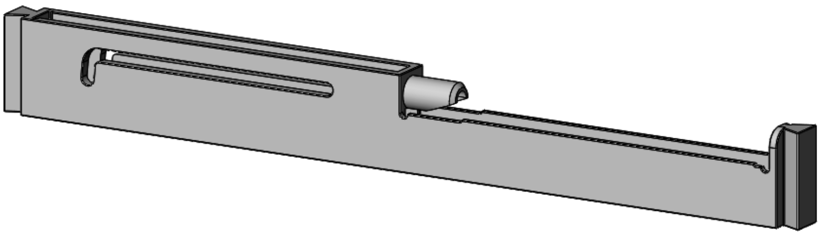

Figure 8.19: The base of the SCG.

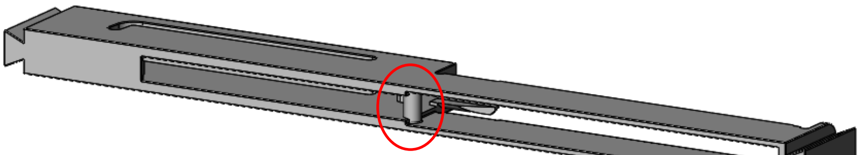

Figure 8.20: The base of the SCG seen from the bottom.

8.3.1.2 The shell

The shell is built up by two parts; one for the front and one for the back. Those to parts assembled can be seen in figures 8.21 and 8.22 and the exploded view in figure 8.23 shows them apart. It is the shell that attaches the SCG to the door and it is in the shell that the base moves up and down. Therefore, it has tracks cut out for where the base slides.

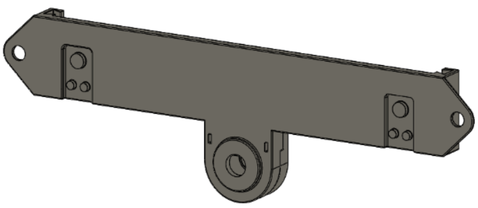

Figure 8.21: The shell with parts assembled.

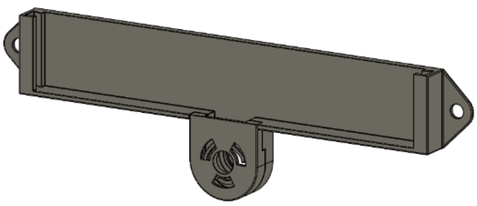

Figure 8.22: The shell in exploded view.

Figure 8.23 below shows the shell from the backside where the two separate parts connect to each other. They are assembled through pins and snap fittings.

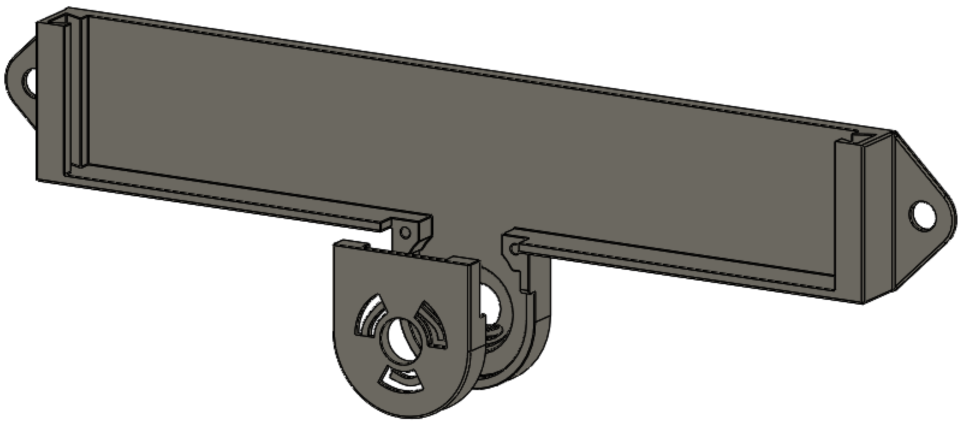

Figure 8.23: The shell from the backside.

The shell, or more specifically the two parts that stand out at the bottom of it, is designed to control the crankshaft during the movement of the SCG. Figures 8.24 and 8.25 on the next page shows two of the parts zoomed in, in order to see the details. These are the front and the back part of the shell.

The track marked with A is what limits the user from being able to keep turning the key, and thus the crankshaft, when it reaches its two positions. Without this, the user could keep turning the key when the SCG is in its top position and it would be lowered again. This track stops the user from turning the key too far in both directions. This makes it difficult for the user to install the SCG in the wrong way since it is being moved with control. The crankshaft has a pin that runs in these tracks.

The details marked with B is what locks the crankshaft when the SCG is in its non-hidden position. The crankshaft is being pressed against the front part through the flies in the back part, marked with C. These flies are supposed to be in a flexible material. Since the crankshaft is pushed against the front part, this results in the arms of the crankshaft being locked by the parts marked with B when it is turned. Preventing it from being turned back, counter clockwise. To unlock it, the crankshaft is pushed in, which is possible because of the flexibility of the flies. This enables an inwards movement that moves the crankshaft, most importantly the arms of the crankshaft, away from the locking parts and the key can be turned counter clockwise. Thus, hiding the SCG.

The details marked with D is the snap fitting through which the front and the back part of the shell are assembled.

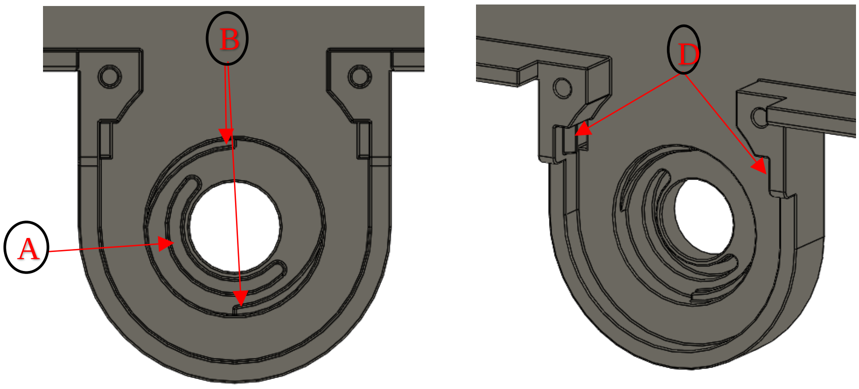

Figure 8.24: Zoomed in detail of the front of the shell

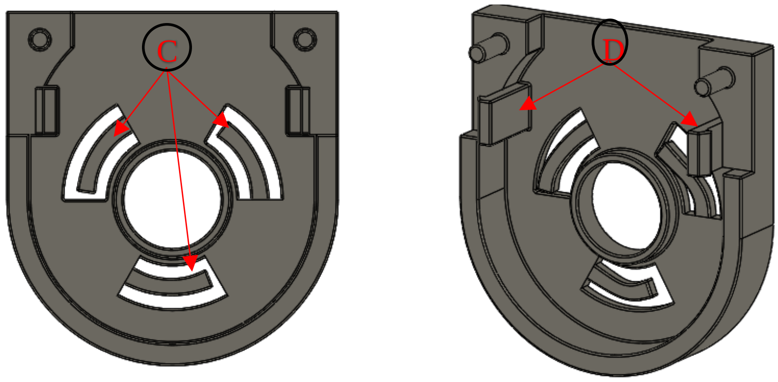

Figure 8.25: Zoomed in detail of the back of the shell

8.3.1.3 The twisting mechanism

This, together with the shell, is the complex part of concept I++. It is a feature that makes it very simple for the user but a bit more difficult for the manufacturer. Nevertheless, it is possible to manufacture which will be explained further in section 8.3.3 further on in the report.

