Development of Sliding Mechanism for IKEA Furniture

Emma Kroon & Amanda Nilsson

DIVISION OF PRODUCT DEVELOPMENT | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2019

MASTER THESIS

Development of Sliding Mechanism for IKEA Furniture

Emma Kroon & Amanda Nilsson

Development of Sliding Mechanism for IKEA Furniture

Published by

Department of Design Sciences
Faculty of Engineering LTH, Lund University
P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Product Development (MMKM05)
Division: Product Development
Supervisor: Per-Erik Andersson
Co-supervisor: Mikael Reimer & Niclas Persson
Examiner: Giorgos Nikoleris

Abstract

This Master Thesis cover a product development process based on an investigation of an existing product at IKEA. A study regarding potential improvements of the existing low-cost roller slide was performed. The roller slide enables opening and closing of drawers in some of today's IKEA furniture. The existing product contains of four metal plates where each plate has a plastic wheel attached by a rivet and a washer. Today's solution fulfills all the technical requirements, but the perceived quality of the end consumer is considered being poor. The aim was to investigate potential improvements of the roller slide by improving the stability and decreasing the generated noise during use. The study was conducted at IKEA Components AB, a subsidiary company within the IKEA corporate group.

An extensive pre-study including studying the existing product, similar and alternative solutions was performed to gain knowledge and inspiration. New design solutions as well as adjustments of the existing roller slide were considered. The number of ideas was narrowed down due to time and cost limits. In consultations with supervisors, the new design solutions were discarded. Concepts were generated, screened and evaluated based on tested prototypes. The remaining concepts were further developed and assessed based on a qualitative *Blind Test*.

Two concepts were recommended as potential solutions to IKEA Components. One of the concepts, Concept C.1, consist of the current roller slide where the wheels on the drawer are fixed mounted and not able to rotate. The other concept, Concept C.1+, is a development of the first mentioned concept and the non-rotational wheels are replaced by plastic blocks. It is up to IKEA Components to evaluate whether they fulfil all their requirements. For future implementation, both concepts have to be further developed.

Keywords: Product development, IKEA, sliding mechanism, slide, wheel

Sammanfattning

Denna rapport behandlar en produktutvecklingsprocess som baseras på en undersökning av en befintlig produkt hos IKEA. En studie om potentiella förbättringar av den befintliga, lågpris rullexpandern var genomförd. Rullexpandern används för att öppna och stänga lådor i några av IKEAs möbler. Produkten består av fyra metallskenor där respektive skena har ett plasthjul monterat med hjälp av en nit och en bricka. Dagens lösning uppfyller de tekniska kraven men den upplevda kvalitén hos slutkonsumenten anses vara bristande. Syftet var att undersöka möjliga förbättringar av rullexpandern genom att öka stabiliteten och minska det genererade ljudet under användning. Studien genomfördes på dotterföretaget IKEA Components AB.

En omfattande förstudie om den befintliga produkten, liknande och alternativa lösningar genomfördes för ökad förståelse och inspiration. Både nya lösningar och enklare justeringar av den befintliga rullexpandern övervägdes. Antalet idéer reducerades baserat på tid- och kostnadsbegränsningar. I samråd med handledare eliminerades även de nya lösningarna. Koncept genererades, sållades och utvärderades baserat på testade prototyper. De kvarvarande koncepten vidareutvecklades och utvärderades baserat på både kvantitativa och kvalitativa tester. Båda testerna utvecklades och genomfördes av design teamet i samarbete med rådgivare på IKEA.

Två koncept rekommenderades som potentiella lösningar till IKEA Components. Ett av koncepten, Koncept C.1, består av den nuvarande rullexpandern där hjulen monterande på lådans skenor är fixerade och kan inte rotera. Det andra konceptet, Koncept C.1+, är en vidareutveckling av det tidigare nämnda konceptet där de icke roterande hjulen är ersatta med plastblock. Det är upp till IKEA Components att vidare utvärdera ifall koncepten uppfyller alla krav. För framtida implementering krävs vidareutveckling av båda koncepten.

Nyckelord: Produktutveckling, IKEA, glidmekanism, skena, hjul

Acknowledgements

This Master Thesis has been performed at the Division of Product Development at Lund's University, Faculty of Engineering and in collaboration with IKEA Components AB. The project was created and founded by co-workers at IKEA Components and we would like to thank all the people involved for giving us this opportunity. It has been a challenging, instructive and memorable experience which will be of great value for the future.

We would like to give a special thanks to our supervisor, Mikael Reimer, and our manager, Niclas Persson, at IKEA Components, for supporting and guiding us through the thesis. We would also like to thank our supervisor at Lund Faculty of Engineering, Per-Erik Andersson, for your positivity, support and for always being available.

Further, we would like to thank all the people supporting us along the way. Marcus Johnson, for the valuable help regarding tests and test equipment. Henrik Holmgren, Lars-Gunnar Petersson and Fritz Wallis for your help with prototype manufacturing and other useful input regarding the mechanical design. Katarina Elner-Haglund for your great engagement and for sharing ideas and knowledge regarding thermoplastic materials. Finally, we would like to thank all the co-workers at IKEA for welcoming us and for contributing to this great experience.

Lund, May 2019

Emma Kroon & Amanda Nilsson

Table of Contents

1 Introduction

This section presents the introduction of the project including background of the design team and the company, problem description, delimitations, goals and key people for this Master Thesis.

1.1 Background

1.1.1 **Team Background**

The design team consists of Emma Kroon and Amanda Nilsson, two students studying mechanical engineering at the Faculty of Engineering at Lund University. With specialization in product development, the team has achieved knowledge and experiences within the subject, including design aspects and computer knowledge.

1.1.2 **Company Background**

IKEA was founded 1943 in Sweden by Ingvar Kamprad. From being a small, local company, IKEA is today one of the most known companies in the world within the area of home interior [1]. All the products IKEA are offering is based on their vision: *"To create a better everyday life for the many people".* Together with the business idea: *"To offer a wide range of well-designed, functional home furnishing products at prices so low that as many people as possible will be able to afford them"*, IKEA offers a wide range of furniture, including kitchen solutions, home decoration and bathroom interior, within the lower price range [2] .

The IKEA Group consists of many companies where IKEA Components AB is one of them. IKEA Components designs and develops most of the mechanisms and components used in the furniture developed by IKEA of Sweden AB, which is another company within the IKEA Group. Hinges, sliding solutions, accessories and roller slides are example of products that IKEA Components AB develops. The organisation of IKEA Components is divided into specific departments where each department is responsible for a specified mechanism and components. The Master Thesis will be conducted within the department of "Open and Close" which is responsible for the mechanism related to opening and closing of furniture components. Roller slides used in drawers and hinges on cabinets are example of products that are developed within this department. The team will have access to the department, which is located in Älmhult, Sweden, where they also will be able to work on a daily basis.

1.2 Problem Description

Many of the furniture IKEA offers, contains an open and close function based on a sliding mechanism. There are different categories and types of this feature based on quality, function and price range. The product that will be examined in this Master Thesis is a roller slide, which enables opening and closing of drawers. The current roller slide is the one IKEA applies for the lower price furniture. Within this category of furniture, the slide does not require any advanced mechanisms such as soft closing systems. The main objectives with this slide are to fulfil its sliding function while offering a trustworthy quality and keeping the price low.

Today, the roller slide is involved in for example the popular furniture series called MALM, HEMNES and KALLAX, see Figure 1.1-Figure 1.3. One set of roller slide is required to enable opening and closing of a drawer. A set of roller slides contains of two pair of slides, see Figure 1.4, where one pair contains of two metallic plates and two plastic wheels mounted with washers and rivets. The two pairs are identical apart from the fact that the design is mirrored. The wheels are fixed mounted on one plate each and the plates are sliding relative to each other. The part of the slide that is mounted on the cabinet is most often preassembled whereas the part of the slide related to the drawer must be mounted by the end consumer. Since the slide is mounted by the end consumer, the precision of the mounting differs from each case. In order to minimise the error of failure, there are pre-drilled holes on the drawer where the slides shall be mounted. A more detailed description of the roller slide is presented in chapter 3.

The perceived quality of the original design of the roller slide is considered being poor due to loud noise, being unstable and wobbling while sliding. The task of this Master Thesis is to investigate potential solutions in order to improve the perceived quality of the end consumers. The investigation will be performed through a wide perspective since many parameters effects the quality of the slide. Those parameters, among others that might be detected during the project, are the selection of materials, dimensions and tolerances, the mechanism, lubricants and coatings.

Figure 1.1 IKEA's dresser called MALM [3].

Figure 1.2 IKEA's dresser called HEMNES [4].

Figure 1.3 IKEA's dresser called KALAX [5].

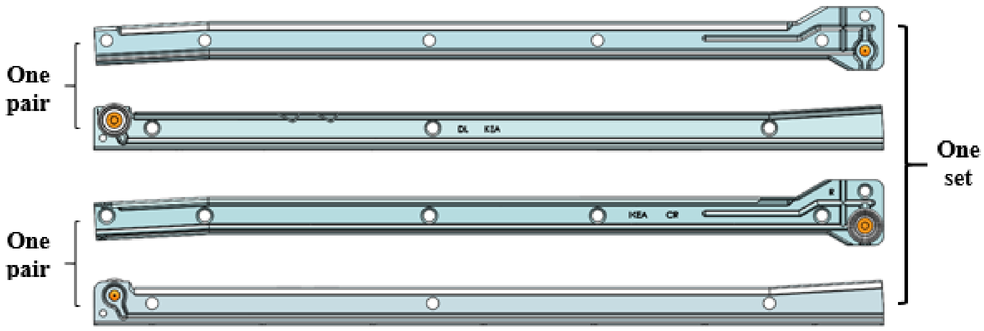


Figure 1.4 One set of roller slide contains two pair of slides where each slide has a plastic wheel mounted.

1.3 Delimitations

The prerequisites of the project were conducted by IKEA Components. Since the main goal with the project is to improve the perceived quality of the roller slide, new design solutions and potential adjustments of the roller slide will be investigated. New design solutions refer to re-designing the roller slide while adjustments refer to more simple modifications of the original design.

The roller slide is allowed to be adjusted but the changes have to interact with existing products. Current tolerances of the furniture, where the roller slide is applied, must be taken into consideration since those are not allowed to be changed. The tolerances regarding the roller slide are allowed to be investigated and potentially changed as long as the economic aspects are considered. Due to the mass production of the slide, all considered changes must be economically investigated in order to keep the total cost low.

Regarding the overall project, the time schedule and the economic aspects are a part of the delimitations. Due to the time schedule of the project, all potential solutions to the problem might not be investigated in the same extent. Thereby are the different solutions prioritised based on preconditions, plausibility, economical, time and manufacturing aspects. The economic aspects of the project are limited based on IKEA Components budget regarding for example prototypes and other expenses.

1.4 Goals

The main goal with this project is to give IKEA Components an examination and potentially a recommendation of improvements regarding the specified roller slide. No specified solution is required from IKEA Components, but all information and evaluation are of value.

The recommendation refers to potential and investigated improvements of the roller slide, by means, developing a more exclusive perceived quality of the product. This will be achieved by stabilizing the slides, minimising the unpleasant noise and prevent the wobbling while sliding. By generating and evaluating product concepts, the objective of the project will be obtained. The concepts will consider material selection, dimensions and tolerances, lubricants and coatings. To evaluate the concepts, tests will be performed on both the original roller slide and on developed prototypes. Other aspects such as reliability, time and economical perspectives will be taken into consideration during the final evaluation.

1.5 Key People

Table 1.1 presents the key people in this Master Thesis.

Table 1.1 Key people in this Master Thesis.

Name		Role
Mikael Reimer	Requirement Engineer for Open and Close ICOMP	Supervisor
Niclas Persson	Deputy EQR Development Manager for Open and Close ICOMP	Manager
Marcus Johnson	Test Engineer, Test Labatory	Advisor on project (Tests)
Henrik Holmberg	Pattern Shop Manager for Prototype Shop Development at IKEA of Sweden	Advisor on project (Prototypes)
Lars-Gunnar Petersson	Prototype Engineer for Metal Prototyping at IKEA of Sweden	Advisor on project (Prototypes)
Fritz Wallis	Prototype Engineer for Metal Prototyping at IKEA of Sweden	Advisor on project (Prototypes)
Carl Ervér	Intellectual Property Leader, Business Navigation Department IoS	Advisor on project (Patents)
Katarina Elner-Haglund	Lecture and M. of Sci. in Chemical Engineering, with specialization polymers, at the Faculty of Engineering, Lund University	Advisor on project (Polymer materials)
Caj Karlsson	Key Account Manager/Sales coordinator at Hexpol TPE AB	Extern expertise (Thermoplastic elastomers)
Hans Walter	Lecturer at Production and Materials Engineering at the Faculty of Engineering, Lund University	Advisor on project (Solution)
Rikard Hjelm	Doctoral at Machine Elements at the Faculty of Engineering, Lund University	Advisor on project (Solution)

2 Methodology

This section covers the method used for this project including planning, strategy, research and the development process.

2.1 Planning

The Master Thesis started with an introduction of the problem in order to achieve an idea of its extent, goals and delimitations. Activities required to complete the project were identified and a defined time duration was assigned to each activity. The different time durations were based on the relevance of the activity in relation to the goal of the project. Co-workers at IKEA Components were also consulted during the time scheduling. Based on this, a predicted Gantt-Schedule was made as shown in Appendix A. The project was expected to be performed during a period of 20 weeks and the timeline shows the activities together with their estimated duration. An updated version of the time schedule with the actual duration time is shown in Appendix A.

2.2 Research

The development process was initiated with a research within the subject to achieve a better understanding of the problem. The IKEA store in Älmhult was visited to understand and compare how the roller slide perform in different furniture. Other sliding mechanisms were also examined to attain an idea of the differences regarding the perceived quality, noise and wobble during sliding. To obtain a broad perspective of existing solutions, other stores with similar products using sliding mechanisms, were visited. Inspiration was collected from drawers at Mio, Jysk and Miljögården in Lund and further information about those visits are found in section 5.3. Furthermore, the physical roller slide was investigated together with related CAD-models. One of the most popular furniture called MALM, which contains the roller slide of interest, was mounted by the design team. This in order to identify and understand potential sources of error during the mounting process. The furniture was also observed during the performance of standardized safety and quality tests required by IKEA. In addition, detailed information and specifications according to the roller slide were given from the co-workers at IKEA Components.

2.3 Approach and Design Process

The process for this project was based on the product development process described in the book *Product Design and Development* written by Karl T. Ulrich and Steven D. Eppinger [6]. To make the model more adapted for this Master Thesis, the model was slightly modified to fit the project.

2.3.1 **Design Process Ulrich and Eppinger**

The product development process stated by Karl T. Ulrich and Steven D. Eppinger [6] is a preferably model to adopt when performing a complete product development process. The model is presented in Figure 2.1 and consists of seven phases. The first phase "Identifying customer needs" aims to understand and define the customers' needs including latent, hidden and explicit needs. The phase is followed by the second phase, "Establish target specifications". In this phase, a target specification is established by translating the customer needs into technical terms. When the target specification is set, the design process begins in the following phase "Concept generation". The aim with this phase is to investigate and develop product concepts based on the customer needs. The generated concepts are then evaluated during the upcoming phase, "Concept selection". The concepts, that are the most promising in relation to the objectives, are then further analyzed by being tested in the phase "Concept testing". The final specifications of the design are established in the phase "Set final specifications" and in the last phase, "Plan Downstream Development", a detailed development schedule for the final concept is created. Economic analysis, benchmarking, test models and prototypes are done continuously throughout the development process.

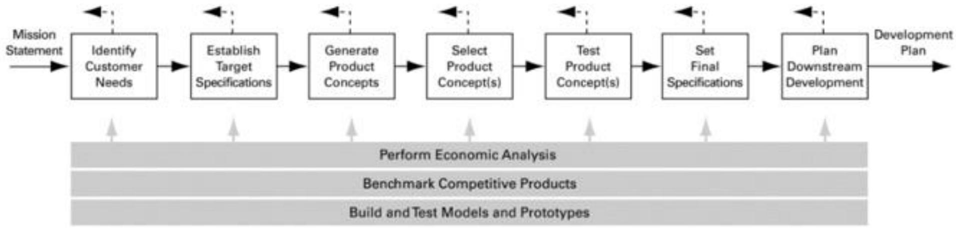


Figure 2.1 The design process according to Ullrich and Eppinger [6], p.74.

2.3.2 **Adjusted Design Process**

The process of this Master Thesis followed the product development process established by Karl T. Ulrich and Steven D. Eppinger [6] to a high extent. Since the project is based on an already existing product, the model presented in Figure 2.1 was slightly adjusted in order to suit the project. The modified and applied model for this project is presented in Figure 2.2. The main adjustments that were made was regarding the two phases “Identifying Customer Needs” and “Final Downstream Development”. The phase “Identifying Customer Needs” was replaced with “Research” since established specifications, requirements and wishes were given from IKEA Components as given prerequisites. The “Research” phase was used to collect relevant information from IKEA Components, IKEA of Sweden and associated products. The seventh step in the original method, “Final Downstream Development”, was replaced with “Final recommendation”, since that was the main goal with this Master Thesis. Lastly, the phase “Patent search” was added as a continuously activity during the development process. The activity was added since it is important for IKEA Components to ensure that no infringements are made on patented solutions.

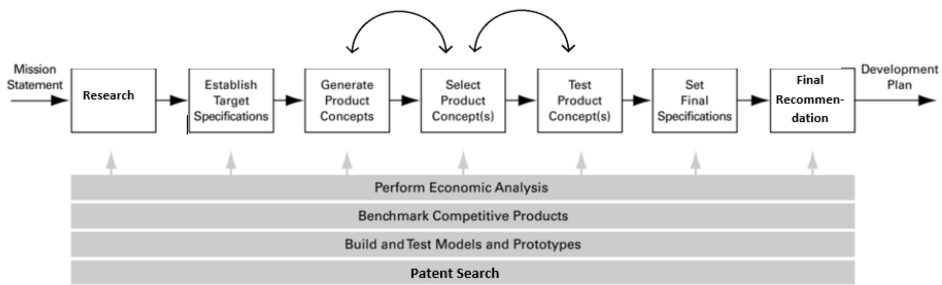


Figure 2.2 The adjusted design process to suit this project.