The rotation of the SCG is conducted by a crankshaft and the design of this can be seen in figure 8.26 below. The details marked with E are the arms that snap into the "locks" in the front part of the shell, marked with B in figure 8.24 on the previous page. The part marked with F is the pin running in the track, making sure that the crankshaft only moves within the angle required to move the SCG between its two positions. The linking arm is snapped onto the detail marked with G and H is the keyhole.

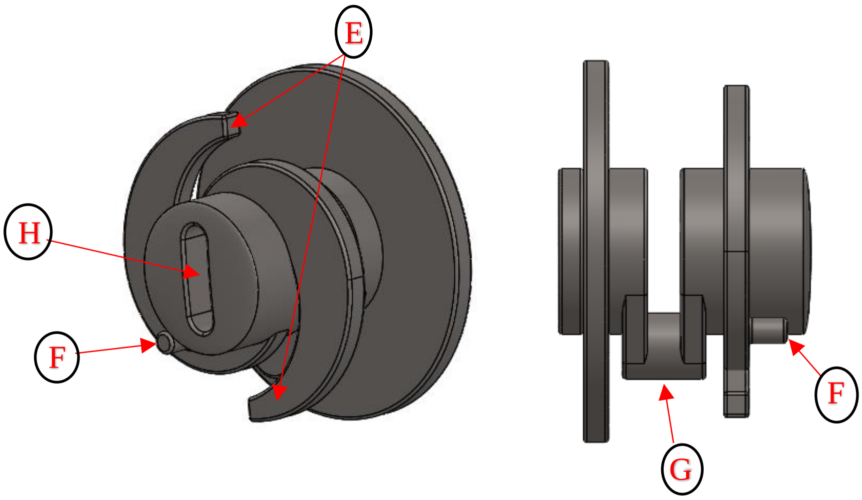

Figure 8.26: Crankshaft.

Figure 8.27 on the next page illustrates how the different parts of the twisting mechanism work together.

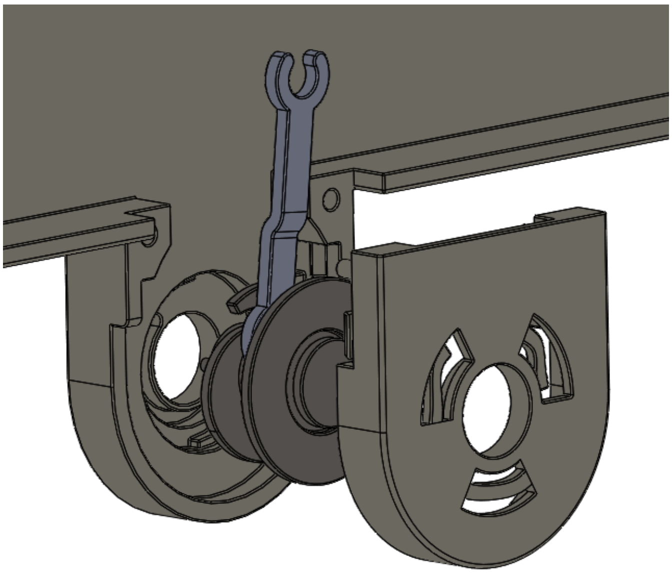

Figure 8.27: How the pieces work together.

8.3.1.4 The arm

The SCG is linked to the twisting mechanism through the arm shown in figure 8.28 below. The design of the part that snaps the arm onto the base and the crank shaft comes from consulting with O. Diegel. From that, it was given that for this kind of snap fitting to work, the angle illustrated in figure 8.29 below should be between 60-80 degrees.

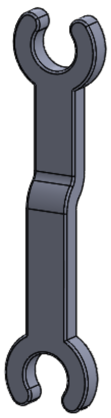

Figure 8.28: The arm

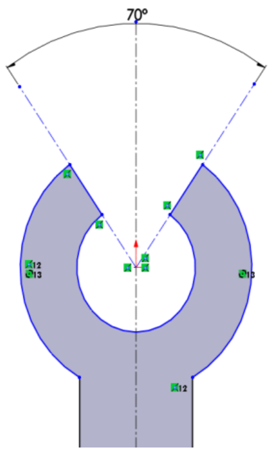

Figure 8.29: The angle for the snap fitting

8.3.1.5 The key

The design of the key is very simple. It is designed to fit into the keyhole. It is also designed for being able to fasten onto the shell so that the user will not lose the key. Since the key will be needed for dismounting, which probably will not happen very often, it is a practical way to store it. The design of the key and the how it is supposed to be used can be seen in figure 8.30 below. To store the key, the user simply snaps the key onto the shell according to figure 8.31.

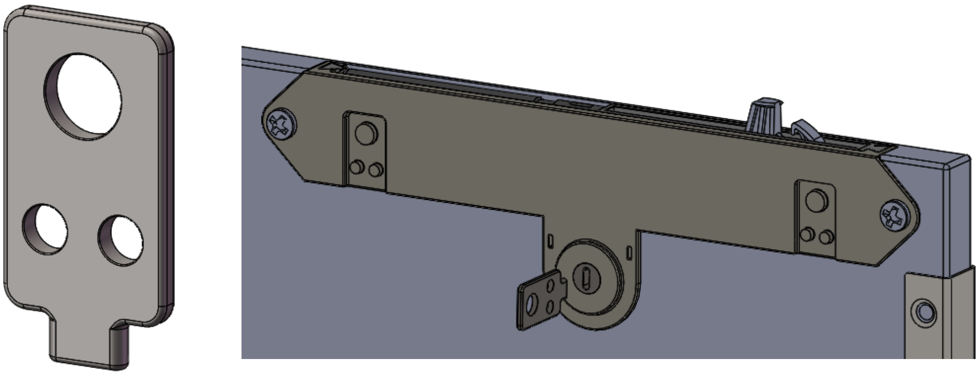

Figure 8.30: The design of the key and how to use it.

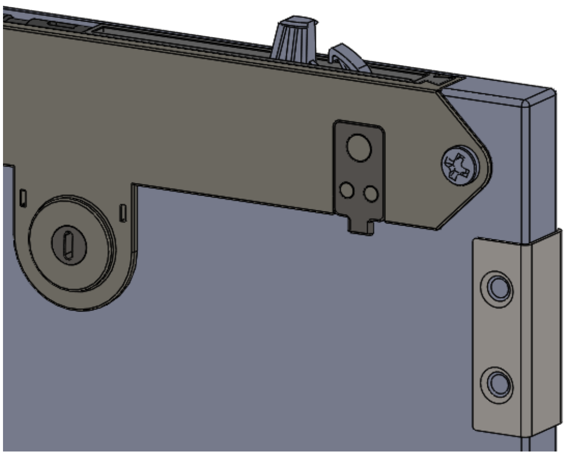

Figure 8.31: How to store the key.

8.3.1.6 The hook

The hook has the same design in this concept as in concept I+. The detailed design can be seen in section 8.2.1.6 earlier in the report.

8.3.1.7 Exploded view

An exploded view for the whole product can be seen in figure 8.32 below.

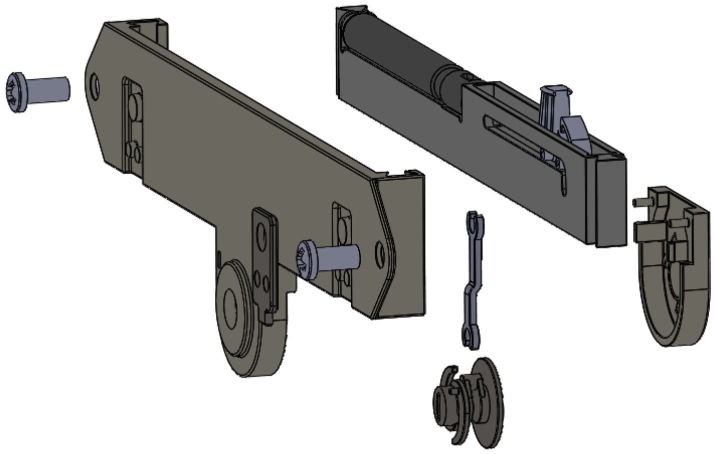

Figure 8.32: Exploded view on concept I++.