2.3.3 **Resources**

The method of finding relevant information for the project highly depend on the type of sought information. Internal knowledge as product specifications, current manufacturing methods, etcetera, are to be found by consulting supervisor and co-workers at IKEA Components and other subsidiaries of IKEA. External resources as expertise at Lund Faculty of Engineering, scientific literature and reports as well as internet and contact with relevant suppliers and competitors were conducted to gain information, inspiration and recommendation. The resources applied for the project were continuously changed based on the generated ideas and concepts.

3 Additional Background

This section describes the research process for the project used to achieve a greater understanding of the product and the problem. The parts and the assembling of the roller slide are described as well as how the opening and closing mechanism works. Data is collected from a previous market survey conducted by IKEA concerning drawers. A test is developed and performed on the original roller slide with the aim of acquire reference values. In addition, the prototypes previous developed by IKEA Components are described and tested.

3.1 Roller Slide

The purpose of the roller slide is to enable opening and closing of drawers. This type of roller slide is used within the low-cost furniture category of IKEA. To fulfill the function, one roller slide set is needed. A set consists of four slides. Two slides are mounted on the cabinet of the furniture and the other two are mounted on the drawer of the furniture. Within the category of roller slides, IKEA Components offers different lengths of the roller slide depending on the depth of the drawer. The existing lengths are 550, 450, 385, 350, 330 mm. This project will be based on one of the most common dressers within the low price category called MALM, as shown in Figure 3.1. The length of the roller slide will therefore be based on the depth of the MALM drawer, which is 450 mm.

Figure 3.1 The dresser called MALM [3].

3.1.1 Definition of the Roller Slide

A roller slide set contains of four slides, see Figure 3.2. Each slide consists of a plate, a wheel, a rivet and a washer, see Figure 3.3. The design of the slides differs depending on its placement and will therefore be defined as either right or left side as well as either being placed on the cabinet or on the drawer. The slide positioned at the left-hand side of the drawer is called drawer left (DL) and its interacting slide, placed on the cabinet, is called cabinet left (CL). On the right hand side, the slide positioned on the drawer is called drawer right (DR) and its interacting slide, placed on the cabinet, is called cabinet right (CR), see Figure 3.4 for further explanation.

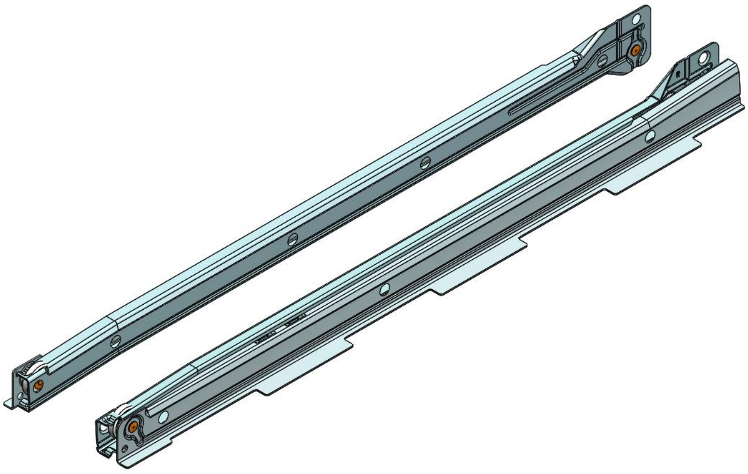


Figure 3.2 One set of roller slide consist of four slides.

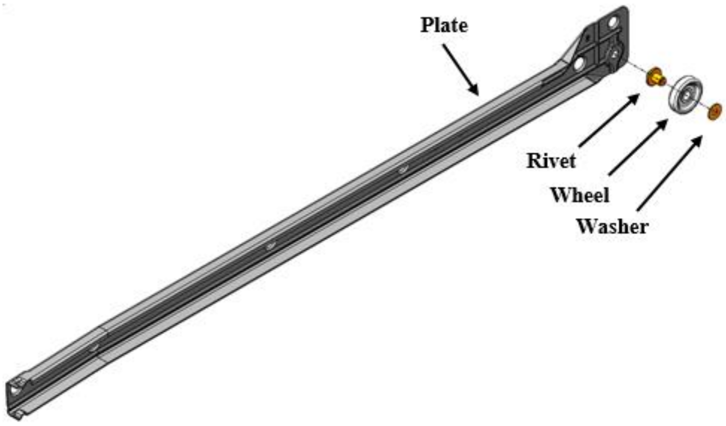


Figure 3.3 A roller slide consisting of a plate, a rivet, a wheel and a washer.

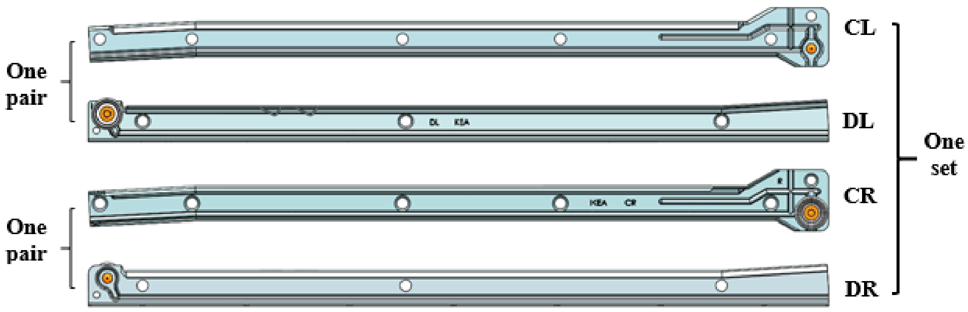


Figure 3.4 The four slides and how they are related.

3.1.2 The Design of the Roller Slide

The design of the four slides slightly differs from each other due to function and position. The plates as well as the plastic wheels have design variations. Both the plates and the wheels are designed differently depending on whether they are placed on the drawer or on the cabinet. The same rivets and washers are used on all four slides and the design of those are therefore independent of its position or slide.

3.1.2.1 The Plates

The four metal plates have a length of 450 mm and a thickness of 0,9 mm. The plates are made of sheet metal which are punched and bended into correct design. An iron-based powder coating is then applied to the plates to prevent corrosion and to decrease the friction. The two plates mounted on the cabinet, CL-plate and CR-plate, have a similar but mirrored design depending on being positioned on the left- or right-hand side, see Figure 3.5. The DL-plate and the DR-plate have also a similar but mirrored design. The design of the plates keeps the drawer in place and the drawer plates have two safety stops integrated in the design to prevent the drawer to slide of the cabinet, see Figure 3.6. The DL- and DR-plates are slightly angled in the front while the CL- and CR-plates are angled at the back, see Figure 3.7. The angle is added to achieve a smooth backwards sliding effect while closing the drawer.

To make sure that the function of the roller slide is independent of the tolerances of the furniture, the plates of CR and DR are designed with a guide. The guide keeps the wheels in place and is designed by a slightly bended metal sheet, see Figure 3.8. In order to maintain the coarse tolerances, the CL- and DL-plates does not have the guides which enables the drawer to move in the horizontal direction.

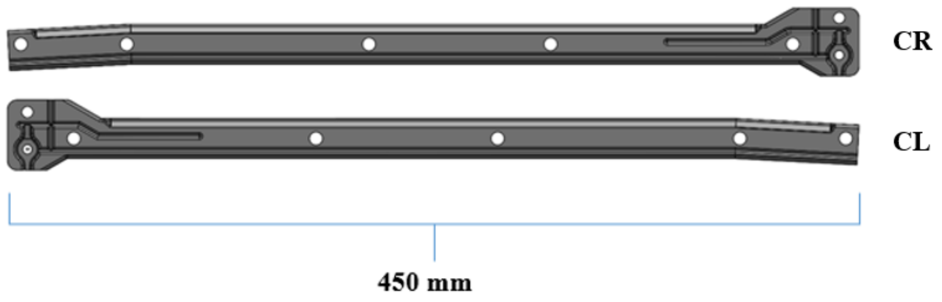


Figure 3.5 General design of the cabinet slides.

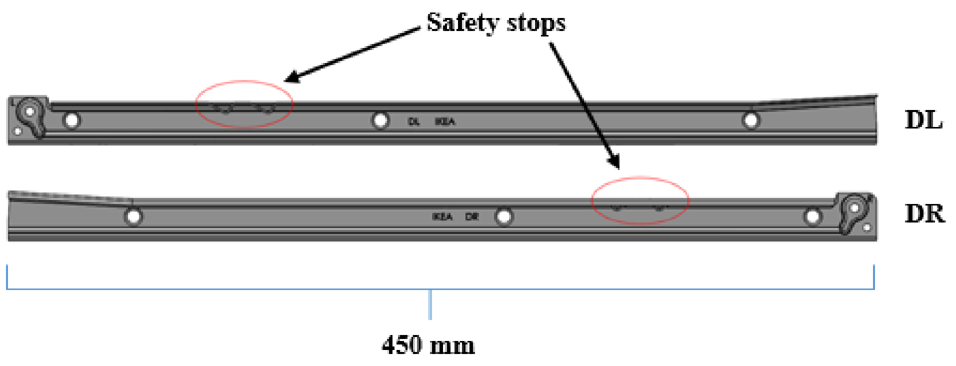


Figure 3.6 Placement of the safety stops on the drawer slides, DL and DR.

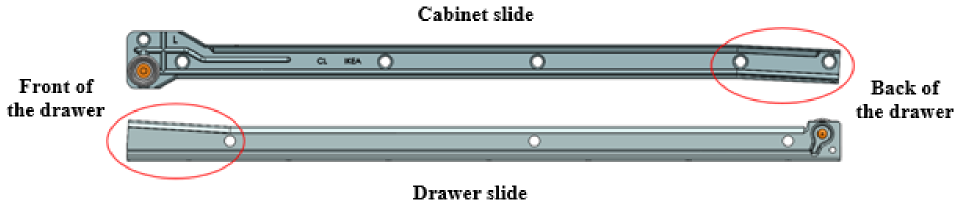


Figure 3.7 Detailed view of the angled parts of the slides.

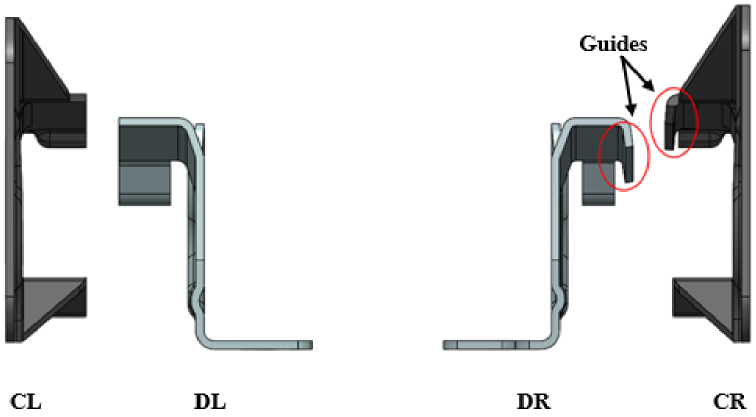


Figure 3.8 Side view of the four plates, showing the guides on DR and CR.

3.1.2.2 The Wheels

The wheels mounted on the drawer slides, DL and DR, are identical and differs from the ones mounted on the cabinet slides, CL and CR. The wheels mounted on DL and DR are placed at the back of the plates in relation to the front of the drawer. On CL and CR, the wheels are instead placed in the front, see Figure 3.9 for further explanation. The dimension of the wheels mounted on the drawer slides have a diameter of 19 mm while the diameter of the wheels on the cabinet slides are 20 mm, see Figure 3.10. The wheels are designed with different dimensions in order to make the drawer slightly slide backwards by itself. All four wheels have an inner diameter of 5 mm and are made in the plastic material acetal (POM). The wheels are manufactured by injection molding, using a mold with multiply cavities.

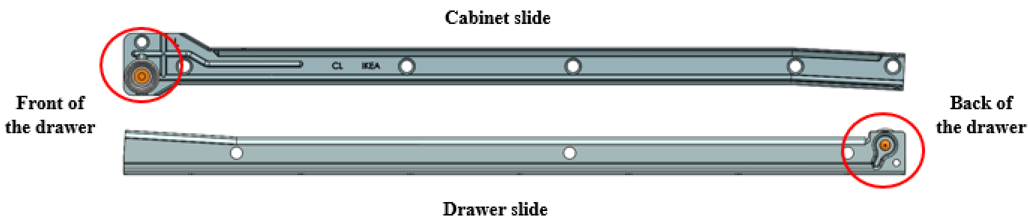


Figure 3.9 Position of the wheels on the cabinet and the drawer slide.

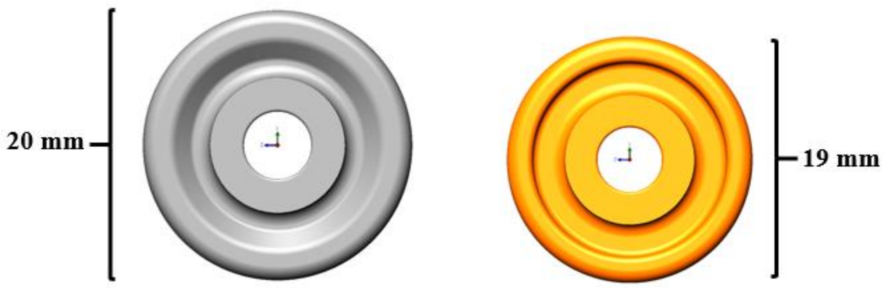


Figure 3.10 The diameter of the grey cabinet wheel and the orange drawer wheel.

3.1.2.3 The Washer and the Rivet

The rivet and the washer are used to mount the wheel on the plate. IKEA have specific requirements on the rivet and washer which the supplier of IKEA follows when purchasing. The geometry of the rivet makes sure that the wheel and the washer are correctly positioned and prevents thereby the washer from locking the rotating wheels. Both the rivet and the washer are made of steel and have a nickel plating to prevent corrosion. The rivet is presented in Figure 3.11 and the washer in Figure 3.12 below.

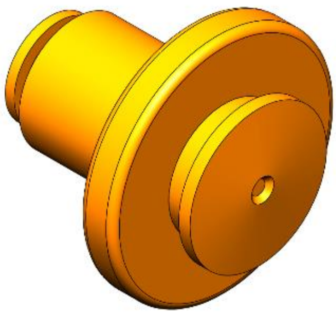


Figure 3.11 The rivet.

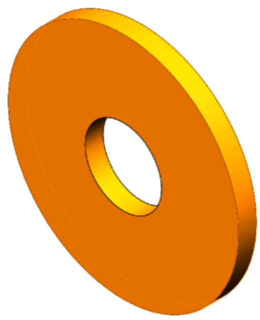


Figure 3.12 The washer.

3.1.2.4 The Mounting

The assembling of the four slides, CL, DL, DR and DR, are identical. Figure 3.13 presents an exploded view of the order in which the components are mounted. The rivet is enclosed to the plate by adding a high pressure at the end of the rivet. Once the wheel is placed on the rivet, the washer is added on the rivet. The washer is locked in place by flattening the rivet.

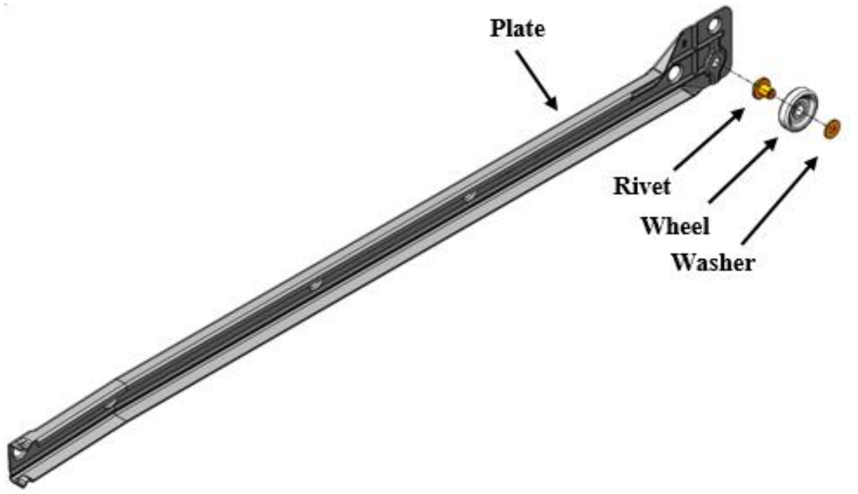


Figure 3.13 The assembling of one slide.

3.1.3 How It Works

The opening and closing mechanism of the roller slide is described in three steps, see Figure 3.14 below. To open the drawer, a small initial force is needed due to the angled plates. During the opening and closing process, the center of gravity changes which results in a changed contact surface between the wheels and the plates. In step 1, the wheels on the drawer slides, DL and DR, are in contact with the downside sliding part of the cabinet slides, CL and CR, see Figure 3.15. In step 2, the center of gravity changes which results in a new contact surface where the upper sliding part of CL and CR acts as support for the wheels on DL and DR, see Figure 3.16. The drawer reaches its opening position when it hits the safety stops, which represents step 3 of the process. To close the drawer, the three steps are performed in the opposite direction. The user pushes the drawer backwards and when it reaches its starting position, the drawer is closed.

Steps:

1. Start position, closed drawer.
2. Changed center of gravity, half open drawer.
3. Opening position, open drawer.

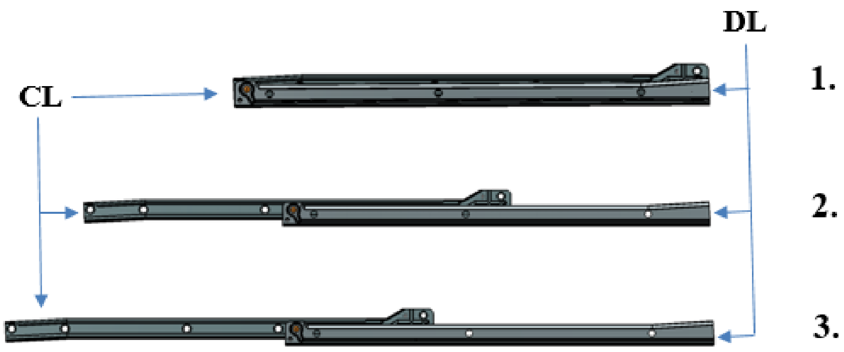


Figure 3.14 Description of the opening and closing mechanism of the roller slide.

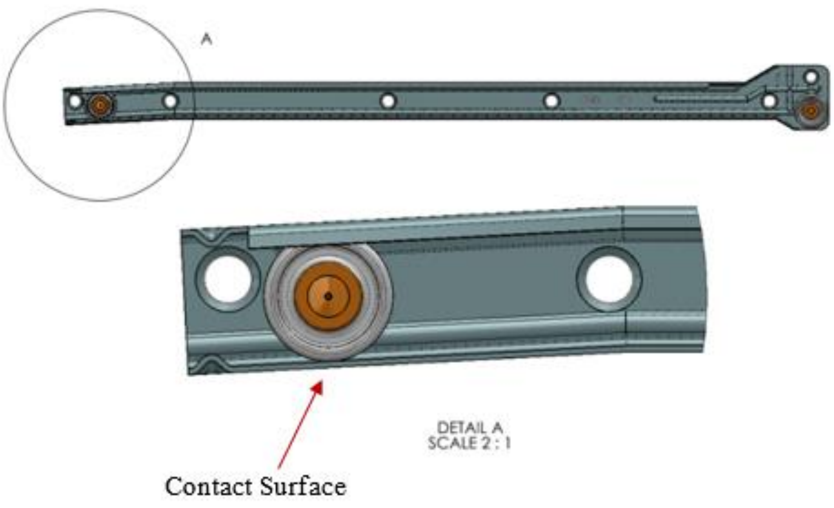


Figure 3.15 The wheel on the DL in step 1, the contact surface is on the downside of the plate.

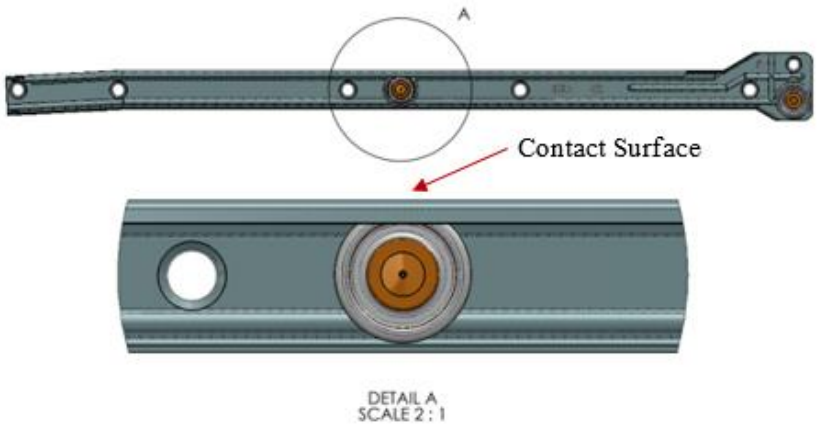


Figure 3.16 The wheel on the DL in step 2, the contact surface is on the upper side of the plate.

3.1.4 IKEA Drawer Survey

IKEA Components has performed a market research, *IKEA drawer survey 2013*, with the aim to conclude potential improvements of selected drawers. The main objectives were to get an insight of what the end consumers thinks about their drawers and what they would like to improve. The quantitative survey was distributed by e-mail to consumers from the five countries; Sweden, Germany, France, China and Italy. The market research covered the most common drawers within the IKEA range, including the MALM-dresser, whose results are of most interest for this project due to its roller slides. Based on the 2750 answers concerning the MALM-dresser, it was concluded that the three most prioritized potential improvements were stability, damping and running motion. The three findings are of high relevance to this project.

3.2 Prototypes from IKEA Components

IKEA Components had, before the start of this Master Thesis, been investigated two potential improvements of the roller slide. The two prototypes of the re-designed roller slide are called BEACH POM and BEACH BEARING. The design team were allowed to further examine and improve those as a part of the project. The two prototypes are based on the original roller slide but have a more narrowed design. All four wheels of the slides have a smaller outer and inner diameter. The wheels mounted on DL and DR have an outer diameter of 15,5 mm and the wheels mounted on CL and CR have an outer diameter of 19 mm. All four wheels have an inner diameter of 4 mm. The two prototypes have a more slimed design and requires therefore guides on both cabinet plates, CL and CR, and the DR-plate as seen in Figure 3.21. The co-workers at IKEA Components states that a slimed design results in less material and thereby a weaker construction. To fulfil the technical requirements, the prototypes must therefore have guides on the three plates. The difference between the two prototypes concerns the wheels. The BEACH POM prototype consists of riveted POM wheels, see Figure 3.17-Figure 3.18. The BEACH BEARING prototype consist of POM wheels where the wheels on CL and CR have integrated ball-bearings, see Figure 3.19-Figure 3.20.

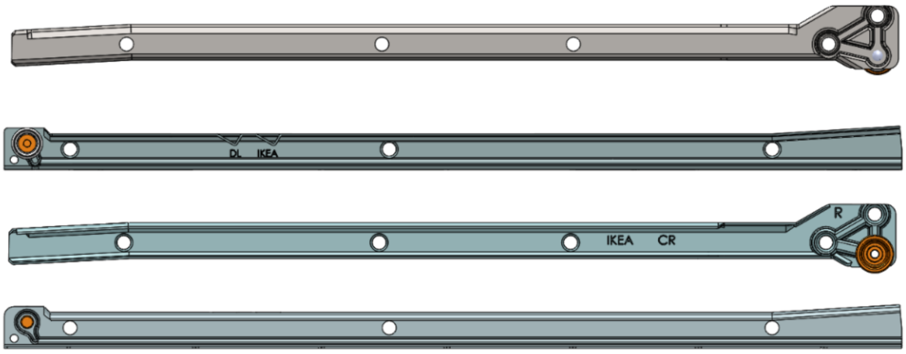


Figure 3.17 The slides of BEACH POM.

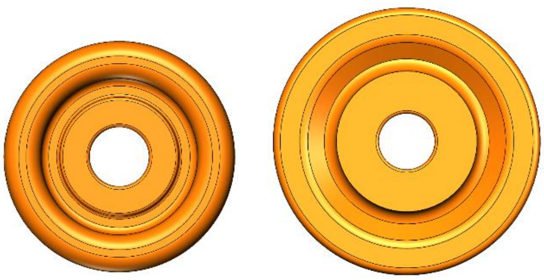


Figure 3.18 Drawer wheels (left) and cabinet wheels (right) of BEACH POM.

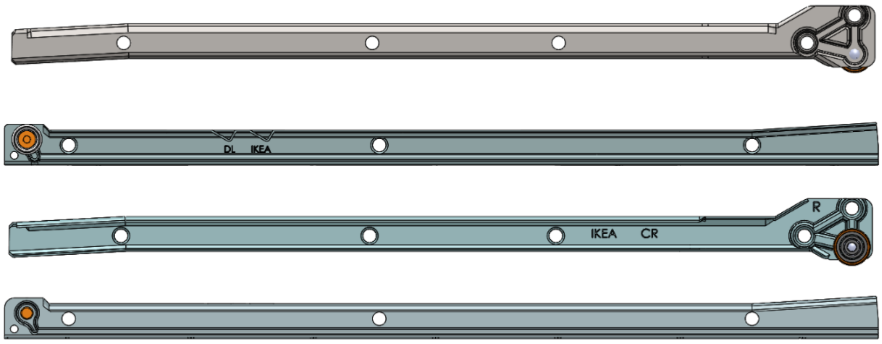


Figure 3.19 The slides of BEACH BEARING.

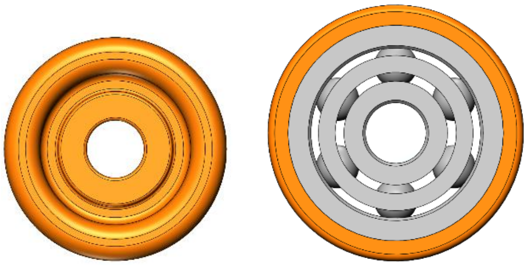


Figure 3.20 Drawer wheels (left) and cabinet wheels (right) of BEACH BEARING.

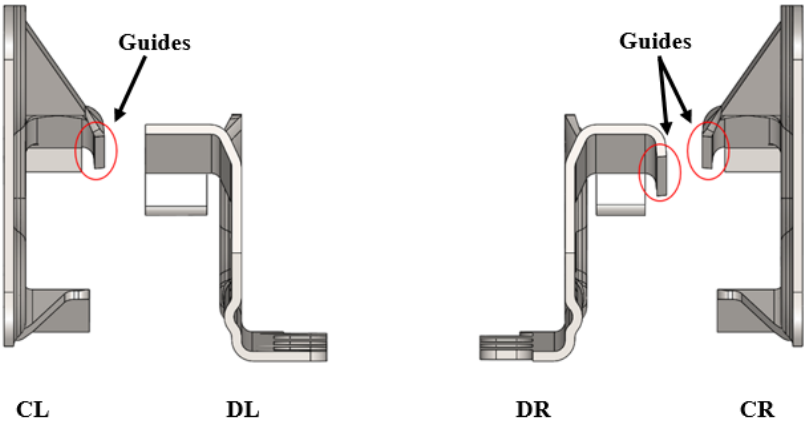


Figure 3.21 Side view of the four plates of BEACH POM and BEACH BEARING, showing the guides on CL, DR and CR.

The co-workers at IKEA Components have tested the two prototypes by mounting those in a MALM-dresser and compare their performance relative to the original design. It was concluded that the co-workers experienced an improvement, but they were not completely satisfied with the solutions. The narrowed design increased the stability and the perceived quality of the running motion was slightly improved. Using ball-bearing wheels improved the perceived quality of the drawer even more since the bearings entails a fixed joint. Due to the fixed joint, the attachment of the wheel is more stable compared to the original and the BEACH POM prototype. The disadvantage with BEACH BEARING is the economical aspect since the ball-bearing is considered being too expensive in relation to the economical target of the furniture. Additionally, the experiences of the two prototypes differs from test person to test person. Some believes that BEACH POM performs better compared to BEACH BEARING, while some experiences the opposite. Although, all test persons find that the prototypes perform slightly better than the original design.

3.2.1 Summary of the Wheel Dimensions

Table 3.1 below presents the design differences regarding dimensions of the wheels for the original roller slide and the two prototypes from IKEA Components.

Table 3.1 Design differences regarding the original wheels and the prototype wheels.

	Type of wheel		
Dimensions of wheel	**Outer diameter [mm]**	**Inner diameter [mm]**	**Total width [mm]**
Original			
Cabinet Right (CR)	$19 \pm 0{,}1$	$5\,^{+0.1}_{0}$	6,4
Cabinet Left (CL)	$19 \pm 0{,}1$	$5\,^{+0.1}_{0}$	6,4
Drawer Right (DR)	$19 \pm 0{,}1$	$5\,^{+0.1}_{0}$	6,4
Drawer Left (DL)	$19 \pm 0{,}1$	$5\,^{+0.1}_{0}$	6,4
BEACH BEARING			
Cabinet Right (CR)	$19 \pm 0{,}1$	$4\,^{+0.1}_{0}$	5,9
Cabinet Left (CL)	$19 \pm 0{,}1$	$4\,^{+0.1}_{0}$	5,9
Drawer Right (DR)	$15{,}5 \pm 0{,}1$	$4\,^{+0.1}_{0}$	5,85
Drawer Left (DL)	$15{,}5 \pm 0{,}1$	$4\,^{+0.1}_{0}$	5,85
BEACH POM			
Cabinet Right (CR)	$19 \pm 0{,}1$	$4\,^{+0.1}_{0}$	5,9
Cabinet Left (CL)	$19 \pm 0{,}1$	$4\,^{+0.1}_{0}$	5,9
Drawer Right (DR)	15.5 ± 0.1	$4\,^{+0.1}_{0}$	5,85
Drawer Left (DL)	15.5 ± 0.1	$4\,^{+0.1}_{0}$	5,85

3.3 Tests of the Roller Slide Models

To achieve reference values of the original slide, the design team developed a noise and vibration test. Analyses considering noise and vibrations are not included in any standard tests at IKEA and a new test had to be developed. Together with the co-worker at IKEA Test Lab, Marcus Johnson, a simple noise test called *Noise and Vibration Test* was developed. The aim with the *Noise and Vibration Test* was to analyse the noise of the roller slide during use based on measurements of the sound and the vibration. The measurement instrument detects the highest noise and the largest vibration, measured in dB respectively mm/s^2, during one measurement. Since the main goal with the project is to improve the perceived quality, the test was designed to meet the reality which in this case was considered being the customers' first impression. To match the reality, all tests was made on the top drawer. When the customers for an example is visiting a warehouse of IKEA, the majority opens the top drawer to test the dresser. The first impression is therefore related to the top drawer and thereby, the perceived quality. A MALM-dresser with three drawers was used in the test where the roller slide was mounted.

Apart from performing the test of the original roller slide, tests analysing the two prototypes produced by IKEA were performed. The original roller slide was replaced with the BEACH POM and the BEACH BEARING. These where then tested in the same way by applying the *Noise and Vibration Test.*

3.3.1 **Test Set-Up**

The *Noise and Vibration Test* consist of the roller slide that will be analysed, a MALM-dresser with three drawers, an elastic band, an inelastic band, a damping pillow and a measuring instrument. The analysed roller slide is mounted in the top drawer, see Figure 3.22. The elastic band is used to illustrate a person closing the drawer with a constant velocity. The inelastic band is used to determine the start position of the drawer, see Figure 3.23. The bands are attached on the top of the dresser and in the front of the drawer, using a bolt, a nut and a washer. The location of the bold, the nut and the washer is presented in Figure 3.24-Figure 3.26. When closing the drawer, an intense sound will occur when the front side of the drawer hits the cabinet. To prevent this sound, a pillow is attached on the back of the drawer to act as a damper, see Figure 3.27.

Figure 3.22 The tested roller slide is mounted on the top drawer of the MALM dresser.

Figure 3.23 Start position of the test determined by the inelastic white band.

Figure 3.24 Bolts, nuts and washers keeping the two bands in place.

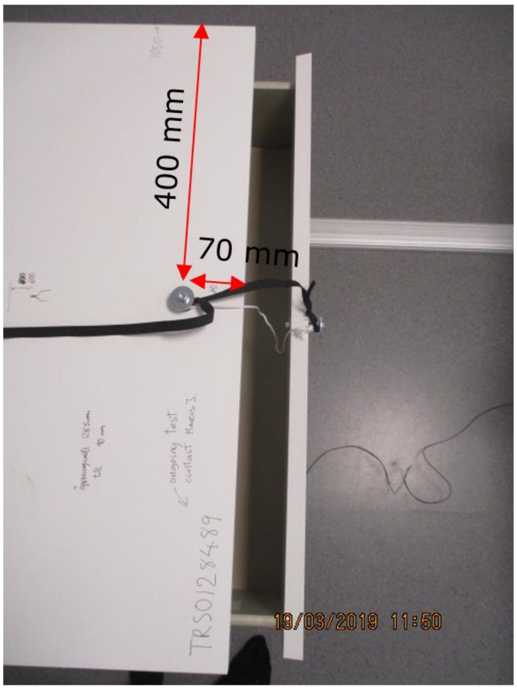


Figure 3.25 The placement of the fixed bolt on the top of the MALM dresser.

Figure 3.26 Close up of the bolt, the nut and the washer.

Figure 3.27 The damper placed at the back of the drawer that will be used for the test.

The measuring instrument consist of a decibel meter with a connected vibration detector, see Figure 3.28. The vibration detector is mounted underneath the drawer at the pre-drilled front hole of the DL-slide, see Figure 3.29 for explanation. The decibel meter is placed centred, in front of the top drawer, see Figure 3.30 and Figure 3.31.

Figure 3.28 Vibration detector connected to the decibel meter.

Figure 3.29 Vibration detector mounted at the pre-drilled front hole of the DL slide.

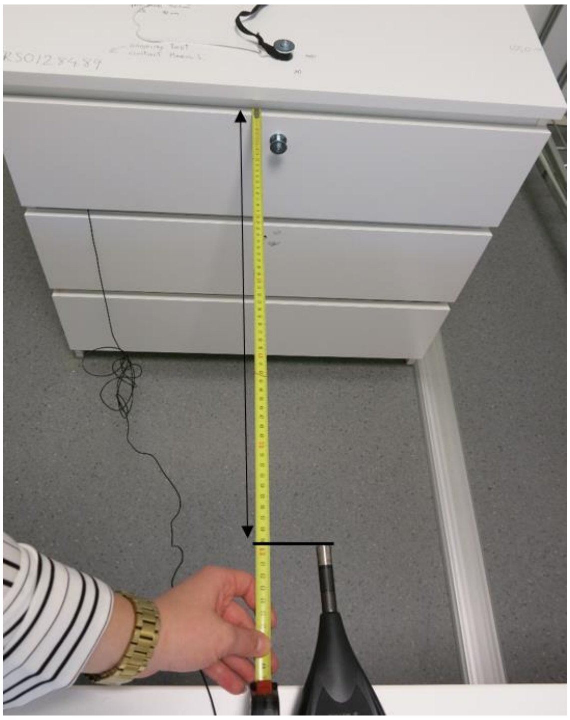


Figure 3.30 Decibel meter placed 60 cm in front of the dresser and centered.

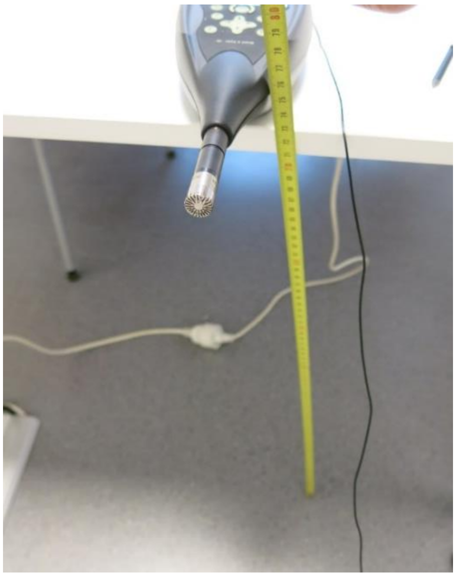


Figure 3.31 The decibel meter placed on a table at a height of 73 cm.