8.3.1.8 The doors

Figure 8.33 below shows how the doors need to be milled in order for the SCG of concept I++ to fit.

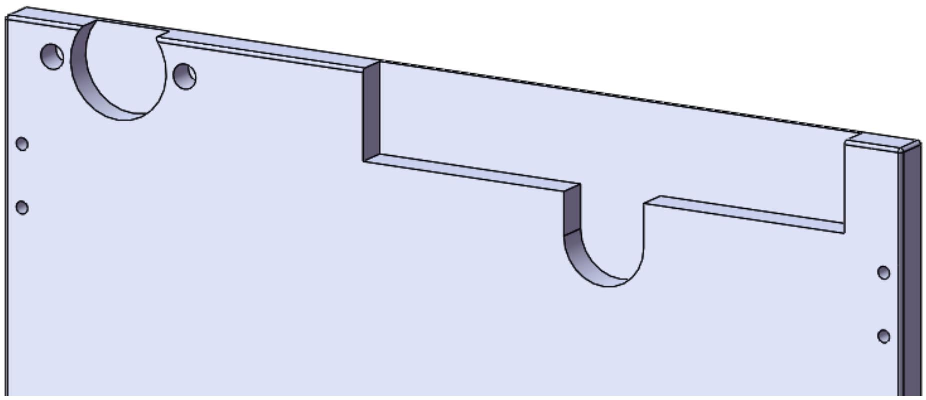

Figure 8.33: Milled tracks on the door.

8.3.2 **Material choice**

The material choice for concept I++ was done through the same way as for concept I+.

8.3.2.1 The base

The base of concept I++ does not have any special feature that differs from concept I+, why it was chosen for them to have the same material. So the material for the base in concept I++ is POM.

8.3.2.2 The shell

Just like for concept I+, the base is now made in POM and the shell should be made in a stronger material for the whole product to withstand the forces. It is chosen to have the same material as for concept I+, so PA6 GF30.

8.3.2.3 The crankshaft

For the crankshaft, Stefan Nilsson presumed that POM should be enough and its low friction coefficient is also an advantage during the twisting.

8.3.2.4 The arm

To make it simple, the arm will also be in POM. S. Nilsson thought that it would be enough to push and pull the SCG. The squeaking noise can be reduced through a surface treatment, but this has not been investigated further.

8.3.2.5 The hook

As in concept I++, the FEM-analyses showed that the hook is strong enough when being in PA6 GF30. It is assumed that this works for concept I++.

8.3.2.6 The key

The key should be as simple as possible and therefore was chosen to have the material ABS. That was the choice because IKEA Components today have a similar product with that material.

8.3.3 **Design for manufacturing**

As previously stated in section 1.3 above, the chosen manufacturing method for the parts is injection moulding. The sections further on in the report explain approximately how the moulds for the parts for concept I++ would have to be designed. Since some of these parts are quite complicated it is only a start of a design that would have to be further developed.

8.3.3.1 The soft closing base

Concept I++ has a few more changes to the inside of the base than the base for concept I+. These, however, are still considered to be such small changes that a very similar mould to the one that is used today, can be used for the base. How the mould looks has therefore not been investigated further since the knowledge is presumed to already exist.

8.3.3.2 The front of the shell

For the shell the mould is quite simple. Just like for concept I+, sliders would have to be used for the tracks on the sides where there are occluded areas (see figure 8.34 below). The most complicated part of the shell was where the front of the shell clicks onto the back of the shell, view figures 8.35 below. This was solved by creating the holes in the shell that can be seen in figure 8.36 below. Without these holes this part would have been incredibly difficult to make, but with this simple solution, the problem was solved.

Figure 8.34: The front of the shell with the undercut analysis.

Figure 8.35: The snap fittings that require the hole for manufacturing.

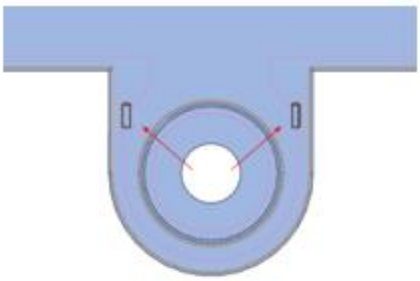

Figure 8.36: The hole on the front of the shell.

8.3.3.3 The back of the shell

For the back of the shell, sliders would have to be used for the snap fittings that latch onto the front of the base (see the red areas in figure 8.37 below). Otherwise the mould could be quite simple.

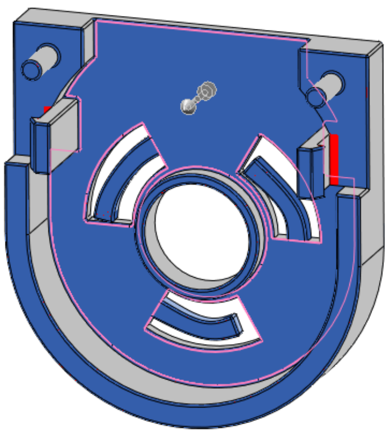

Figure 8.37: The back of the shell with undercut analysis.

8.3.3.4 The crankshaft

The crankshaft is the most complicated part when it comes to the injection mould. Due to its complicated design, there are a lot of occluded surfaces, but after discussions with S. Nilsson, it was concluded that it most likely can be solved with sliders as well. The blue arrows in figure 8.38 below show the direction of the main parts of the injection mould. The red arrows in the same figures show where the sliders would have to go.

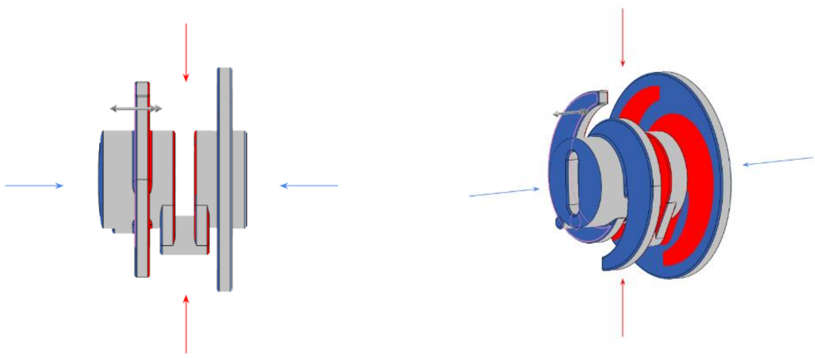

Figure 8.38: The crank shaft with explanatory arrows.

8.3.3.5 The arm

The arm needs a very simple mould without any special features. How the mould would open and close is shown in figure 8.39 below.

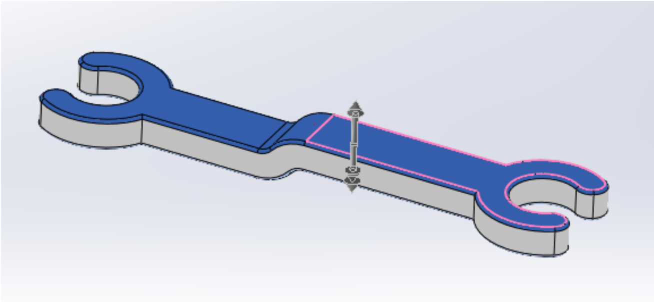

Figure 8.39: The arm with undercut analysis.

8.3.3.6 The Hook

The hook for this concept is the same as the hook for concept I+ and the result for the undercut analysis can be seen in section 8.2.3.3.

9 Result

In this chapter, the result of this thesis is presented and how well it fulfils the specifications. The final prototype is presented and a short evaluation of the democratic design of the concepts.

9.1 Final product

9.1.1 **Rendered images**

9.1.1.1 Concept I+

Figure 9.1 below shows a rendered image of concept I+.