To ensure the test has the same prerequisites, all tests are performed in the conference room BIFMA at Test Lab. Furthermore, the MALM-dresser is located at the same position in the room for all test, see Figure 3.32.

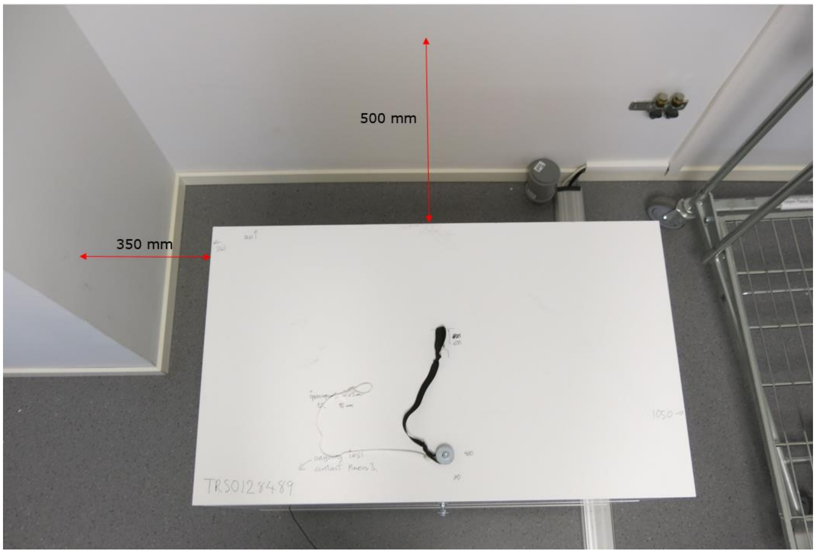


Figure 3.32 The position of the dresser in the room.

3.3.2 **Test Specification**

The *Noise and Vibration Test* consist of ten different measuring points, excluding a background sound test in the beginning of each test. The start position of the drawer is in open position, determined by the inelastic band, see Figure 3.33. The decibel meter starts to record the sound when pressing the centre button, marked with a green circle in Figure 3.34. One measuring point is finished when the drawer has reached its end position, see Figure 3.35. The recording ends by pressing the centre button again followed by pressing the button marked with a blue circle in Figure 3.34. The button marked in blue is used to save the measurement. The test requires a test person that pulls out the drawer to its start position and to start, end and save the recording of the measurement by pressing the buttons.

Figure 3.33 The start position of the test.

Figure 3.34 The button marked in green is the recording button used to start and stop the recording. The button marked in blue saves the recording.

Figure 3.35 The end position of the test.

The test can be divided into four steps where step 2-4 is repeating:

1. Background Sound. The test person records the background sound by pressing the centre button of the decibel meter, marked with a green circle. Record for ~five seconds and then press the same button to stop the recording. Save the recorded background sound by pressing the button marked with a blue circle.

2. Start position. The test person pulls out the drawer to its start position.

3. Start recording. The test person presses the centre button marked with a green circle to start the recording. The test person then releases the drawer and the drawer is pulled backwards by the elastic band.

4. End recording. When the drawer has reached its end position, the test person presses the same button on the decibel meter to stop the recording. One measuring point has been recorded and to save the data, the test person presses the button marked with a blue circle.

Step 2-4 results in one measuring point. Repeat ten times to fulfil one test and make sure that the environment is quiet since the decibel meter is very sensitive.

3.3.3 **Reference Values**

The *Noise and Vibration Test* was performed on the original roller slide as well as on the two prototype roller slides developed by IKEA, BEACH BEARING and BEACH POM, to achieve reference values. The average, minimum and maximum value for respective roller slide is presented below in Table 3.2. The complete results of the tests combined with diagrams are presented in Appendix B.

Table 3.2 Summary of the average, minimum and maximum values for each type of roller slide.

	Type of wheels		
	Original	**BEACH BEARING**	**BEACH POM**
Noise [dB]			
Average	11	18	19
Min. Value	10	17	18
Max. Value	13	19	21
Vibration [mm/s^2]			
Average	205	274	326
Min. Value	165	239	288
Max. Value	239	301	378

3.4 Democratic Design

All products IKEA designs and develops are based on their Democratic Design model which includes the five dimensions; Form, Quality, Low price, Sustainability, Function and Form [7]. IKEA believes that everyone has the right to a better everyday life and works hard to achieve the best balance of the five dimensions. In this Master Thesis, the Democratic Design will be taken into account with the aim to consider and balance the five dimensions, presented in Figure 3.36.

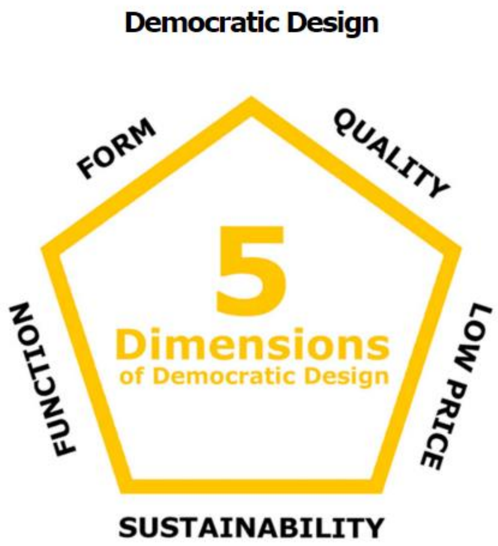


Figure 3.36 The Democratic Design [7].

4 Establish Target Specification

This section describes the target specifications which were established based on requirements and information collected from IKEA.

4.1 Method

When establishing the target specification, the design team followed the four steps presented below. The steps are based on the method described by Ulrich and Eppinger [6] and have been modified to fit to this project.

1. Prepare a list of criteria
2. Collect information of relevance
3. Set ideal and marginal values
4. Reflect on the results and the process

The list of criteria is mainly based on specifications and requirements stated in the beginning of the project by the co-workers at IKEA. Wishes collected from the *IKEA Drawer Survey 2013* has also been considered and interpreted into specifications. In addition, the design team has continuously added criteria and requirements which were identified throughout the project. The importance of the criteria was discussed both within the design team and together with supervisors and other co-workers at IKEA Components. Based on the consultation, the specifications could be further improved and finalised.

4.2 Target Specification

In Table 4.1 the finalised specifications are presented. Each target specification have been ranked from 1 to 5 based on importance. A factor of 1 represents the lowest importance while a factor of 5 represents the highest importance. The specifications assigned with a low number of importance impacts the evaluation of upcoming generated concepts less than specifications assigned with a high number of importance. In cases where the metric could be measured or numerically examined, an ideal value or a point of direction have been assigned. An explanation of each metric is presented in Appendix C.

Table 4.1 Summary of the target specifications.

No.	Metric	Importance factor (1-5)	Unit	Margin value	Ideal value
1	Volume of noise during sliding	5	dB	-	0
2	Vibration during sliding	5	mm/s^2	-	0
3	Stability	4	Subj.	-	-
4	Material cost	4	SEK	-	-
5	Total Cost	4	SEK	-	-
6	Easy to install	2	Subj.	-	-
7	Changes of existing tolerances of the MALM-dresser	4	Binary	No	No
8	Dismountable	2	Binary	Yes	Yes
9	Easy to dismount	2	Subj.	-	-
10	Smooth sliding	5	Subj.	-	-
11	Environmentally friendly	3	Binary	No	Yes
12	Damping	1	Binary	No	Yes
13	Few tools needed when installing	1	Subj.	3	0
14	Few changes on existing roller slide	2	Binary	Yes	No
15	Initiative for the user	3	Subj.	-	-
16	Appealing to the user	3	Subj.	-	-

5 Concept Generation

This section describes the method used during the concept generation where ideas for potential solutions were developed. The idea generation phase includes brainstorming, internal and external benchmarking and patent search.

5.1 Method

To generate as many concepts as possible, a number of different strategies were applied to gain inspiration. According to Karl T. Ulrich and Steven D. Eppinger [6], there are two ways of gathering this type of information; by searching internally and externally. The internal search refers to making use of the knowledge within the design team by brainstorming and the external search refers to benchmarking, consulting experts and performing patent and literature search. The internal and external search were performed concurrently since one method or idea led to another. As new information was gained, some phases were remade or extended. For example, ideas from the brainstorming sessions caused a more broadened benchmarking and vice versa. The concept generation was initiated by establishing the problem and divide it into subcategories in order to clarify and simplify the process.

5.1.1 **Categories of Interest**

The main problem described in section 1.2 was divided into subcategories. The categories were used in order to simplify and structure the concept generation and to identify as many solutions within the defined categories as possible. The division of the subcategories during the concept generation was based on the preconditions of the project. Since the design team were allowed to investigate many design aspects, each subcategory represented therefore a specific category of potential solution to the problem.

5.1.2 **Brainstorming**

The brainstorming was divided into two sessions. During the first session, the design team brainstormed individually while the second session was performed together. By brainstorming individually, the design team avoided impacting each other and a wide range of ideas could be explored based on individual knowledge and experiences. The objective was to generate as many ideas as possible without taking realistic aspects and opinions into consideration. The original roller slide and the two prototypes were neglected in order to enhance the creative process and to avoid being limited to those solutions.

The ideas generated from the first session was summarized and discussed within the design team. The second brainstorming session was initiated by further developing some of the concepts and by combining different solutions with each other. As a result of the second session, a number of more detailed concepts were generated and discussed with M. Reimer and N. Persson at IKEA Components and with H. Holmberg and L-G Petersson from the Pattern Shop at IKEA of Sweden. The discussions resulted in new ideas, improvements of the previously generated ideas and some ideas were discarded. All generated ideas and reason for discarding are presented in Appendix D.

5.1.3 **Benchmarking**

The internal and external benchmarking were performed continuously. The internal benchmarking was performed within IKEA, IKEA Components and by discussing with co-workers. By visiting the IKEA warehouse, many types of roller slides installed in different furniture were investigated and used as inspiration. To achieve a better understanding of the roller slide and of the perceived quality, the design team decided to mount a MALM-dresser. Additionally, information about the slides were gathered from the internal PDM-system.

Information and inspiration from the external benchmarking were gained continuously throughout the project. By searching on internet and by visiting stores offering relevant, competitive furniture, similar solutions were identified and used as inspiration.

5.1.4 **Patent Search**

In order to proceed a successful product development process, a patent search is important to avoid unnecessary patent infringes. Therefore, patent search is of high value at IKEA Components when developing new products. To ensure that new ideas and concept does not infringe on an existing patent, patent search based on the generated concept will be investigated.

In consultation with Carl Ervér, an intellectual property leader at IKEA, a method for the patent search was established. Based on the ideas and concepts generated by the design team, C. Ervér could get an overview of the technical solutions that might infringed on existing patents. Relevant patents where then found by different search methods. Using search words or citations are two basic methods for finding patents. In this case, C. Ervér recommended to investigate patents that IKEA continuously collects within the category of sliding mechanisms. By using this method, the number of relevant patents were easier to overview compare to using search words and citations. C. Ervér also suggested to search for patent by using classifications in combination with search words. All published patents are classified and by searching within a specific class, a more narrowed search result is achieved.

To conclude whether a patent is infringed or not, expertise is required since it is a complex process. In this Master Thesis, the patent search will only result in patent suggestions to further investigate. The design team will, therefore, not draw any conclusions but rather search for similar patents that might be relevant for the investigation of infringements. The patent search will also aim to find inspiration during the concept generation.

5.2 Establish the Problem

The research phase resulted in valuable information and a broad perspective of the problem but to find suitable solutions, the main problem had to be outlined. Before initiating the development process, the actual problem was clarified. The main problem was summarized as: to improve the perceived quality of the roller slide by decreasing the generated noise, improve the stability and eliminate the wobbling during sliding and in the meantime, taking the economical aspect into consideration. Once the problem was concluded, subcategories relevant in the search for a product solution, were identified.

5.2.1 **Subcategories**

The subcategories were used in order to more thoroughly investigate solutions within a specific design area. By using the subcategories, the design team could concentrate the concept generation within each subcategory and thereby, examining as many potential solutions as possible. The selection of subcategories was based on the preconditions of the project stated by IKEA Components and along with ideas from the design team. The subcategories were defined as wheel, attachment, plate, other and new designs.

5.2.1.1 Wheels

This subcategory involves all solutions related to the wheels of the roller slide. Both ideas regarding simple modifications of the current design and new alternative solutions developed by the design team are included. The subcategory also involves ideas and concepts that may replace the rolling function of the wheels.

5.2.1.2 Plates

All ideas related to the plates of the roller slide are included in this subcategory. The solutions involve adjustments of the original design with the aim to decrease the noise during sliding and improve the perceived quality during use.

5.2.1.3 Attachments

This subcategory explores alternative attachment methods as well as improvements of the current solution. The subcategory is limited to all the components necessary for assembling and enabling rotation of the wheels.

5.2.1.4 New Design Solutions

Ideas concerning a new solution of the roller slide are included in this subcategory. Those solutions imply for example new sliding mechanisms or a new general design of the slides.

5.2.1.5 Other

This subcategory includes ideas and concepts that cannot be categorized within either wheels, plates, attachments or new solutions. Either the idea is a developed concept given by IKEA Components or the idea does not mean any modification on the original design, but rather a changed position regarding the mounting of the roller slide.

5.3 Benchmarking

Both an internal and an external benchmarking were performed. The internal benchmarking was made within the assortment of IKEA and IKEA Components, while the external benchmarking focused on relevant products provided by competitors and other external sources. Internet search was also used within the external benchmarking and involved material search, attachment methods and fact about friction and noise. The benchmarking was used as inspiration for the concept generation.

5.3.1 Internal Benchmarking

The aim with the internal benchmarking was to investigate products within the IKEA assortment which have some type of sliding mechanism. IKEA offers a wide range of this mechanism where the choice of design is based on the price category of the furniture. Some roller slides contain a damper and are therefore more complex compared to the one examined in this project. The investigation of the different slides was therefore mainly used as inspiration in terms of material selection and design for the following concept generation. Additionally, the design team mounted a MALM dresser in order to achieve a better understanding of the problem and the roller slide. Information about the roller slide was also gathered from the internal PDM-system. This information contained CAD-models, specified materials and drawings and were valuable both in order to define the existing roller slide and to generate new ideas.

5.3.1.1 TYSSEDAL

The furniture TYSSEDAL has a more complex sliding mechanism integrated. This type of slide contains of two metal slides which are sliding relative to each other, see Figure 5.1. The slides are mounted on the cabinet and the drawer is positioned on the top of the slides. The sliding mechanism consist of a damping function which means that the drawer will be closed in a soft and silent way. This type of slide belongs to a more exclusive price category compare to the roller slide [8].

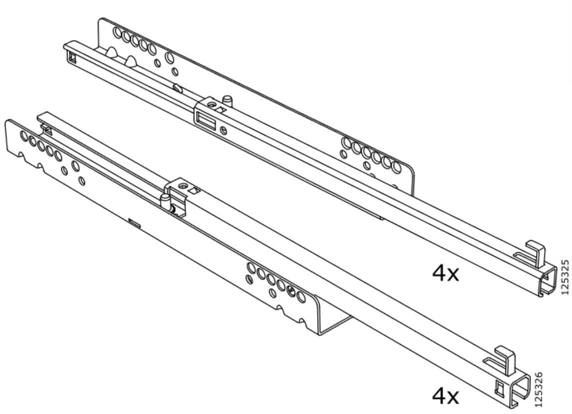


Figure 5.1 Slide used in the IKEA furniture TYSSEDAL [9].

5.3.1.2 VADHOLMA

One of IKEA's slides used in kitchen furniture is shown below in Figure 5.2. This slide is used in the kitchen VADHOLMA and has an even more advanced sliding mechanism compared to the previously described slide used in TYSSEDAL. The slide consists of three plates sliding relative to each other which enables full extension. This means that the drawer can be totally drawn out of the cabinet. The slides also include dampers which enables soft and silent closing of the drawer. The advanced design of this slide is included in the more exclusive price category of furniture [10].

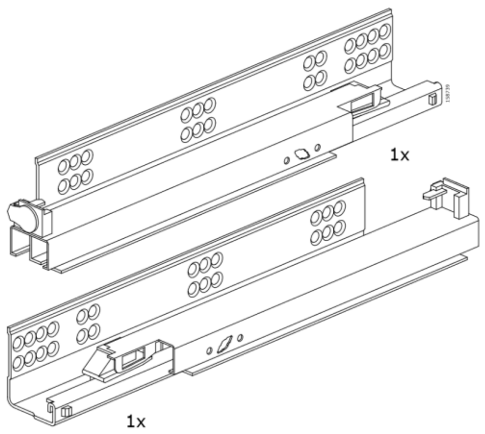


Figure 5.2 Slide used in IKEA kitchen furniture VADHOLMA [11].

5.3.2 External Benchmarking

The external benchmarking proceeded continuously during the concept generation. As ideas were generated, new information was needed. The information was mainly gained by visiting physical stores, performing internet search and by making use of expertise.

5.3.2.1 Competitors

Similar sliding mechanisms are provided by other companies apart from IKEA. It was therefore of interest to see how other furniture companies have solved this problem and thereby find useful inspiration. The design team decided to compare furniture, not only offered by the companies within the same low-price range, but also to look at furniture from more exclusive brands. By comparing similar solutions within the low-price category, the design team could get a holistic perspective of how to solve the problem within the actual economical range. On the other hand, while looking at the more exclusive solutions, the solutions themselves may not be applicable due to economic aspects, but rather inspirational. Lastly, the design team argued that by comparing a wide range of sliding mechanisms, the concept generation will be enriched. The stores Mio, Jysk and Miljögården in Lund were visited where Mio and Jysk were considered being within the lower price range.

5.3.2.1.1 Mio

At Mio, different types of slides were found including both simple and more complex designs. One of the slides was similar to the roller slide examined in this project since it contained of metal plates with integrated guides, plastic wheels and rivets in order to attach the wheels to the plates, see Figure 5.3. The slides that differed from the current roller slide had more integrated functions such as dampers and consisted of a more complex geometry. The design of those slides was similar to other, more exclusive slides offered by IKEA and are used within more expensive price ranges. An example of a more complex slide offered by Mio is presented in Figure 5.4-Figure 5.5. This slide contains of two metal plates mounted on the sidewall of the drawer. The sliding occurs between the metal of the plates and an attached plastic part, causing a low friction. The design team experienced the drawer sliding smoothly and it did not generate unpleasant noise.

Figure 5.3 Similar roller slide offered by MIO.

Figure 5.4 A more complex sliding mechanism mounted on the drawer of the ELVIRA furniture at MIO.

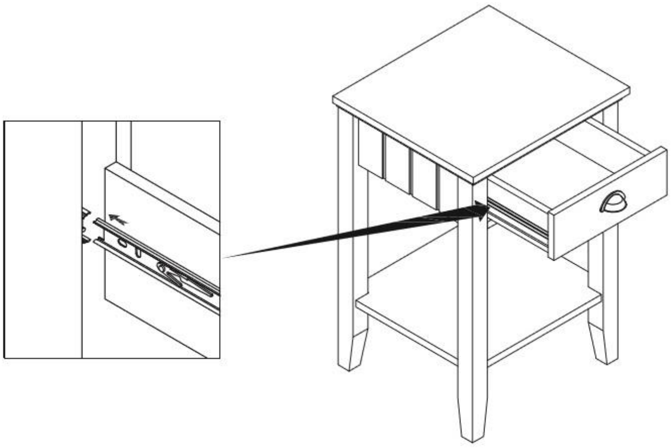


Figure 5.5 The position of the complex sliding mechanism [12].

5.3.2.1.2 Jysk

The other low-price furniture store, Jysk, offered similar solutions as Mio, including both more or less complex slides. An example of a more complex slide is shown in Figure 5.6. The slide consists of three integrated plates which slides relative to each other. The three plates are used in order to expand the slide in a smooth and more robust way. The slide is positioned at the sidewall of the drawer and the design contains of a soft closing mechanism. The perceived quality of the slide was good due to its stable design and smooth sliding. The design was considered being too complex and not suitable through an economical perspective in relation to this Master Thesis. Although, the slide may still be used as a source of inspiration.

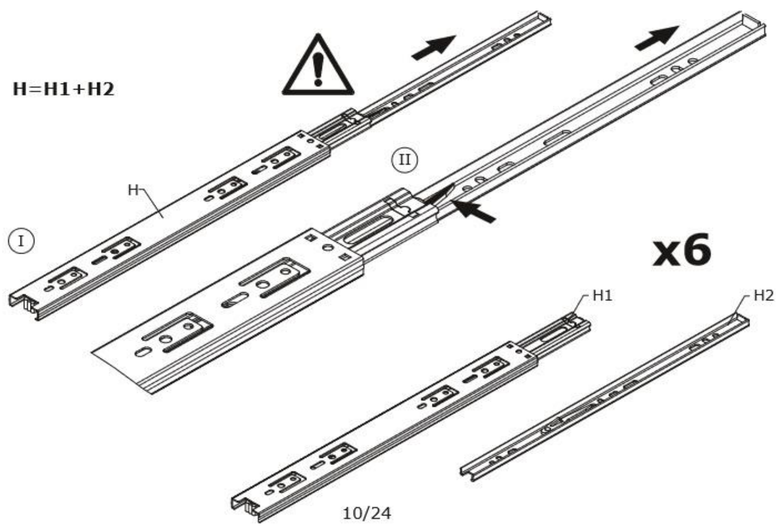


Figure 5.6 Complex sliding mechanism used in furniture's at Jysk [13].

5.3.2.2 Expertise

In this Master Thesis, experts have been consulted in order to gain knowledge and inspiration for the development of concepts. The design team decided to have meetings with experts within relevant subjects in relation to this project. During the idea generation, the need of expertise arose, and the meetings processed therefore parallel to this phase. The contacted experts are presented in Table 1.1 together with other key people for this Master Thesis.

The design team contacted Katarina Elner-Haglund to gain inspiration, information and potential suggestions regarding thermoplastic solutions. Material selection of the wheels was mainly discussed during the meeting. Based on ideas generated by the design team, K. Elner-Haglund suggested some potential thermoplastic elastomers and advised the design team to contact Hexpol TPE AB to gain further information. Other inspirational ideas and comments were also taken into consideration after the meeting.

After contacting Hexpol TPE AB, the design team was directed to the key account manager Caj Karlsson. Both technical solutions and material selections were discussed regarding the wheels of the roller slide with the aim to reduce the generated noise. Double injection molding was suggested as a potential solution in order to gain a hard core covered by an outer layer of a softer, noise isolating material. By developing this kind of wheel, the perceived quality of the roller slide could be improved since the soft, outer layer would act as a stabilizer and a noise damper. The suggested material for the soft layer was the thermoplastic elastomer, TPE-E. In order to test the material, samples were sent to the design team. It was also discussed whether a solid wheel made of thermoplastic elastomer would be a potential substitute to the POM wheel. This idea was neglected since C. Karlsson pointed out the risk that the inner surface of the wheels would wear down and affect the rolling of the wheels. To gain inspiration and information regarding technical solutions of the whole roller slide, Hans Walter and Rikard Hjelm, who both works at Lund Faculty of Engineering, were contacted. During the meeting, alternative attachments and different solutions to reduce vibrations were discussed. Using bushings was considered an alternative in order to improve the stability of the wheels. To decrease the generated noise during use of the roller slide, it was suggested to minimize the propagation of the vibrations. By adding a layer of a damping material between the roller slide and the cabinet, the generated noise could potentially be reduced.

5.3.2.3 Internet Search

In order to find relevant information as well as inspiration for the idea generation, an internet search was performed. The aim was to find technical information about materials, alternative attachment methods for the wheels and to find theoretical knowledge about certain physical principles, for example the relation between noise and friction. Since the idea generation and the development of concepts were performed during many different stages of the project, the internet search was continuously extended to cover the required information.

Generally, the information search was limited based on time aspects, economical limits of the project and the economic aspects of the sought solution. The time limit of the project implies that the design team had to focus on finding background information related to ideas and solutions that are most likely to be successful as well as limiting the number of examined potential alternatives in order to be able to compare and evaluate the information in an appropriate manner. Through an economical perspective, information about alternatives that are obviously too expensive to fit the project, for example ball-bearings and certain material, were neglected.

In consultation with M. Reimer, it was concluded that regarding material selections of the roller slide, the wheels are of greatest interest. Material search for the plates, rivets and washers are neglected due to several reasons. The main reason is the fact that M. Reimer suggested the design team to focus on the design of the wheel and the joint. The current materials are already optimized, and it would therefore be difficult for the design team to investigate all design aspects due to time limitation.

5.3.2.3.1 Attachments

In order to attach the wheels to the plates of the roller slide, an attachment is necessary. It is of high importance that the joint allows the wheel to rotate, contributing to a stable design and a smooth sliding motion. The joints are allowed to be permanent attached, but this is not required. The distance between the slide mounted on the cabinet and the slide mounted on the drawer is limited due to dimensions of the furniture and the attachment must therefore fit to those preconditions. Moreover, it is important that the attachment is corrosion resistant since transportation of the slides implies climate variations and causes moisture. The search of potential attachments is based on technical and economic aspects since the roller slide is a low-cost product.

5.3.2.3.1.1 Rivets

Rivets are a permanent mechanical fastener, consisting of a cylindrical shaft with a head and are used to secure two or more pieces of materials together [14]. A rivet can be fastened manually using a tool or automatically using a machine [15]. When installing a rivet, the shaft expands and creates a field head which fastenings the materials together [14]. Rivets exists in many types where each type has its specific advantages and is more or less suitable for certain types of applications. The two most common types of rivets are solid rivets and blind rivets [16], p.14. A solid rivet is solid throughout which results in greater strength properties compare to a blind rivet. Blind rivets, more commonly known as pop rivets, are tubular. Solid rivets and blind rivets require different installation methods. Solid rivets require fastening from both sides of the workpiece which results in two operations and a more expensive manufacturing process. By using machines, the cost can be decreased compare to using manual methods. An advantage with blind rivets is that two pieces can be fasting to each other from only one side of the workpiece. This results in a fast assembling process and blind rivets are today one of the most cost effective and technically efficient systems [15], p.128.

5.3.2.3.1.2 Bearings

A bearing is a tribological component that controls and supports rotational or linear movements. Basically, there are two types of bearings; plain and roller bearings. Plain bearings, also commonly known as bushings, consists of no moving parts and can be used for sliding, rotating, oscillating as well as reciprocating motion [17]. Bushings have a broad range of applications and a large standard assortment exists. Bushings are easy to mount, have a low weight and are inexpensive [18]. Compared to bushings, roller bearings are considerably more expensive because of their complexity. Even if roller bearings enable extremely low friction, bushings offer a quieter operation because of their absence of internal moving parts. In addition, an improved corrosion resistance can be achieved on bushings since several material possibilities exist [17]. However, operation characteristics depends on the sliding material and the type of bushing. A comparison of seven different types of bushings and their operating characteristics have been made by Svenska Kullagerfabriken, SKF, and is found in Appendix E [19].

Lubricants have an important role when it comes to the sliding characteristics but does also increase the durability of a bushing. It reduces the friction and the generated heat and protects against dust, dirt and corrosion of the shaft [20]. Depending on the type of bushing and its material, different lubricants are to be recommended to provide the correct support. Either lubricants with oil or grease can be used for solid bronze bushings. For standard applications, lithium greases are recommended whereas for closed systems, oils are preferable [21]. When using lubricant additives, it is important to control eventual chemical reactions. The additive molybdenum disulfide, MoS_2, is not recommended when for example using bushings made in bronze. It is important to consider the sulfur content of MoS_2 since it together with copper forms copper sulfate. The copper sulfate increases the wear resistance which results in a negative effect of the lubricant instead of improving the sliding characteristics [16]. Bushings made of PTFE, called PTFE polyamide bushings, are designed for dry operations. This implies that the bushing does not require lubricants but to increase the rotation and thereby improve the performance of the bushing, an adequate supply of either grease, oil, water or liquid can be added. Considering POM composite bushings, it is preferable to use lithium-based greases for operations up to 80 degrees Celsius. The sliding surface of the POM composite bushings contains grease reservoirs which are filled prior to installation and the bushing is designed to operate under marginal lubrication conditions. It is recommended to apply grease on the mating surface to prevent corrosion. As for the PTFE polyamide bushing, it is important to control eventual chemical reactions. For POM composite bushings, greases that contains solid lubricants, for example MoS_2 is not suitable [17].

5.3.2.3.2 Wheel Materials

To improve the perceived quality of the roller slide, the material selection of the wheels is of interest. By optimizing the properties of the material, a smoother, quieter and a more stable rolling might be achieved. The search of potential materials was limited based on technical requirements and economical aspects of the roller slide. The preconditions that the wheels have to withstand implies that the material have to be abrasion and moisture resistant, dimensionally stable, have a low friction while interacting with the plate and enable mechanical joining to the plate. Through an economic perspective, the wheels must be inexpensive, both regarding the material cost and regarding the required manufacturing method. Based on those limitations, the design team focused the material search to thermoplastics since this type of materials offers a variety of properties and manufacturing methods [22], p. 11. The thermoplastic elastomers, which is a subcategory of the thermoplastics, were also examined as a potential material for the wheels due to their high toughness and soft elastic properties. Most of the thermoplastic elastomers also offers a more cost-effective alternative to rubbers due to the many different processing methods, including for example injection molding, extrusion, film and blow molding. The thermosets were neglected due to difficult machining processes, limitation regarding recycling and due the fact that they offer unnecessarily good material properties [22], p. 11. Along with co-workers and supervisors at IKEA Components, it was concluded that metals could be neglected during the material search.

To evaluate which thermoplastics and which thermoplastic elastomers that were of interest as a substitute to the existing POM wheels, materials with low friction and properties similar to POM were examined. The selection of the materials was based on information provided by the retailer Hexpol TPE AB, consulted experts and material properties stated in the book *User's Guide to Plastics* [22]. Thermoplastic materials that were selected and further examined are acetal (POM), polyvinylchloride (PVC), polypropylene (PP), acrylonitrile-butadiene-styrene (ABS), polyester based thermoplastic elastomer (TPE-E), vulcanized thermoplastic elastomer (TPE-V) and thermoplastic polyurethane (TPE-U).

5.3.2.3.2.1 Acetal (POM)

The thermoplastic material acetal, also called POM, is the most crystalline material of all the engineering polymers and exist both as homopolymer and copolymer [22], p.25. The polymer chain of a homopolymer consist of only one monomer while a copolymer consists of different types of monomers [22], p.9. The homopolymer has better mechanical properties compared to the copolymer and the copolymer is more resistance to hot water. The mechanical properties of POM characterize the material since it is the stiffest non-reinforces engineering polymer, have a high toughness, fatigue and creep resistance and is slightly changed within the temperature range of -40 C to +80 C. The material is dimensionally stable, does not absorb moisture, have excellent spring, friction and wear properties. The disadvantages with the material are its sensitivity to stress concentrations such as sharp corners, its maximum continuous service temperature limited to +80 C and that it squeaks against itself. POM is recyclable and processable by injection molding and extrusion [22], p. 25.

5.3.2.3.2.2 Polyvinylchloride (PVC)

Polyvinylchloride, commonly called PVC, is an amorphous commodity plastic which, depending on the use of additives, can be modified from being soft to stiff. The mechanical advantages with PVC are its low material cost and density, its high stiffness, toughness and good dimensional stability. The material has excellent resistance to chemicals and microorganisms and is therefore commonly used for disposable products in the healthcare. The main disadvantage with PVC is that when burning, hydrochloric acid is formed. Due to its long-term durability and stiffness, the material is often used in construction components and cables [22], p. 17.

5.3.2.3.2.3 Polypropylene (PP)

The second largest plastic on the market is polypropylene, PP, which is a semi-crystalline commodity plastic. Depending on the polymerization method, the molecular structure of PP can be modified. The material can also be modified by mixing it with elastomers, adding talc or being reinforced with for example glass fiber. Due to the many methods of modifying PP, it is the one material whose properties and characteristics can be varied the most. The advantages with PP are its low material cost and density, its fatigue resistance and good slidability. It does not absorb moisture and has an excellent chemical resistance. Although, the material is brittle at low temperatures when it is unmodified, and it has a low resistance to UV radiation and to scratches. Polypropylene is commonly used within the manufacturing of machines, vehicles, electrical applications and within the food and medical industry [22], p.15-16.

5.3.2.3.2.4 Acrylonitrile-Butadiene-Styrene (ABS)

ABS is an amorphous copolymer whose properties depends on the level of the two monomers acrylonitrile and butadiene during the manufacturing and depending on the different type of blends. The properties of ABS are often further adjusted by blending it either with polycarbonate (PC/ABS) or with polyester (PBT/ABS). The combination of PC and ABS improves the flow properties as well as the temperature and UV resistance while a combination of PBT and ABS offers better chemical resistance and improved dimensional stability at elevated temperatures. The advantages with ABS are its dimensional stability during stress, its combination of toughness, strength and stiffness and good electrical insulation. The material is often used in esthetical applications due to the many possibilities of surface finishes and colors. The disadvantages are the materials' low resistance to heat, UV-radiation and solvents. ABS is also sensitive to stress cracking. Possible manufacturing methods are injection molding and extrusion [22], p. 20-21.

5.3.2.3.2.5 Polyester Based Thermoplastic Elastomer (TPE-E)

The polyester based thermoplastic elastomer, called TPE-E, has an excellent toughness and elasticity and offers a high resistance to creep, impact, flex-fatigue and flexibility at low temperatures. Other advantages with TPE-E is that the temperature has a negligible effect on the mechanical properties and the material acts good as a noise and vibration damper. The material is also resistant to oil and solvents and is easy to process due to its good thermal stability. TPE-E is widely used within the automotive, electrical and electronic industry as well as for certain sport equipment's [22], p. 35.

5.3.2.3.2.6 Vulcanized Thermoplastic Elastomer (TPE-V)

TPE-V is a vulcanized thermoplastic elastomer which is made of a polypropylene and EPDM rubber blend. The material is characterized by its hardness, good abrasion, tear and chemical resistance as well as its wide service temperature. TPE-V is easy to process and has a good adhesion to other thermoplastics. Compared to other thermoplastic elastomers, TPE-V offers better mechanical and chemical properties as well as a wider service temperature than TPE-O and better fatigue resistance compared to both TPE-O and TPE-S. The material is often used as sealing within different industries and as accessories for outdoor connectors and cables [22], p.33.

5.3.2.3.2.7 Thermoplastic Polyurethane (TPE-U)

TPE-U exists in two versions, one based on polyester and one based on polyether. When based on polyester, the material offers better resistance to oil and heat as well as providing better mechanical properties compared to being based on polyether. TPE-U based on polyether offers better flexibility at low temperatures and is more resistance to hydrolysis and microbiological impacts. High shear strength, elasticity and transparency are along with excellent abrasion resistance, good oil, grease and hydrolysis resistance the advantages with thermoplastic polyurethane. The material does also perform excellent at low temperatures but requires more difficult processing methods compared to other TPE-materials. Due to its excellent adhesion and damping properties, the material is commonly used as shoe soles and treads an on wheels [22], p.34.

5.3.2.3.3 Friction and Friction Sound

Sound occurs due to vibrations. The vibrations cause pressure waves that propagates in either a gas, a liquid or a solid. The volume of the sound is determined by the amplitude of the pressure waves and is measured in the unit decibel (dB) [23]. Vibrations and oscillations occur for example due to friction, when two contact surfaces slide relative each other, which leads to radiation of sound. The sound varies depending on the contact forces between the sliding surfaces. The contact forces are in turn dependent on the external forces causing the sliding and the interface properties of the sliding surfaces. If the sliding components are part of a greater system, the acoustic response of the system does also impact the appearance of the sound [24], p.1525-1526. Friction is a complex phenomenon which refers to the force resisting the relative motion between surfaces in contact. The friction force can be influenced by adding a fluid lubricant layer between the contact surfaces. There are several types of friction and the appearance of friction can be explained due to different phenomenon and physical preconditions. Mainly, friction can be divided into static friction and kinetic, also called, dynamic friction. When there is no slipping between the two surfaces, static friction occurs while kinetic friction refers to the opposite case, when slipping between the surfaces occurs. One of the first mathematical friction models, the Coulomb friction law, states that the friction force is proportional to the normal force and directed in the opposite direction of the motion. The model only involves one parameter which is the coefficient of friction. The law also states that the friction is independent of both the contact area and the velocity. Although, further researches suggest that the friction force is dependent on two types of friction coefficients, one “static” and one “kinetic”. This since the Coulomb friction law shows a discontinuity of the friction force when the velocity is set to zero and the direction of the velocity is thereby undefined. The transition between these two friction coefficients have been studied and explained by different models. The models state that it is not only the relative velocity that have an impact on the friction force, but also the displacement. The displacement occurs when an external tangential force is applied between two bodies in contact. The displacement can be explained due to the fact that in the presence of a normal force, the two contact surfaces tend to adhere. To overcome this adhesion, an elastic deformation followed by a plastic deformation of the two surfaces’ roughness must happen. When the sticking of the surfaces is overcome, the bodies starts to slide. The force required to initiate the motion is called the breakaway force [25], p.1408.