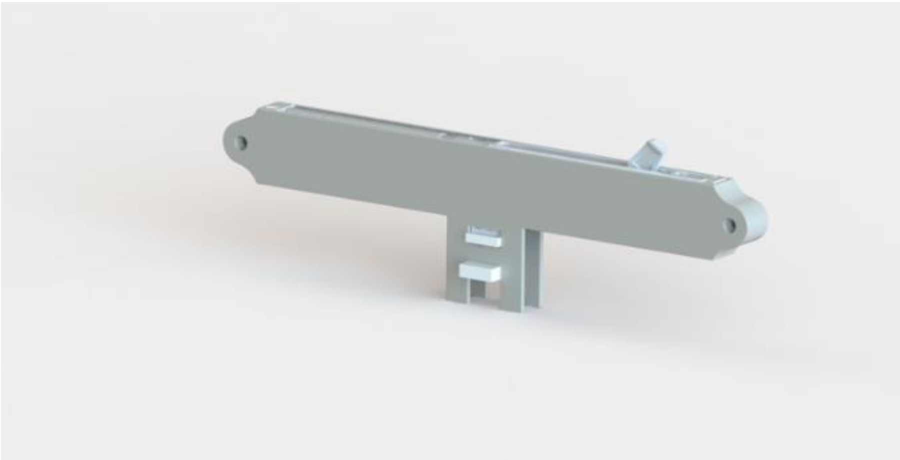

Figure 9.1: Rendered image of concept I+.

9.1.1.2 Concept I++

Figure 9.2 below shows a rendered image of concept I++.

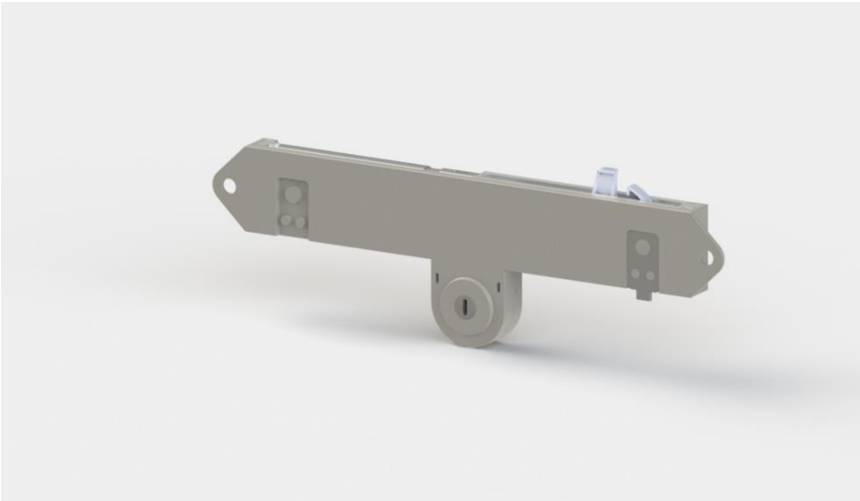

Figure 9.2: Rendered image of concept I++.

9.1.2 Product specifications

To illustrate how well the final concept fulfil the product specification list, one column has been added in tables 9.1 and 9.2 below and on the next page where it says if the specification is fulfilled or not. The subjective specifications has been judged based on the intuition from the design team.

9.1.2.1 Concept I+

Table 9.1: How well concept I+ fulfils the specification stated in the beginning of the project.

No.	Criteria	Importance factor (1-5)	Unit	Margin value	Ideal value	Fulfilled
1	Intuitive for the user	3	Subj.	-	-	Yes
2	Easy to install	4	Subj.	-	-	Yes
3	Material cost	3	SEK	1	0,825	No
4	Ergonomic when installing	3	Subj.	-	-	Yes
5	Few changes on existing doors	2		1	Yes	No
6	No loose pieces to assemble	4	Binary	Yes	Yes	No

Table 9.1 Cont.

7	Few tools needed when installing	1	No.	1	0	Yes
8	Easy to dismount	3	Binary	Yes	Yes	Yes
9	Symmetric SCG	5	Binary	Yes	Yes	No
10	Safety	5		-	-	Yes
11	Robustness	2	Subj.	-	-	Yes
12	Total cost	3	SEK	9,770	<9,770	Cannot know
13	Manage height adjustment	5	mm	± 2	± 2	Yes
14	Material choice – gliding noise	4	Binary	Low noise	No noise	Yes
15	Act as guide and soft closing	5	Binary	Yes	Yes	Yes
16	Depth limitations	5	mm	12	<12	Yes
17	Slam shut test	5	No. cycles	10 times 4 kg	10 times 4 kg	Yes*
18	Durability	5	No. cycles	20000	20000	Yes*
19	Made in plastic	2	Binary	No	Yes	Yes
20	Pressure force from outside	5	N	200	200	Yes
21	Pressure force from inside	5	N	200	200	Yes
22	Intuitive for user	3	Subj.	-	-	Yes
23	Not visible in normal use	5	Binary	Yes	Yes	Yes
24	Dismountable	5	Binary	Yes	Yes	Yes

*Has not been tested, but the hook is similar to the design that it has today which manages the specification

As can be seen, concept I+ fulfils the majority of the specifications. The specifications “few changes on the door” and “no loose pieces to assemble” turned out to be difficult to fulfil. Moreover, the “symmetric SCG” specification is not fulfilled by concept I+. The base is not designed to be used for both left and right door. Despite this, the design team chose to have it as one of the final concepts. That was after consulting with N. Persson and P. Lindberg. They concluded that it is manageable as long as the product has marked which one is for the right and the left door. The total cost was difficult to determine due to lack of information about manufacturing, transport, man-hours etc. The material cost turned out to be higher than the margin value, but the team quickly realised that this margin value was unrealistic.

9.1.2.2 Concept I++

Table 9.2: How well concept I++ fulfils the specification stated in the beginning of the project.

No.	Criteria	Importance factor (1-5)	Unit	Margin value	Ideal value	Fulfilled
1	Intuitive for the user	3	Subj.	-	-	Yes
2	Easy to install	4	Subj.	-	-	Yes
3	Material cost	3	Euro	1	0,825	No
4	Ergonomic when installing	3	Subj.	-	-	Yes
5	Few changes on existing doors	2		Yes	No	No
6	No loose pieces to assemble	4	Binary	Yes	Yes	No
7	Few tools needed when installing	1	No.	1	0	Yes
8	Easy to dismount	3	Binary	Yes	Yes	Yes
9	Symmetric SCG	5	Binary	Yes	Yes	Yes
10	Safety	5		-	-	Yes
11	Robustness	2	Subj.	-	-	Yes
12	Total cost	3	SEK	9,770	<9,770	Cannot know
13	Manage height adjustment	5	mm	±2	±2	Yes*
14	Material choice – gliding noise	4	Binary	Low noise	No noise	Yes
15	Act as guide and soft closing	5	Binary	Yes	Yes	Yes
16	Depth limitations	5	mm	12	<12	Yes
17	Slam shut test	5	No. cycles	10 times 4 kg	10 times 4 kg	Yes*
18	Durability	5	No. cycles	20000	20000	Yes*
19	Made in plastic	2	Binary	No	Yes	Yes

Table 9.2 Cont.

20	Pressure force from outside	5	N	200	200	Yes
21	Pressure force from inside	5	N	200	200	Yes
22	Intuitive for user	3	Subj.	-	-	Yes
23	Not visible in normal use	5	Binary	Yes	Yes	Yes
24	Dismountable	5	Binary	Yes	Yes	Yes
*Has not been tested, but the hook is similar to the design that it has today which manages the specification						

The way that concept I++ fulfils the specifications is almost identical as for concept I+. The difference is that this concept is symmetric and therefore compatible to both the left door and the right door. The material cost turned out to be higher than the margin value, but the team quickly realised that this margin value was unrealistic.