5.4 Idea Generation

The generated ideas from the brainstorming session as well as ideas that was detected during the development phase can be found in Appendix D. The ideas are divided into five main categories where each idea is assigned a name, a description and a simple sketch. The concepts given from IKEA Components are called 4.1 BEACH POM and 4.2 BEACH BEARING and these are described in section 3.2.

After the brainstorming session, the generated ideas were primary screened to conclude if any of the ideas for some reason could be directly discarded. The screening was performed by the design team together with M. Reimer and N. Persson at IKEA Components and the conclusions were based on previous test experiences, reliability and economical as well as time aspects. Since the roller slide is a component within the low-cost category, the co-worker at IKEA decided that the design team should focus on investigating small adjustments of the design instead of re-designing. This resulted in a lot of discarded ideas since all generated ideas that included a new type of solution were removed.

To further assess which ideas that could be developed into prototypes, a second evaluation was performed by the design team together with H. Holmberg, L-G Petersson and F. Wallis from the Pattern Shop at IKEA of Sweden. Ideas that were considered being valuable and reasonable to investigated were then further developed and manufactured. Discarded ideas with the reason why to exclude it can be found in Appendix D.

5.4.1 Promising Ideas

The ideas that were considered being promising based on the two screening sessions are presented in Table 5.1and further explained below.

Table 5.1 Promising ideas within the different subcategory.

Promising ideas			
Wheels	*Plates*	*Attachments*	*Other*
1.1 Wheel Profile	2.1 Isolators	3.3 Bushing	4.1 BEACH POM
1.2 Soft Layer	2.3 Topology	3.5 Washer Dimension	4.3 Integrated Slide
1.3 Dimensions			4.4 Fixed Drawer
1.5 Wheel and Block			
1.6 Sliding Blocks			
1.7 Turning Wheel			
1.8 Longer Hub			

5.4.1.1 Wheels

This category consists of ideas concerning the wheels, where it includes both small adjustments, new designs of the wheels and material modifications.

5.4.1.1.1 Wheel Profile (1.1)

The aim with this idea is to adjust and optimize the contact surface between the wheels and the plates. The idea is based on the fact that a decreased contact surface, and thereby a decreased friction, will generate less noise.

5.4.1.1.2 Soft Layer (1.2)

By applying a layer of soft material on the outer diameter of the wheels, the purpose is to both stabilize the wobbling wheels and to decrease the generated noise during sliding. The soft layer must be optimized by terms of both dimensions and material selection in order to achieve an optimal result and to fulfill the technical requirements of the roller slide

5.4.1.1.3 Dimensions (1.3)

The idea refers to decreasing respectively increasing the outer and inner diameter of the wheels. This in order to evaluate the impact of the lever between the rivet and the outer diameter of the wheel. With an increased inner diameter, the lever decreases which should result in a more stable joining of the wheels. A decreased inner diameter will be considered as well in order to determine which combination of dimensions are the best.

5.4.1.1.4 Wheel and Block (1.5)

The idea is to replace the wheels on either the drawer slides or the cabinet slides with plastic blocks. By decreasing the number of rolling elements, the generated noise during sliding will probably decrease. The roller slide will also potentially become more stable since the rotating attachment are replaced with a fixed joint.

5.4.1.1.5 Blocks (1.6)

This idea is similar to the idea above, Wheel and Block (1.5), but consist of four fixed blocks on all slides. The principle is to optimize the friction between the blocks and the plates and thereby achieve a well-functioning sliding mechanism. The fixed joint, which the blocks will be attached with, will potentially improve the stability and decrease the noise.

5.4.1.1.6 Turning Wheel (1.7)

The idea is to investigate if an increased roundness of the wheels will have an impact on the perceived quality of the drawer. Due to the current manufacturing method of the wheels, the roundness of the wheels is not ideal and might vary. By using the manufacturing method turning, an increased roundness can be achieved. The roundness of the wheels may have an impact on the wobbling and the noise during slide.

5.4.1.1.7 Longer Hub (1.8)

With a longer wheel hub, the idea is to achieve a more stable design. By increasing the contact surface between the hub and the rivet, the wobbling might decrease since the hub supports the wheels.

5.4.1.2 Plates

This category of ideas consists of modified plates. The plates are either modified by changing the dimensions or the general design.

5.4.1.2.1 Isolators (2.1)

By adding a thin layer of a damping material between the slides and the cabinet, the vibrations and the noise might be decreased. The aim with the damping material is to eliminate and prevent the vibrations, caused during sliding, to propagate in the dresser.

5.4.1.2.2 Topology (2.3)

The idea is to create cavities in the plate with the aim to decrease the generated noise during use. The idea is based on the theory that the noise propagates along the metal material and by removing pieces of metal material from the plate, the noise will probably be damped by the wood of the dresser.

5.4.1.3 Attachments

This category of ideas consists of different methods of attaching the wheels to the plates as well as modifications of the current joining method.

5.4.1.3.1 Bushing (3.3)

This idea is an economic alternative to ball-bearings. The use of bushings will improve the rolling and the stability of the wheels since the bushing is attached with a fixed shaft.

5.4.1.3.2 Washer Dimension (3.5)

By modify the dimensions of the washer, the idea is to improve the support of the wheels.

5.4.1.4 Other

This category consists of ideas that could not be categorized within the other categories. The ideas categorized as *Other* are either a previous developed concept by IKEA Components or ideas relating to the positions of the roller slide.

5.4.1.4.1 BEACH POM (4.1)

This concept is developed by IKEA Components and is described in the research section 3.2.

5.4.1.4.2 Integrated Slide (4.3)

This idea is similar to the current solution apart from that the CL and the CR will be integrated in the wood of the cabinet. By integrating the two cabinet slides, the theory is that the position and the wood material will damp the generated noise.

5.4.1.4.3 Fixed Drawer (4.4)

This idea refers to eliminating factors impacting the perceived quality of the dresser. By improving the robustness of the drawer, the idea is to decrease the wobbling caused by the unstable drawer. In that way, the instability of the roller slide will be examined separately.

5.4.2 **Established Concepts**

To evaluate the promising ideas presented above, the ideas were developed into concepts. Many of the ideas could be developed into concepts by applying the ideas to either the original roller slide or to the BEACH POM prototype. In the cases where the concept could be divided into many variants, configurations of those concepts were made. Mainly, the concepts aim to evaluate and test one adjustment at the time. This in order to verify and evaluate the impact of the adjustments separately.

5.4.2.1 Concept A

Concept A is the BEACH POM concept developed by IKEA Components. The concept is a narrowed version of the original roller slide. The plastic wheels are smaller, and the plates have a more tightened design. A more detailed description can be found in section 3.2.

5.4.2.2 Concept B

This concept refers to examining the impact of the dimensions of the wheels and is based on idea 1.3. Both the inner and the outer diameter will be modified. Many variations of the dimensions are of interest in order to find the optimal relation between the inner and the outer diameter. The concepts have therefore been divided into a number of configurations. In the cases where the outer diameter is decreased, the previous developed wheels of BEACH POM will be used. In the cases where the BEACH POM prototype will be applied, the concept is based on a combination of idea 1.3 and 4.1.

5.4.2.2.1 Concept B.1

This concept is based on the original design where the inner diameter of the wheels is adjusted. The inner diameter is decreased to 3 mm, see Figure 5.7.

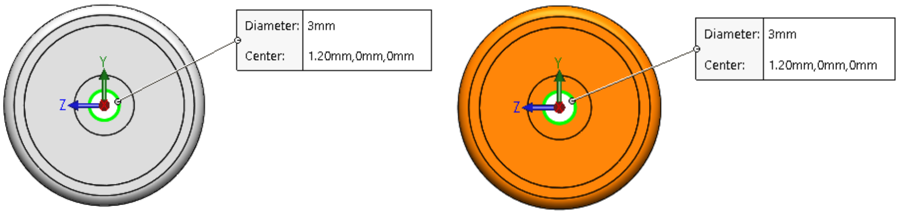


Figure 5.7 Cabinet wheels (grey) and drawer wheels (orange) with an inner diameter of 3 mm.

5.4.2.2.2 Concept B.2

This concept is based on the original design where the inner diameter of the wheels is adjusted. The inner diameter is increased to 7 mm, see Figure 5.8.

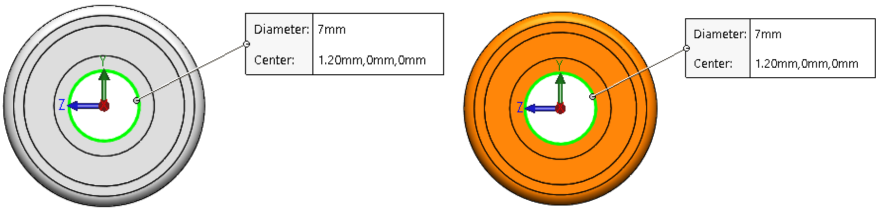


Figure 5.8 Cabinet wheels (grey) and drawer wheels (orange) with an inner diameter of 7 mm.

5.4.2.2.3 Concept B.3

This concept is based on the original design where the inner diameter of the wheels is adjusted. The inner diameter is increased to 10 mm, see Figure 5.9.

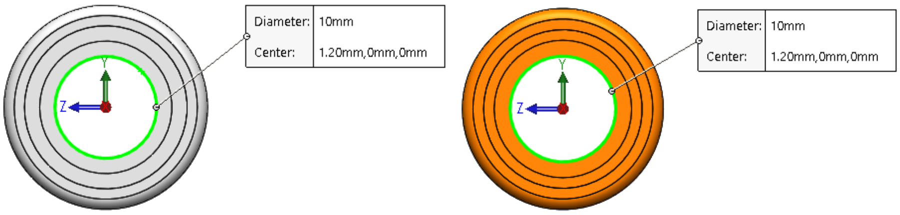


Figure 5.9 Cabinet wheels (grey) and drawer wheels (orange) with an inner diameter of 10 mm.

5.4.2.2.4 Concept B.4

This concept is based on the BEACH POM design to evaluate the impact of a decreased outer diameter combined with a decreased inner diameter of 3 mm, see Figure 5.10.

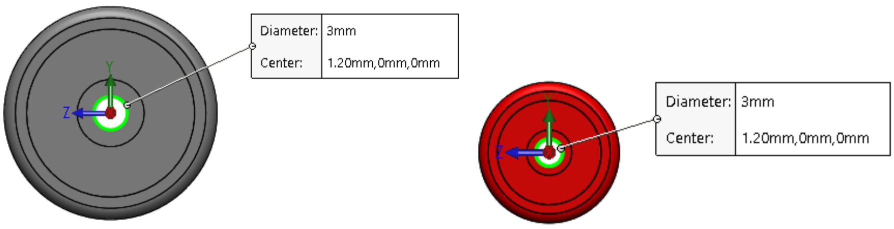


Figure 5.10 Cabinet wheels (dark grey) and drawer wheels (red) with an inner diameter of 3 mm.

5.4.2.2.5 Concept B.5

This concept is based on the BEACH POM design to evaluate the impact of a decreased outer diameter combined with an increased inner diameter of 7 mm, see Figure 5.11.

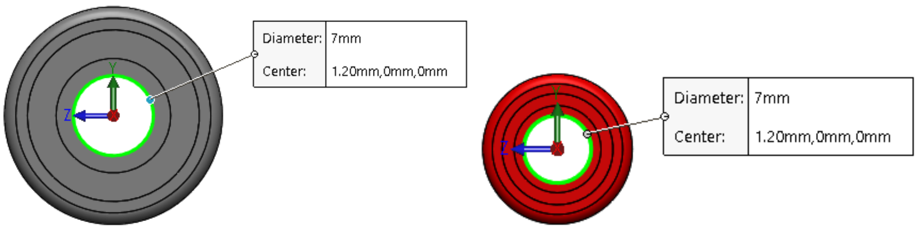


Figure 5.11 Cabinet wheels (dark grey) and drawer wheels (red) with an inner diameter of 7 mm.

5.4.2.2.6 Concept B.6

This concept is based on the BEACH POM design to evaluate the impact of a decreased outer diameter combined with an increased inner diameter of 10 mm, see Figure 5.12.

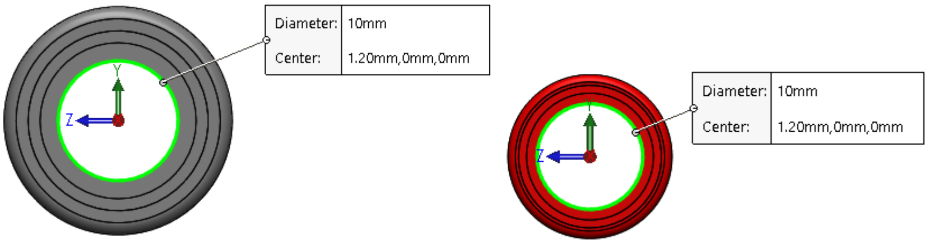


Figure 5.12 Cabinet wheels (dark grey) and drawer wheels (red) with an inner diameter of 10 mm.

5.4.2.3 Concept C

This concept is divided into two configurations and is based on idea 1.5. The division of the configurations is performed in order to evaluate the impact of the position of the fixed sliding blocks.

5.4.2.3.1 Concept C.1

The concept consists of the original roller slide where the rolling wheels on the drawer slides, DL and DR, are replaced with fixed plastic blocks, see Figure 5.13. The cabinet slides, CL and CR, are unmodified, see Figure 5.14.

Figure 5.13. Modified drawer slides with blocks instead of wheels.

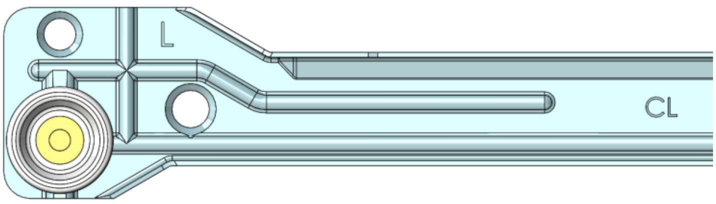


Figure 5.14. Original cabinet slides.

5.4.2.3.2 Concept C.2

The concept consists of the original roller slide where the rolling wheels on the cabinet slides, CL and CR, are replaced with fixed plastic blocks, see Figure 5.15. The drawer slides, DL and DR, are unmodified, see Figure 5.16.

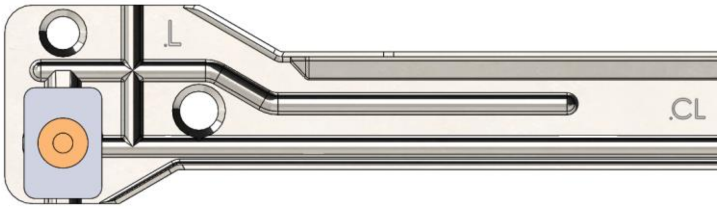


Figure 5.15. Modified cabinet slides with blocks instead of wheels.

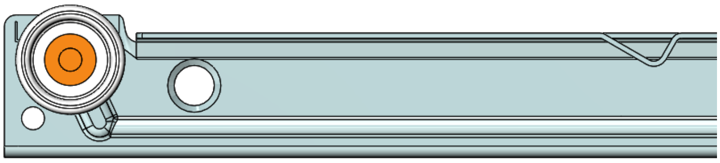


Figure 5.16. Original drawer slides.

5.4.2.4 Concept D

This concept is based on idea 1.6 and is performed in order to evaluate the impact of implying sliding rather than rolling mechanisms. The concept consist of the original roller slide where the all wheels on the drawer slides, DL and DR, and the cabinet slides, CL and CR, are replaced with fixed plastic blocks, see Figure 5.17-Figure 5.18.

Figure 5.17. Modified drawer slides with blocks instead of wheels.

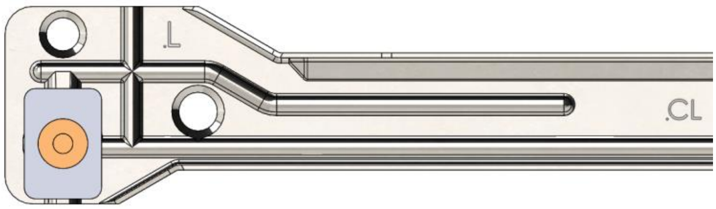


Figure 5.18. Modified cabinet slides with blocks instead of wheels.

5.4.2.5 Concept E

Concept E refers to examining the impact of the dimension of the washer and is based on idea 3.5. To evaluate two different dimensions of the washer, the concept was divided into two configurations.

5.4.2.5.1 Concept E.1

The concept consists of the original roller slide where the original washer is replaced with a new modified washer. The new washer has an increased outer diameter of 11 mm, see Figure 5.19.

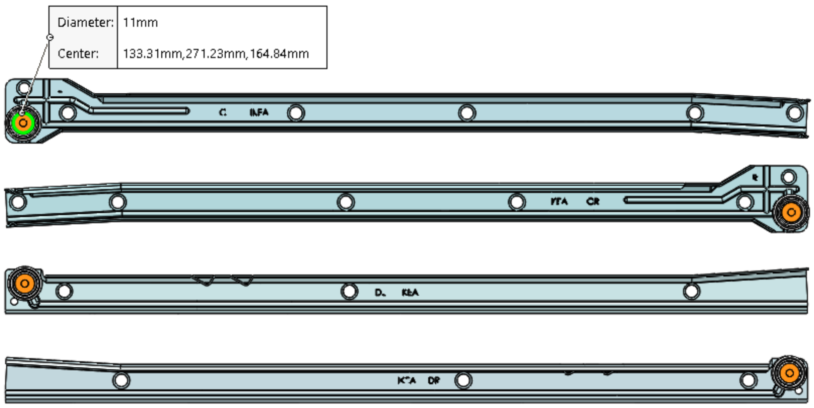


Figure 5.19 Using a washer with an increased outer diameter of 11 mm.