9.2 Prototype

The final prototype were 3D-printed at the workshop at LTH. Figures 9.3-9.5 below show the printed prototypes of the concepts.

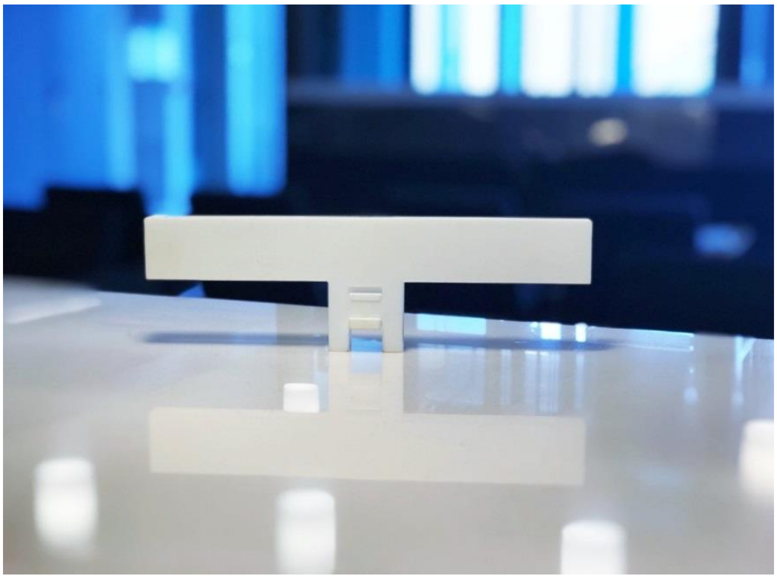

Figure 9.3: Printed prototype of concept I+.

Figure 9.4: Printed prototype of concept I++ from the back.

Figure 9.5: Printed prototype of concept I++ from the front.

9.3 Democratic design

To evaluate the way that the final products fit into the way of designing at IKEA, the democratic design model is used. Due to the both concepts being very similar as a whole, the concepts are evaluated through democratic design together.

9.3.1 **Form**

The designs of the SCG's is easy for the user to just take the product and install it to the door. It is also easy to manufacture with injection moulding.

9.3.2 **Function**

The way of moving the soft closing is very intuitive and leaves very small room for the user to make mistakes.

9.3.3 **Quality**

As is described above, it is difficult to evaluate if the lifecycle of the concepts are long enough. However, since the concepts have the same material and similar designs as is being used at IKEA Components today, it is predicted to have the same quality.

9.3.4 **Sustainability**

The concepts are designed so that all parts are separable and every part only contains one material. This makes it easier to recycle than if it different kinds of materials were combined.

9.3.5 **Price**

Table 9.3 below shows the calculated material price for the new concepts. They are compared to the total material price of the original guide and soft closing used today. To the total material price, the price of the hook is included in all cases. Only the material price is illustrated, since it would be difficult at this stage to calculate all the other costs, such as transport and the price on the mould. Since the final concepts are bigger than the original soft closing, it was expected that the price would be higher. Also, the SCG is one product that has to withstand the same loads as the two products separate, which puts a higher demand on it.

Table 9.3: Table of material costs and differences between new and old device.

	Soft closing + Guide today (SEK)	Concept I+ (SEK)	Concept I++ (SEK)
Material cost	0,825406	1,7432649	2,1426975
Difference		+ 0,9178589	+ 1,3172915

9.4 Recommendations for further development

There are a few things that need to be done before this concept could be a real product. First of all, the actual risk of the "sticky draw effect" should be investigated. The risk was discovered through testing the 3D-printed models, which had the wrong materials and way to coarse tolerances. The concept should be tested with its assigned materials and through that discover whether or not this is a problem.

If it turns out to be a big risk, it is suggested to try some of these suggestions:

- Design a feature onto the base or the shell that balances the base during movement, making it impossible for it to tilt. This is described in section 7.3.1.
- Use a surface finish on the outside of the base or the inside of the shell that makes the material glide smoother against each other.
- Evaluate how fine the tolerances need to be in order for this risk to decrease or be eliminated.

Moreover, a new, more qualified patent search should be made considering these two final concepts. This has not been done at all by the design team due to lack of time.

IKEA Components should also consider the possibility of these concepts work even for other types of storage units or adjust them to work.

A more thorough idea of design for manufacturing should be done. The design team just investigated whether or not it is possible to manufacture with injection moulding, but have not really adapted the design for the general rules. The design of the mould should be done, there was no time for that in this thesis.

A cost analysis for the total cost should be done. This was only made for the cost of the material consumed but of course there are other important cost sources.

10 Discussion and conclusion

This section contains thoughts and reflections concerning the project and its final result. At the end, a summary of the conclusions can be found.

10.1 Discussion

The goal of this thesis was to combine a soft closing with a guide for the standing sliding doors in Mackapär in order to give a more luxurious feeling of the cabinet. The two products that this thesis resulted in have these functions. They manage everything that both a soft closing system and a guide does today and they fulfil all the demands given. If they in the end will give the user a larger sense of luxury is hard to predict. When initiating the project, we did not expect to have two concepts as the final concepts. However, we felt that we could not choose only one of them to present to IKEA Components, why we chose to present both and let them make the decision. Also, we expected to be able to actually try to mount the final product into Mackapär and try the function. When the project was coming to an end, it was made clear that this expectation was a bit overambitious given the time we had.

Design wise, the original soft closing has not been modified as much as we expected. As time went by, we realized how limited the possibility of changing the product actually was. The final concepts that represent the results are bigger and more material consuming than the original soft closing mechanism. This seems like something that could be predicted since two products are being designed to work as one. Nevertheless, we wanted to keep the material cost down as much as possible. If the idea that IKEA had come up with had been possible, it might have been feasible to lower the amount of material. But since this kind of solution proved to be too difficult for the user it was made clear that the use of materials likely would increase.

The delimitations has helped us to really frame the important parts of this thesis. To only look at one storage unit has been good for the simplicity of the design. On the other hand, if we would have looked on other cabinets, the result might have been more universal and applicable on other units. Moreover, something that would have saved a lot of time is if we from the beginning had gotten an even greater understanding of the complexity of the soft closing. For example, the information about how much of it that would be difficult to change, might have shortened the process in some aspects. Some of our early ideas concerned a lot of changes on the hook and on the spring. Co-workers from IKEA Components then predicted that this would be too complicated and would rather not see changes made on these parts. If we would have made that delimitation earlier, it would have made the scope of this thesis clearer and that might have given more time to work on the result.

We are overall satisfied by the choice of methodology set up from the beginning and have tried to follow it as much as possible. Using the methods from Ulrich & Eppinger have been a good tool in order to perform a structured thesis. It was difficult to do everything in its predefined order though. In real life, conditions change and information is added along the way. From our perspective, the majority of the tasks in the methods was performed in parallel which led to some difficulties in the structure of the report. This can also be seen when comparing the actual time plan to the one we estimated. In the end, we decided to have everything in the order that made the most sense in the report, which we feel is the most readable option.

The research that was done gave a wide picture of what needed to be known before starting brainstorming ideas. One thing that we should have done differently is to print prototypes in an earlier stage. The concept that IKEA Components presented to us should have been investigated deeper right away by printing a prototype. After having gotten this idea presented to us, we feel that we might have been influenced by having this idea in our head. If a prototype had been made earlier, we would have discovered that it is hard to make that kind of concept work. This would have saved a lot of time in the brainstorming sessions and we could have put more time in to generating other kinds of ideas from the start. When this idea was eventually ruled out during the testing of the concepts we felt that we started opening up a lot more towards new ideas and we experimented a bit more.