5.4.2.5.2 Concept E.2

The concept consists of the original roller slide where the original washer is replaced with a new modified washer. The new washer has an increased outer diameter of 13 mm, see Figure 5.20.

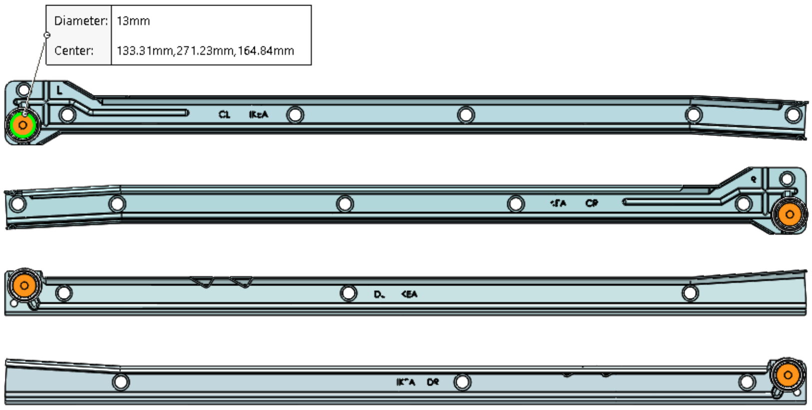


Figure 5.20 Using a washer with an increased outer diameter of 13 mm.

5.4.2.6 Concept F

In order to examine the impact of the wheels' roundness, the original roller slide is modified by replacing the wheels. The examined wheels are manufactured by using turning as a method. The concept is based on idea 1.7.

5.4.2.7 Concept G

Idea 2.3 is tested in three different ways and are applied on the original roller slide. The configurations of the concepts vary in terms of the amount of removed material. Different patterns are examined in order to investigate how much removed material is necessary to achieve an impact of the generated noise.

5.4.2.7.1 Concept G.1

The original roller slide is applied where the plates have been modified by adding a number of holes, see Figure 5.21.

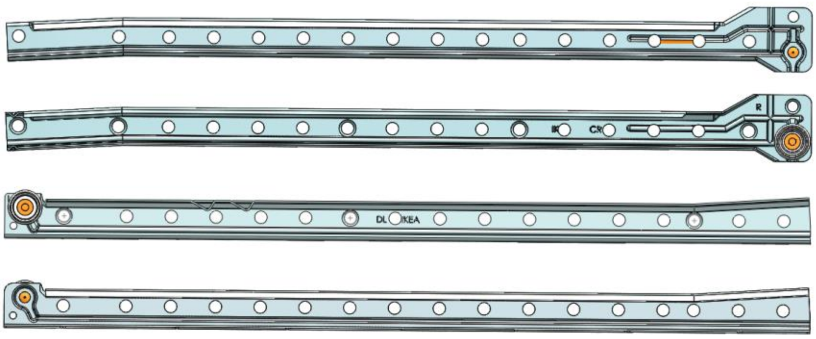


Figure 5.21 Modified plates by adding a number of holes.

5.4.2.7.2 Concept G.2

The original roller slide is applied where the plates have been modified by removing a certain material according to Figure 5.22.

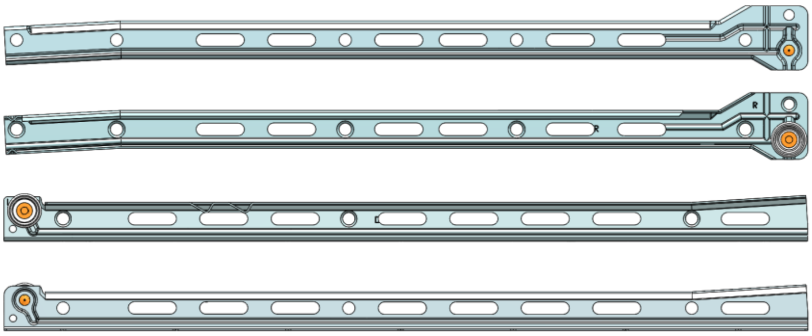


Figure 5.22 New design of the plates where certain material have been removed.

5.4.2.7.3 Concept G.3

The original roller slide is applied where the plates have been modified by removing as much material as possible as shown in Figure 5.23.

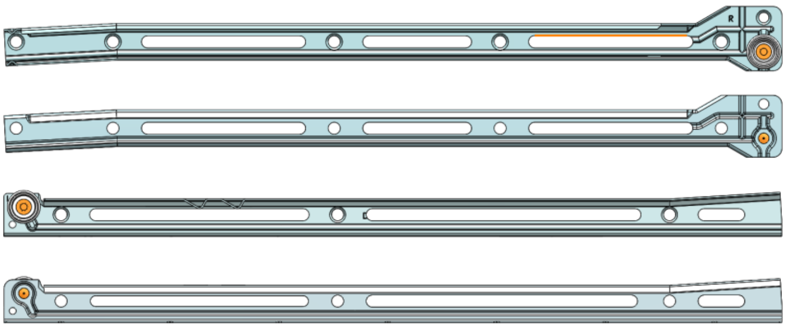


Figure 5.23 New design of the plates where a lot of material have been removed.

5.4.2.8 Concept H

Concept G is based on idea 1.1 where different profiles of the wheels are examined on the original design. To investigate different profiles of the wheels, the concept is divided into two different configurations.

5.4.2.8.1 Concept H.1

The original roller slide is used where the wheel profiles are modified by adding a track in the middle of the wheels as shown in Figure 5.24.

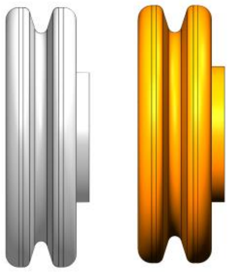


Figure 5.24 A track added on the wheels.

5.4.2.8.2 Concept H.2

The original roller slide is used where the wheel profiles are modified by narrowing the wheels as shown in Figure 5.25.

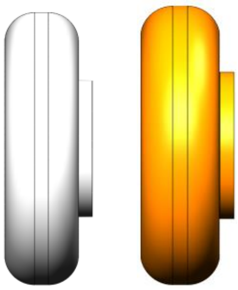


Figure 5.25 Narrowed wheel profile.

5.4.2.9 Concept I

This concept is divided into three configurations and is based on idea 3.3. The division of the configurations is performed to evaluate the impact of using bushings.

5.4.2.9.1 Concept I.1

The concept consists of the original roller slide where bushings are mounted on the wheels related to the drawer slides, DL and DR, as shown in Figure 5.26. The bushings enable a fixed rotation of the wheels. The cabinet slides, CL and CR, are unmodified as shown in Figure 5.27.

Figure 5.26. Bushings mounted on the drawer wheels.

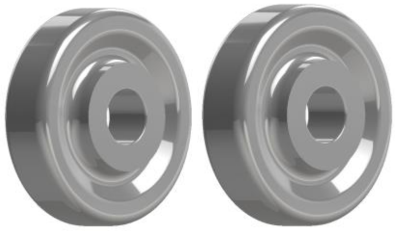


Figure 5.27. Unmodified cabinet wheels without bushings.

5.4.2.9.2 Concept I.2

The concept consists of the original roller slide where bushings are mounted on the wheels related to the cabinet slides, CL and CR, see Figure 5.29. The bushings enable a fixed rotation of the wheels. The drawer slides, DL and DR, are unmodified as shown in Figure 5.28.

Figure 5.28. Unmodified drawer wheels without bushings.

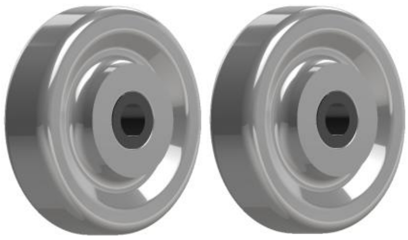


Figure 5.29. Bushings mounted on the cabinet wheels.

5.4.2.9.3 Concept I.3

The concept consists of the original roller slide where bushings are mounted on the four wheels. The bushings enable a fixed rotation of the wheels, see Figure 5.30.

Figure 5.30. Bushings mounted on the four wheels.

5.4.2.10 Concept J

This concept is based on idea 1.2 of using a soft layer of material on the wheels. The aim with the concept is to evaluate if a soft layer applied on a harder core will decrease the generated noise and increase the stability. The concept is divided in two configurations to investigate the impact of the design of the soft layer.

5.4.2.10.1 Concept J.1

This concept consists of a hard core made of POM and a thin layer of TPE-E, see Figure 5.31.

Figure 5.31. POM material marked in orange and a TPE-E layer marked in black.

5.4.2.10.2 Concept J.2

This concept consists of a hard core made of POM and two thin strings of TPE-E, see Figure 5.32.

Figure 5.32. POM material marked in orange and two soft strings of TPE-E marked in black.

5.4.2.11 Concept K

This concept is based on idea 1.8 and refers to examine if a longer wheel hub will result in a more stable design. The concept applies the original slide, using the same diameter of the wheels but with a longer wheel hub, see Figure 5.33.

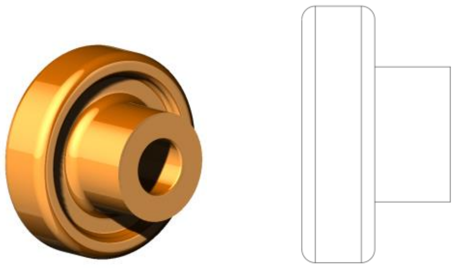


Figure 5.33. A wheel with longer hub.

5.4.2.12 Concept L

Concept K is based on idea 4.3. The cabinet plates of CL and CR are integrated in the cabinet, see Figure 5.34-Figure 5.35. An integrated roller slide might result in a decreased noise during sliding since the wooden material might damp the noise more efficiently. In addition, by removing material and integrate the roller slide, a wider drawer is possible to achieve combined with an improved packaging solution since the sides of the cabinet can easier be stacked.

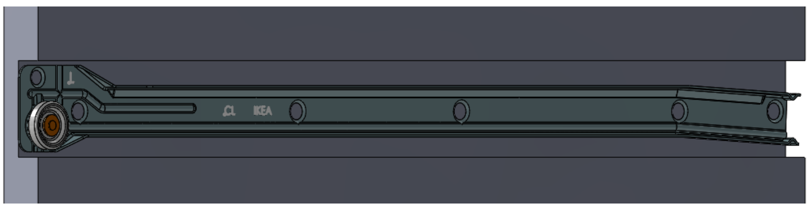


Figure 5.34. Cabinet roller slide integrated in the cabinet.

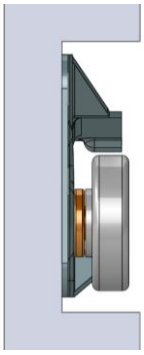


Figure 5.35. Integrated cabinet in profile.

5.4.2.13 Concept M

This concept is based on idea 2.1 where a thin layer of damping material is added between the cabinet and the cabinet slides, CL and CR. The aim with the concept is to evaluate if adding a soft layer of material will decrease the noise and vibration during sliding. The concept is divided into two configurations to investigate different types of damping materials.

5.4.2.13.1 Concept M.1

This concept refers to adding a layer of damping material on the backside of the cabinet slides, see Figure 5.36.

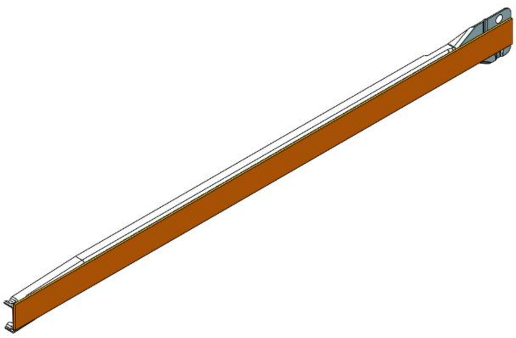


Figure 5.36 Damping material added on the backside of the cabinet slide.

5.4.2.13.2 Concept M.2

This concept refers to coat the backside of the cabinet slides with a noise-damping coating, see Figure 5.37.

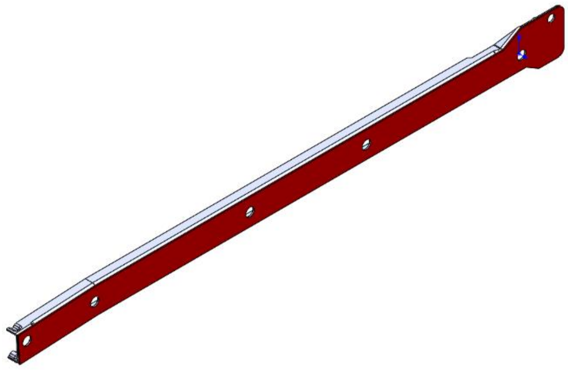


Figure 5.37 Coating added on the backside of the cabinet slide.

5.4.2.13.3 Concept M.3

Concept M.3 refers to adding washers between the cabinet slides and the cabinet as showing in Figure 5.38. The washers are made of the noise-damping material TPE-E provided from the retailer Hexpol TPE AB and the material specification are attached in Appendix F.

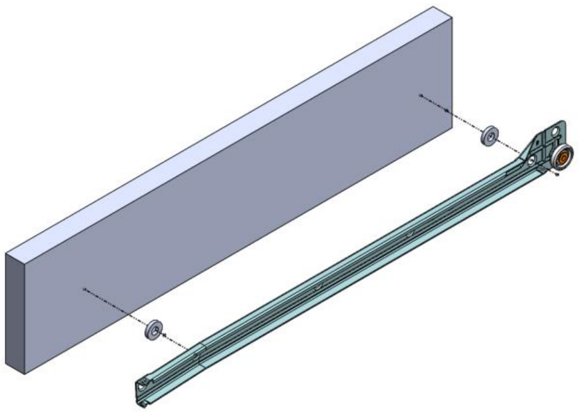


Figure 5.38 TPE-E washers added between the cabinet slide and the cabinet.

5.4.2.14 Concept N

This concept is based on idea 4.5 and refers to stabilizing the drawer in the MALM-dresser. The drawer can be stabilized by adding ribs inside the drawer or by using other permanent attachment methods. By using the original roller slide, the instability and wobbling caused by the roller slide can be examined more separately.

5.5 Patent Search

The patent search was mainly performed in collaboration with C. Ervér. In order to patent an invention, it must meet certain requirements. The requirements imply that the invention must be new, inventive and industrially applicable [26]. The technique behind the roller slide are according to C. Ervér, more than 20 years old and therefore, he states that the risk of infringements is low. In addition, the concepts generated by the design team are mainly simple and obvious adjustments or modifications of the existing design and would therefore most likely not be considered being inventive.

Even though the risk of infringement is considered being low, the design team performed a brief patent search in order to find patents that might be of interest to investigate. The patents that were found are presented below. Generally, all the patents cover some sort of sliding mechanism. The patent search was performed at Espacenet [27].

- EP3346874 – 2018 [28]
- DE102012105182 – 2013 [29]
- DE899015 – 1953 [30]
- DE636859 – 1936 [31]

6 Concept Selection

This section describes the selection of concepts and how those have been evaluated. The section contains concept screening, prototype testing, evaluation and further development.

6.1 Method

To select concepts, the design team used the methodology described by Ulrich and Eppinger as an inspiration [6], p.149. The methodology had to be adjusted in order to fit this project. This since the evaluation of the concepts had to be based on performed tests. The concept selection followed a four-step process as followed:

1. Concept screening
2. Prototype testing
3. Evaluation and selecting concepts
4. Further development

In the first step of the concept selection, the established concepts presented in section 5.4.2 were screened by the design team together with supervisors and prototype manufacturers. The screening of the concepts were based on the target specification as well as time and manufacturing limitations. In the cases when concepts consisted of several configurations, the extreme cases were prioritized.

The remaining concepts were then rated and ranked based on tests performed on manufactured prototypes. A prototype for each concept was developed and then tested in two steps. The first step involved the *Noise and Vibration Test*, described in section 3.3, and the second step contained of a subjective evaluation based on the perceived quality experienced by the design team. Concepts that passed the tests were further developed and improved for further concept testing.

6.2 Concept Screening

The concept screening was performed by discussing the established concepts with supervisors at IKEA Components and with prototype manufacturer at IKEA's prototype workshop. Based on the target specification presented in Table 4.1, concepts that did not meet the metrics were discarded. Manufacturing and time limitations implied that in the cases where configurations of concepts existed, only one configuration was determined to be further evaluated. The selected configuration was the one that was most likely to result in the greatest improvement. The concepts that were discarded and the reason for dismissal are presented in Table 6.1.

Table 6.1 Discarded concepts.

Concept	Reason for dismissal
B.1	Dismissed due to many configurations
B.3	Dismissed due to many configurations
B.4	Dismissed due to many configurations
B.6	Dismissed due to many configurations
E.1	Dismissed due to target specification 3 and 10
E.2	Dismissed due to target specification 3 and 10
F	Dismissed due to time limitations
G.1	Dismissed due to many configurations
G.2	Dismissed due to many configurations
J.1	Dismissed due to time limitations
J.2	Dismissed due to time limitations
K	Dismissed due to many configurations
L	Dismissed due to time limitations
M.3	Dismissed due to target specification 6 and 7

6.3 Prototype Testing

The remaining concepts from the concept screening were further evaluated by prototype testing. The prototypes were developed by the design team together with IKEA's prototype manufacturers. To get an overview and to evaluate each concept in an efficient way, simplified prototypes were developed. It was not required to manufacture the prototypes in a fully appropriate manner, but rather focus on being able to get an indication whether the concepts were an improvement or not. The manufactured prototypes are briefly described in section 6.3.1.