The specifications given from IKEA was used as the “user needs” and therefore no collection of customer data was made. We still believe that collecting data from end users would not give any essential information, since the customer’s only real experience of the soft closing is that it closes the door smoothly and quietly. The “user needs” for this product, we felt, were the needs of how IKEA Components wanted it to work and look, more than how it would be for the end user. Nevertheless, if we would have structured the specifications earlier, we might have had some ideas ruled out earlier. The importance of some of the specifications was not made clear in the beginning. This led to us having some difficulties at first to really understand the complexity and the scope of the product.

The small area of place to work with in the original soft closing turned out to be one of the biggest challenges for us. It sounds fairly easy to design something where one part needs to be able to hide. But to do it in this small area where movements has to have millimetre precision, that is a bigger challenge. We feel that this has been limiting the scope of ideas, giving a rather simple result. On the other hand, there was not much we could do about that.

Other specifications that really complicated the concept generation was “demountable” and “symmetric”. The result might have been easier and more though through if these specifications would not have been in the way. In many cases, we came up with ideas that we felt were really good, but then let down by the fact that these to specifications where crucial. However, in the end one of the final concepts is not completely symmetric, which still turned out to be acceptable.

The generation of ideas is probably the part that we did in the most unstructured way and where there is most room for improvement. We tried to go through the brainstorming in the most open way as possible. However, as we mentioned before, seeing that first idea put restrictions in our head and it was not until we ruled it out that we felt that we really started to explore. Still, the idea that came from IKEA Components was a relevant idea that had to be investigate and that would have been really good if it had worked. So it is hard to say if we really could have done that part any differently. We could have had an even bigger brainstorming in the beginning. It sometimes felt like we moved a little too fast and a lot of the greater ideas came later. If we had stayed in the brainstorming phase longer, some of these ideas might have come up sooner.

For the patent search, we do wish we had been able to know earlier that concept I had a great likelihood of infringing on an existing patent. It could have been checked earlier and it might have given us a little more time at the end. That could have given us time to really work out a better, more thought through result and eliminating the risks with them. But we are pleased with what we have accomplished during this time and since the world of patents is big and complicated, there is a great chance that if would have been difficult to know sooner.

To start printing prototypes of the concepts already after the screening turned out to be a good call. Getting a feel of the concepts so early and being able to test them in real life was very useful. It led to knowledge about good as well as bad things about the concept that could not be discovered in theory. Through that, we could rule out some of the concepts sooner because of something that could only be felt by holding the product. However, as mentioned above, the concept given from IKEA Components should have been made to prototype earlier.

Due to the fact that the concepts cannot be tested exactly as they are meant to be when finalised, it is hard to know whether or not the risk of “sticky drawer effect” is a problem. Two solutions were created in the event that this risk occurs. However these were left at the idea stage due to lack of time. It would result in a more complicated design and more material and we felt it was unnecessary to include it in the final design since it could just as well not be an issue.

The concepts we ended up with resulted from a lot of back and forth, but it is a result that we are really pleased with. A product development process like this really shows that there will be unpredictable problems that come up along the way. We dealt with the problems as they occurred and we believe that our final two concepts are the result of the whole process; even the problems and the concepts that did not work helped us to end up where we did.

We have learned using the people around you that have even more knowledge to work through problems is an effective way to go. As can be seen through this whole report, there are not a lot of references coming from outside of IKEA. This is on one hand positive since it was easy to access information but one the other hand, external information sources can give a broader perspective.

We have found that the initial brainstorming phase is very important. It is worth putting in extra time into it to make sure that you have really gotten as much as possible out of it. This could lead to predicting problems or issues early and then having backups. This also regards the research part of the project. It is vital to collect as much information about the project as possible, before starting too much of the work. Even the tiniest detail can change a lot for the function or appearance of the final product and it is therefore important to know as much as possible. In our case, the subproblems really helped getting a grip of the problem. Nevertheless, it is basically impossible to know everything. It is hard to retain all the new information at the beginning while it is also hard for the person giving the information to know what is important. It is however good to at least be aware of this to make sure you have the best possible circumstances when starting out.

10.2 Conclusion

Two new products combining a soft closing system and a guide has been presented. The two final concepts have different pros and cons, and the recommendation to IKEA Components is to move forward with the one they feel suits their wishes and strategy the most. According to the design team they are both easy for the user, why it is up to IKEA Components to evaluate them.

Furthermore, the risk of the “sticky draw effect” should be evaluated together with the solutions presented in this thesis. It should also be considered to use this solutions in other storage units, giving it a greater value.

This project showed that the idea given from IKEA Components was difficult to realize, even though it seemed like a very smooth solution in theory. It has resulted into two other concepts being fully possible to work as a combined soft closing system and guide for a standing sliding door.

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Appendix A Time Schedule and work distribution

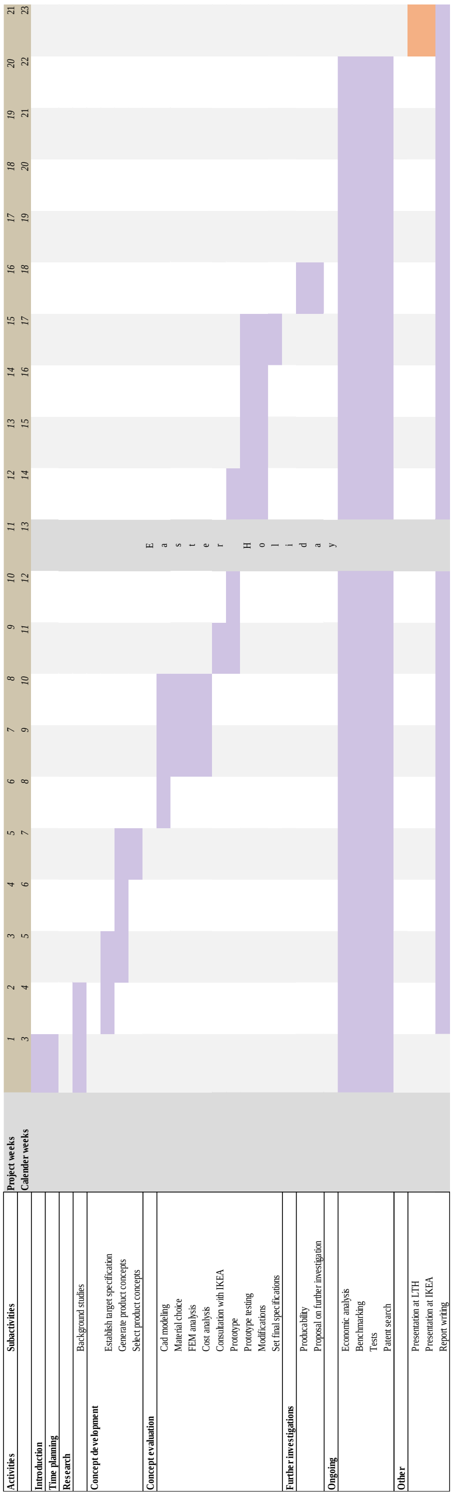
This section shows the GANTT-schedules, the version that was made in the beginning of the project and the corrected version made at the end with the actual times.

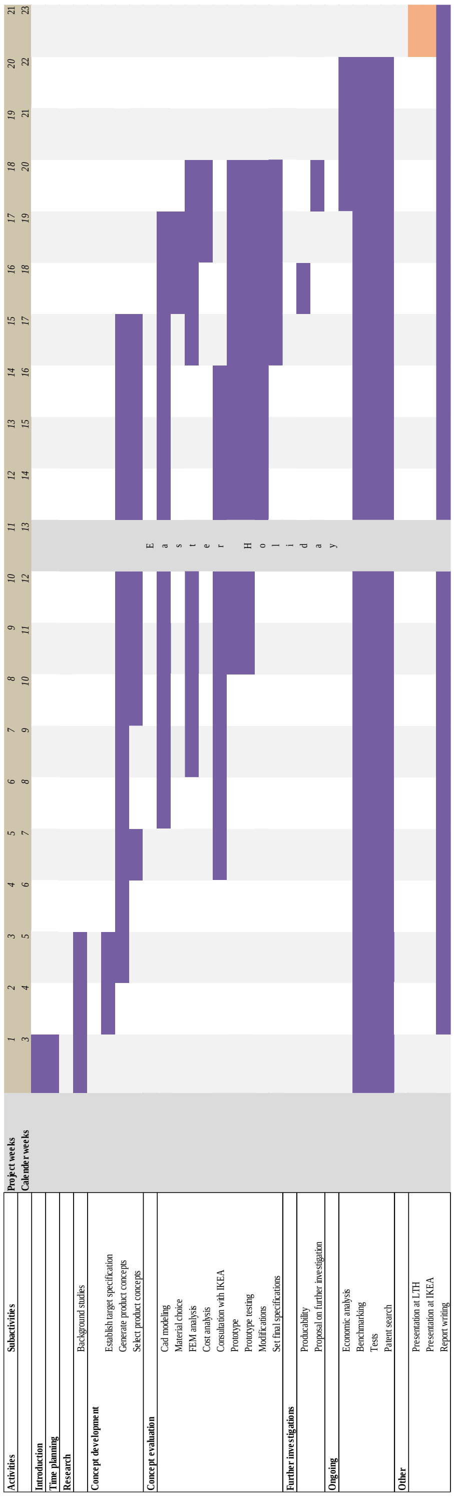
A.1 Work distribution

During the thesis the work was distributed equally between the students. Both student were present for all of the decisions, activities and everything else that was done during the project.

A.2 Time schedule

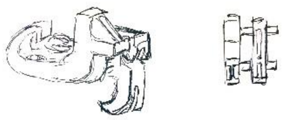
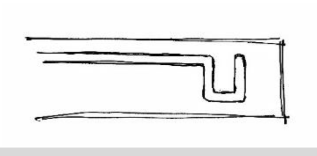
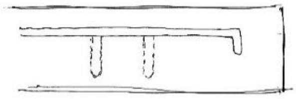
The light purple colour is the, in the beginning, estimated time for the different tasks. The darker purple is the times that in the end was used for each task. The light orange colour represents the different presentation times for the University and at IKEA.

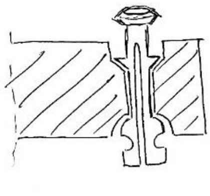
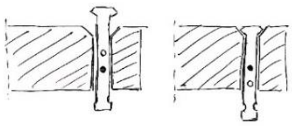
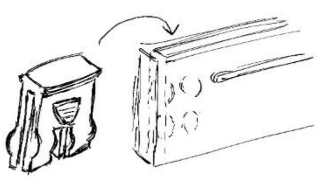
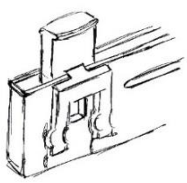

Activities
Subactivities
Project weeks
Calender weeks
Introduction
Time planning
Research
Background studies
Concept development
Establish target specification
Generate product concepts
Select product concepts
Concept evaluation
Cad modeling
Material choice
FEM analysis
Cost analysis
Consultation with IKEA
Prototype
Prototype testing
Modifications
Set final specifications
Further investigations
Producability
Proposal on further investigation
Ongoing
Economic analysis
Benchmarking
Tests
Patent search
Other
Presentation at LTH
Presentation at IKEA
Report writing
Easter Holiday

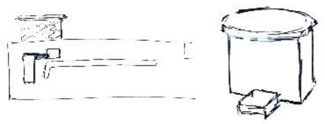
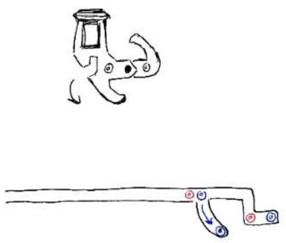
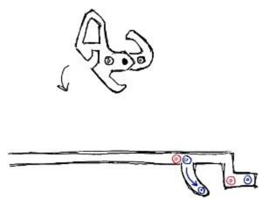
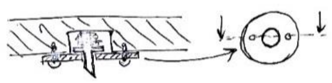

Activities
Subactivities
Project weeks
Calender weeks
Introduction
Time planning
Research
Background studies
Concept development
Establish target specification
Generate product concepts
Select product concepts
Concept evaluation
Cad modeling
Material choice
FEM analysis
Cost analysis
Consultation with IKEA
Prototype
Prototype testing
Modifications
Set final specifications
Further investigations
Producability
Proposal on further investigation
Ongoing
Economic analysis
Benchmarking
Tests
Patent search
Other
Presentation at LTH
Presentation at IKEA
Report writing
Easter Holiday

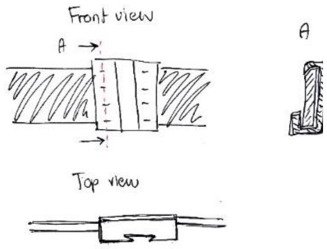
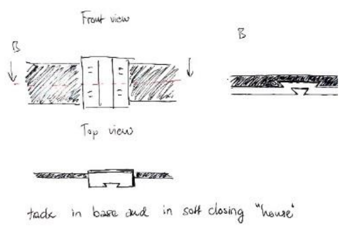
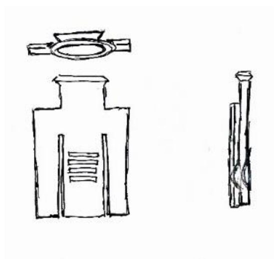
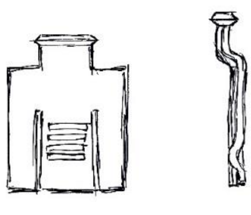
Appendix B Brainstorming Ideas

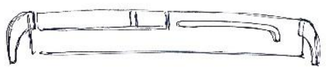
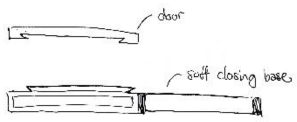
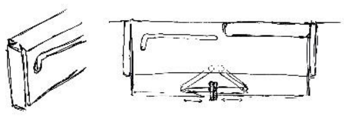
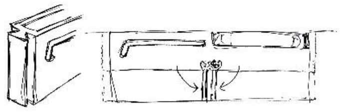
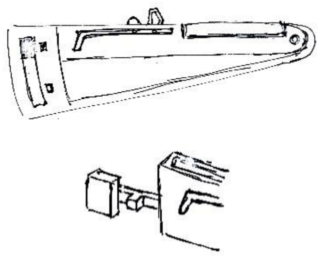
The ideas that were generated during the brainstorming sessions, explanations, drawings and reason for possible dismissal.

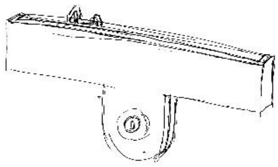
Name of idea	Picture	Description	Reasons for dismissal
1 Guide and hook			
1.2 Guide-hook		For IKEA's two step solution the hook had not been adapted to work as a guide as well as a hook. This idea is the solution for this problem.	Not dismissed
1.3 Side-hook		For this solution the hook has been separate into two with a connection between the two parts. Meaning that the part that hold the spring and the rod is still on the inside and the part that catches the activator is placed on the outside of the soft closing base.	Not dismissed.
2 U-track			
2.1 U-track		The U-track hides the hook/guide by folding it down to the left (in this sketch, it depends on the orientation of the system).	Not dismissed.
3 Inside Track			
3.1 Inside track		The hook/guide is hidden by using tracks located in the middle of the soft closing track.	This looked promising, but preventing the hook from slipping back into the "hiding tracks" was proven to be too complicated.

Name of idea	**Picture**	**Description**	**Reasons for dismissal**
4 Separate Guide			
4.1 Separate Guide 1		This solution is a separate guide that would be fitted on an elongated soft closing. It works as a snap fitting. When it is pulled down the side flex inwards and the guide can be pulled down. This guide is cylindrical. To assemble the guide, the top is unscrewed and then put back when the guide has been placed in the base.	Not dismissed.
4.2 Separate Guide 2		Separate guide. This idea uses a “button” on a spring that flexes out into to the positioning hole on the guide.	This idea was dismissed due to the fact that the “button” proved to be too difficult to construct.
4.3 Separate Guide 3		Separate guide. This solution is a cylindrical guide that is regulated by a spring. To hide the guide the guide is pulled down and the spring is stretched. To lock it in the hidden position the guide is twisted so that the pin leaves the track. To reposition it is just twisted back into the track.	It was quickly decided that the use of springs would be overly complicated and unnecessary and this idea was then dismissed.
4.4 separate Guide 4		Separate guide. This guide is held in place by the snap fittings that fit into the “tracks” on the inside if the soft closing. It is moved up and down by the handle.	Not dismissed.
4.5 Separate Guide 5		Separate guide. Similar to 4.4 but the snap fitting have been moved to the outside of the soft closing.	Not dismissed.

Name of idea	Picture	Description	Reasons for dismissal
4.6 Separate Guide 6		Separate guide. This guide has a rectangular “leg” what slides in the track	This idea was dismissed due to the fact that no solution was found that secured the guide in its top and bottom position.
5 Foldable Hook			
5. 1 Foldable Hook 1		This hook/guide has a joint in the middle that makes it foldable. The track is then used to hide the guide part of the hook to the left in the picture. The different colours represent different positions of the legs of the hook.	This idea was considered to be unnecessarily complicated compared to other solutions and the folding of the hook was deemed to possibly be weakening and it was therefore dismissed.
5.2 Foldable Hook 2		This hook works in the same way as the hook/guide in 5.1 except the guide has not been integrated and is instead separate. Needs to be combined with one of the solutions in 4.	This ideas was dismissed for the same reasons as 5.1.
6 Activator			
6.1 Activator		This idea is a solution for the activator to be able to move. In the original soft closing the hook has to have a springy back end to be able to pass over the activator if it ends up on the wrong side. With this solution that can be done in a different way.	This idea was considered to be too complicated as well as not solving enough of the main problem and was therefore dismissed.

Name of idea	Picture	Description	Reasons for dismissal
7 Snap Guide			
7.1 Snap Guide Base 1		This idea consist of first base that snaps on to the soft closing and then a guide that is attached to the base. The soft closing is placed so that the hook is moved away from rails and only the guide is placed in the rail.	The ideas from 7.1 to 7.4 were all dismissed due to the realisation that the soft closing could not be placed so that the hook would be moved out of the way and the idea was therefore not possible.
7.2 Snap Guide Base 2		This is the second base. This slides on to the soft closing for a little more support in the horizontal direction.	See explanation for 7.1.
7.3 Snap Guide 1		This is the idea for the first guide. It attached by sliding it on to the base.	See explanation for 7.1.
7.4 Snap Guide 2		This is the second idea for the guide. It has the same function as the first guide but with the part that slides in the tracks a bit translocated to the side. This so that it reaches the track if the soft closing is to be placed differently.	See explanation for 7.1.

Name of idea	Picture	Description	Reasons for dismissal
8 Movable base			
8.1 Movable Base 1		For this idea the whole base is moved instead of the hook or the guide. The base is snapped into place in a similar way to of the guide today is fitted.	Not dismissed.
8.2 Movable Base 2		For this idea the soft closing slides on to the door in a milled track. The position of the track is yet to be decided.	This was deemed unnecessary in comparison with better ideas and was therefore dismissed.
8.3 Movable Base 3		This idea is very similar to 8.2, but with the fitting on the ends of the soft closing. The soft closing is held up by two “legs” with a hinge on the middle of the les and a movable hinge where it is attached on the base. The legs are pulled together and locked with a snap fitting.	Not dismissed.
8.4 Movable Base 4		This idea has the same fitting on the ends of the soft closing as idea 8.3, but the base is held up by the legs that automatically unfold when the soft closing is pushed up.	Not dismissed.
8.5 Movable Base 5		For this idea the soft closing is placed in a shell. It is fasted with a snap fitting in on end and spins around the snap fitting like an axis. It is fastened on the other side in two positions. Hidden and not hidden.	Not dismissed.

Name of idea	Picture	Description	Reasons for dismissal
8.6 Movable Base		This idea has a rather complicated inside that was developed during the creation of the 3D-model du to its complexity. It works by using a “key” (a spare part that is attached to the SCG) in the slot on the front of the SCG, shown in picture to the left. When the key is turned the SCG is pushed up by an arm that is attached to the mechanism inside.	Further development.

Appendix C Explanation of product specifications

Criteria	Explanation
Intuitive for the user	How easy it is for the user to figure out how the product is installed. The simplicity of the steps to mount the base into the door and pushing up the guide.
Easy to install	How demanding it is o mount the door with the SCG in it. This is a criteria that needs to be tested in real life to get a sense of it.
Total cost	An estimation of the cost based on the amount of material. The team chose not to take in tools as a factor, since this is estimated to be around the same price for the ideas.
Ergonomic when installing	How demanding it is for the user when fixating the door while it is standing in the unit. This is mostly depending on the handle design and/or the guide design
Changes on existing doors	How much the doors need to be changed in order for the new SCG to be integrated.
Few loose pieces to assemble	The number of loose pieces for the customer to assemble for the SCG.
Few tools needed when installing	The amount of extra tools necessary to install the door/SCG. Today it is fastened with screw and

	screwdriver which should be enough.
Easy to dismount	The simplicity of removing the door and/or the SCG from the storage unit.
Symmetric SCG	The parts that the concept consist of can be used for the unit on the left as well as the right door.
Safety	The risk of anyone hurting themselves when using the product
Robustness	The amount of material to withstand forces or tearing.
Total cost	Cost of manufacturing, material and producing
Manage height adjustments	The wheels at the bottom of the doors can be adjusted. The height of the door can vary +-2 mm. The guide should be designed to manage this
Material choice	The material should be chosen so that no noise occurs during use.
Act as a guide and soft closing	The final product has to have the function as a guide and a soft closing integrated
Depth limitations	The depth is limited by the distance between the two sliding doors. The distance in Mackapär is 14, but the SCG should be a bit smaller than that.
Slam shut test	This is a standard for this kind of unit. The doors, and therefore the SCG should manage the door being slammed shut 10 times with a force of 4 kg.
Durability	This is a standard for this kind of unit. This concers that the door should in daily use manage being opened and closed normally for 20000 times.
Made in plastic	A request but not a demand.

Pressure force from outside	The SCG should manage someone pushing the door from the outside in the Z-direction with 200 N.
Pressure force from inside	The SCG should manage someone pushing the door from the inside in the Z-direction with 200 N.
Not visible during normal use	The SCG should not be visable when looking at the door from the outside.
Dismountable	It should be possible for the user to dismount the SCG and the door.

Appendix D Calculations material cost

	Soft closing base today	Base	Hook	**Guide today**	Base	Tip	**Concept I+**	Shell	Base	**Concept I++**	Shell front	Shell back	Crank shaft	Arm	Key	Base	**Guide-hook**
Material		*PA6 GF30*	*PA6*		*PA6 GF15*	*POM*		*PA6 GF15*	*POM*		*PA6 GF15*	*PA6 GF15*	*POM*	*POM*	*ABS*	*POM*	*PA6 GF30*
Mass		0,01543	0,00118		0,011808	0,00336		0,0465187	0,025		0,05634	0,00377	0,00244	0,00041	0,0006867	0,023	0,00138
Cost		0,41661	0,0295		0,318816	0,06048		1,2560049	0,45		1,52118	0,10179	0,04392	0,00738	0,0171675	0,414	0,03726
Total cost	**0,44611**			**0,379296**			**1,7060049**			**2,1054375**							
Assembled	**0,825406**						**1,7432649**			**2,1426975**							
Difference							*0,9178589*			*1,3172915*							