Once the prototypes were manufactured, each prototype was rated and ranked based on a two-step test. In the first step, each concept was tested according to the *Noise and Vibration Test* which is described in section 3.2. The results from each test were then summarized and presented in Table 6.2 together with reference values. The reference values are based on tests performed on the original roller slide and the two prototypes previous developed by IKEA Components, BEACH POM and BEACH BEARING. The second step covered a subjective evaluation based on the perceived quality experienced by the design team. Each concept was experienced and evaluated by mounting the prototype in a MALM-dresser. The perceived quality of each concept was compared to the perceived quality of the original roller slide. Smooth sliding, generated noise, wobbling and stability are the main factors that were evaluated. By comparing the concepts with the original roller slide, the concepts were scored by receiving a (+), (0) or (-). In case the concept was considered being better than the reference concept, it received a (+). If the concept instead was considered being worse, it received a (-) and if the concepts were considered being equal, it received a (0). The design team tested each concept individually and concluded the results by discussing the individual experiences. The results and the conclusions from the subjective evaluation are summarized and commented in Table 6.3.

6.3.1 **Prototypes**

Prototypes of the remaining concepts were developed. All concepts except from Concept A, the one prototype previously developed by IKEA Components, were manufactured by the prototype workshop, IKEA Pattern Shop.

6.3.1.1 Concept A

The previously developed prototype BEACH POM is presented in Figure 6.1. This concept was not developed by the prototype manufactures at IKEA Pattern Shop since a prototype already was produced.

Figure 6.1 Prototype of Concept A developed by IKEA Components.

6.3.1.2 Concept B.2

This concept is based on the original roller slide where the manufactures drilled the inner diameter of the wheels to 7 mm. Because of the increased inner diameter, new rivets were required and manufactured. The modified wheels were then mounted on the original plates using the new rivets and the original washers. The modification of the wheels where performed on all four slides. Figure 6.2 below shows one of the drawer slides and one of the cabinet slides with the modified wheels attached. The wheels and the new rivets are shown in Figure 6.3.

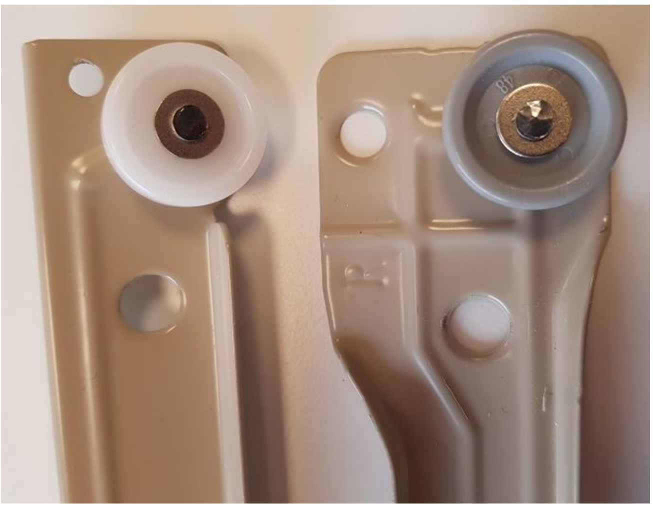


Figure 6.2 Prototype of Concept B.2.

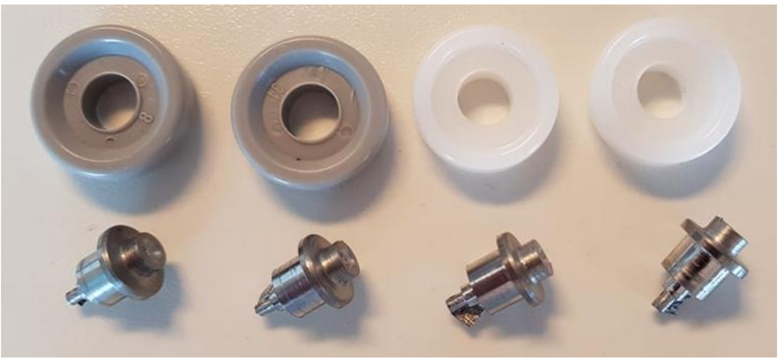


Figure 6.3 Increased inner diameter of the wheels and the new manufactured rivets.

6.3.1.3 Concept B.5

This concept aims to investigate a decreased outer diameter and an increased inner diameter of the wheels. The previously developed prototype BEACH POM could be used since the wheels of this prototype have a decreased outer diameter. The manufactures drilled the inner diameter of the four wheels to 7 mm. Because of the increased inner diameter, new rivets were required and manufactured. The modified wheels were then mounted on the BEACH POM plates using the new rivets and the original washers. Figure 6.4 shows one of the drawer slides and one of the cabinet slides with the new wheels attached.

Figure 6.4 Prototype of Concept B.5.

6.3.1.4 Concept C.1

Instead of replacing the wheels on the drawer slides with plastic blocks, a simplified prototype was made. The prototype is based on the original roller slide where the wheels on the drawer slides, DL and DR, are fixed by locking the wheels. The wheels are thereby prevented from rotating. The cabinet slides, CL and CR, are not modified. Figure 6.5 below shows the modified drawer slides where the wheels are locked.

Figure 6.5 Prototype of Concept C.1.

6.3.1.5 Concept C.2

Instead of replacing the wheels on the cabinet slides with plastic blocks, a simplified prototype was made. The prototype is based on the original roller slide where the wheels on the cabinet slides, CL and CR, are fixed by locking the wheels. The wheels are thereby prevented from rotating. The drawer slides, DL and DR, are not modified. Figure 6.6 below shows the modified cabinet slides where the wheels are locked.

Figure 6.6 Prototype of Concept C.2.

6.3.1.6 Concept D

The prototype for this concept is based on Concept C.1 and Concept C.2. By combining the modified slides with the locked wheels from each concept, a prototype representing a roller slide with four fixed blocks is produced. Figure 6.7 below shows the slides where the wheels on both the drawer and the cabinet slides are non-rotational.

Figure 6.7 Prototype of Concept D.

6.3.1.7 Concept G.3

This prototype is based on the original roller slide where material has been removed from all four slides according to Figure 6.8.

Figure 6.8 Prototype of Concept G.3.

6.3.1.8 Concept H.1

The prototype for this concept is based on the original roller slide where the manufactures milled a track in the middle of the four wheels. The new wheels were then mounted on the original plates, DL, DR, CL and CR, using the original rivets and washers. Figure 6.9 shows the tracked wheels on two of the four slides, the drawer slide to the left and the cabinet slide to the right.

Figure 6.9 Prototype of Concept H.1.

6.3.1.9 Concept H.2

The prototype for this concept is based on the original roller slide where the manufactures tapered the four wheels. The new wheels were then mounted on the original plates, DL, DR, CL and CR, using the original rivets and washers. Figure 6.10 shows the tapered wheels on two of the four slides, the cabinet slide to the left and the drawer slide to the right.

Figure 6.10 Prototype of Concept H.2.

6.3.1.10 Concept I.1

The prototype for this concept is based on the original roller slide. Bushings with an outer diameter of 7 mm and an inner diameter of 5 mm were applied to the drawer slides, DL and DR. To assemble the bushings to the wheels, the manufactures drilled the inner diameter of the two drawer wheels to a suitable size. The bushings were then clamped to the drawer wheels and mounted to the drawer slides, DL and DR, using the original rivets and washers. The cabinet slides, CL and CR, are not modified. Figure 6.11 shows the unmodified cabinet wheels to the left and the modified drawer wheels with the bushings to the right.

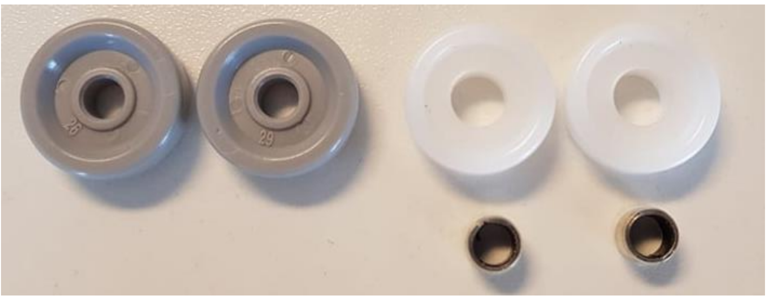


Figure 6.11 The wheels and the bushings for the prototype of Concept I.1.

6.3.1.11 Concept I.2

The prototype for this concept is based on the original roller slide. Bushings with an outer diameter of 7 mm and an inner diameter of 5 mm were applied to the cabinet slides, CL and CR. To assemble the bushings to the wheels, the manufactures drilled the inner diameter of the two cabinet wheels to a suitable size. The bushings were then clamped to the cabinet wheels and mounted to the cabinet slides, CL and CR, using the original rivets and washers. The drawer slides, DL and DR, are not modified. Figure 6.12 shows the modified cabinet wheels with the bushings to the left and the unmodified drawer wheels to the right.

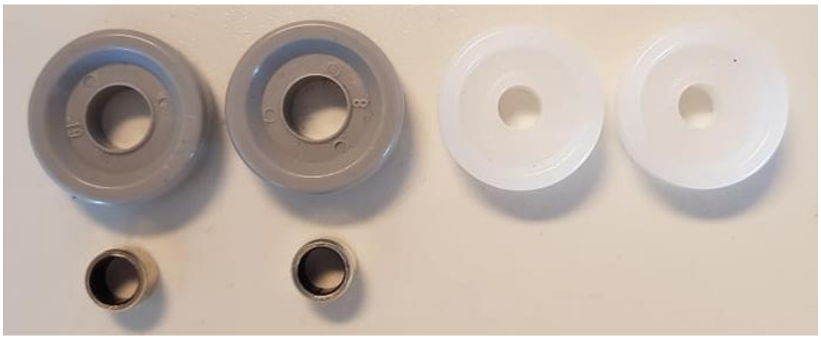


Figure 6.12 The wheels and the bushings for the prototype of Concept I.2.

6.3.1.12 Concept I.3

The prototype for this concept is based on Concept I.1 and Concept I.2. By combining the modified slides with the integrated bushings, a new prototype with bushings on all four slides was established. Figure 6.13 below shows the modified wheels together with the bushings.

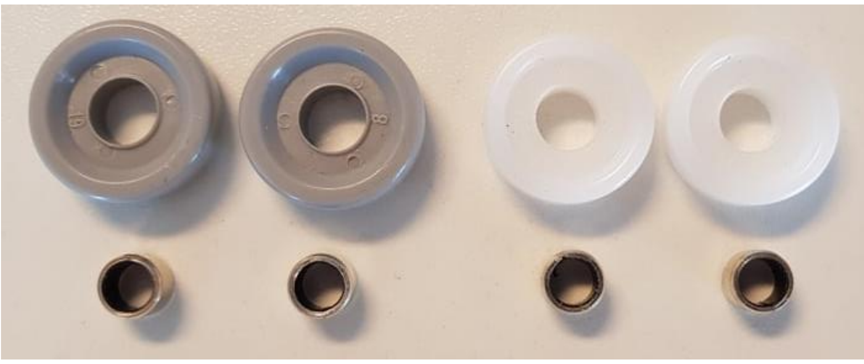


Figure 6.13 The wheels and the bushings for the prototype of Concept I.3.

6.3.1.13 Concept J.1 and J.2

These two prototypes are based on the original roller slide where the wheels have been replaced with 3D-printed wheels. Figure 6.14 shows the 3D-printed wheels for Concept J.1 and Figure 6.15 shows the wheels for Concept J.2. The wheels are 3D-printed with a harder core and a softer outer layer. The design of the softer layer differs from the two concepts. The materials used for the 3D-printing were photopolymers and the aim were to imitate the materials POM and TPE-E. POM is representing the hard core and TPE-E the soft layer. The idea was to mount the 3D-printed wheels to roller slides, using the original rivets and washers but due to time limitations, these two concepts were not investigated.

Figure 6.14 Prototypes of Concept J.1.

Figure 6.15 Prototypes of Concept J.2.

6.3.1.14 Concept M.1

This prototype was made by using the original roller slide. A 0,8 mm thick tape was added on to the backside of the cabinet slides. This side of the slide is the one connected to the cabinet. The drawer slides were unmodified. Since the tape resulted in an increased width of the roller slide, the drawer where the slides were mounted had to be grinded to enable opening and closing. Figure 6.16 shows the cabinet slides, CL and CR, with the added tape.

Figure 6.16 Prototype of Concept M.1.

6.3.1.15 Concept M.2

Based on the original roller slide, the backside of the cabinet slides was sprayed with a noise-damping material called *Plasti Dip*. The drawer slides were unmodified. Figure 6.17 shows the cabinet slides, CL and CR, sprayed with the material.

Figure 6.17 Prototype of Concept M.2.

6.3.1.16 Concept N

This prototype was developed using a drawer from the MALM-dresser. The bottom of the drawer was nailed to the frame of the drawer, see the red area in Figure 6.18. The original roller slide was used to evaluate the impact of a more stable drawer.

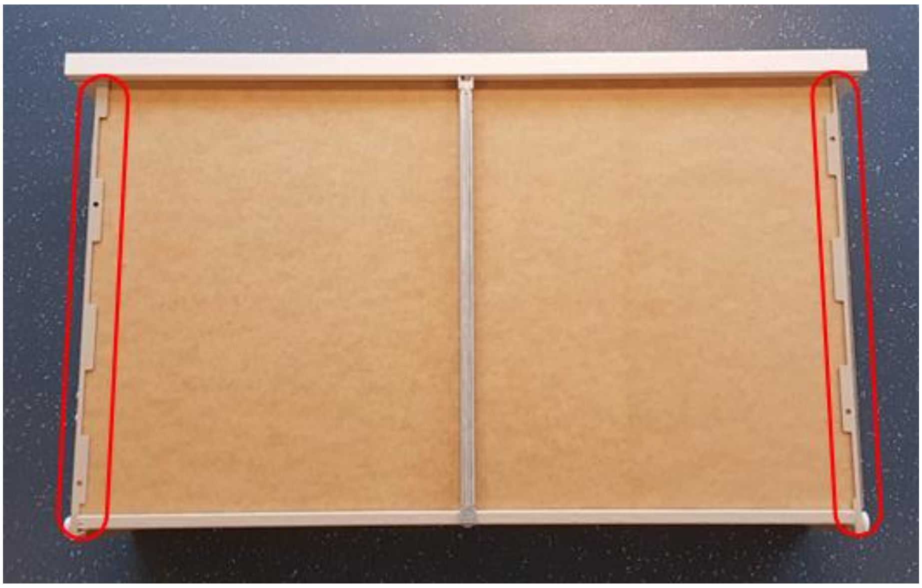


Figure 6.18 Nails added to the drawer within in the red area.

6.3.2 Step 1 - Result from the Noise and Vibration Test

A summary of the results from the *Noise and Vibration Test* are presented in Table 6.2. The complete results of the tests combined with diagrams are presented in Appendix B.

Table 6.2 Results from the Noise and Vibration Test.

Concept	Noise [dB]			Vibration [mm/s^2]		
	Average	Min	Max	Average	Min	Max
Reference Values						
Original Roller Slide	11	10	13	205	165	239
BEACH POM	19	18	21	326	288	378
BEACH BEARING	18	17	19	274	239	301
Concepts						
A	19	18	21	326	288	379
B.2	16	3	19	637	95	902
B.5	14	11	19	424	315	637
C.1	9	8	10	260	202	292
C.2	17	15	18	539	415	791
D	6	4	7	103	76	131
G.3	14	12	15	205	171	261
H.1	14	13	16	280	252	324
H.2	57	12	437	528	409	673
I.1	23	22	25	659	538	883
I.2	11	10	13	233	187	265
I.3	14	8	17	310	258	367
M.1	12	9	14	629	442	924
M.2	10	7	12	178	133	216
N	14	8	17	517	104	871

6.3.3 Step 2 - Result from the Subjective Evaluation

The qualitative results from the subjective evaluation are presented in Table 6.3.

Table 6.3 Results based on experience.

Concept	Scoring	Comment
Original roller slide (ref)	0	-
A	+	More stable design and better generated noise except from when the slides scratch against each other.
B.2	0	The stability is improved in some extent but is highly dependent on the fitting between the wheels and the rivets. The generated noise is not improved.
B.5	+	Stability improved and the drawer is experienced being less wobbling. The slides scratches against each other making the generated noise difficult to evaluate.
C.1	+	Comfortable noise during use and the sliding was considering being improved. Noise due to scratch appeared.
C.2	-	Not improved due to scratching noise and was considered being difficult to close.
D	-	Not improved due to scratching noise and poor sliding.
G.3	0	Scratching noise due to poor fitting. Generated noise and stability of the wheels were considered being unchanged.
H.1	0	The stability unchanged and the generated noise slightly improved.
H.2	-	Decreased stability and the generated noise unchanged.
I.1	0	Rolls easier but generates a rattling noise.
I.2	-	A bit more stable but generates unpleasant noise and poor rolling.
I.3	+	Improved stability but a bit rattling noise.
M.1	0	The stability is improved in some extent but are highly dependent on the fitting. The drawer must be pushed backwards in order to close the drawer. Noise due to scratch rather than wobbling.
M.2	0	Potentially improved generated noise. Stability unchanged since it is still wobbling.
N	+	Stability improved and the generated noise is unchanged.

6.4 Evaluation and Selection of Concepts

The evaluation of the concepts is based on the manufactured prototypes which implies that the quality of the prototypes is highly affecting the results and the perceived experiences. Some of the tests were difficult to evaluate due to manufacturing aspects. Each prototype was handmade which resulted in a varied fitting of the included parts of the roller slide. In some cases, the rolling of the mounted wheels differed from slide to slide. The varied quality caused a misleading experience. For example, regarding the prototype of Concept B.5, two of the four wheels did not rotate properly whereas the other two did. It was therefore concluded that the variety of the handmade prototypes affected the fitting and the evaluation.

To achieve a consistent evaluation, the design team considered the defects of the prototypes. During the tests, the design team focused on the general experience and considered whether an improved prototype would impact the outcome. The concepts where an improved prototype most likely would not enhance the test results were discarded. The results from the *Noise and Vibration Test* presented in Table 6.2 were due to many reasons difficult to evaluate. No consistent pattern or relationship between the measurements and the actual perceived experience of the concepts existed. For example, this is clearly stated by comparing the reference values based on the original roller slide and the BEACH BEARING. The perceived quality of BEACH BEARING is considered better than the original roller slide although the results indicates the opposite. It is also difficult to conclude whether a high or low noise, measured in dB, implies a better or worse perceived quality. A low decibel value does not necessarily imply a pleasant noise since the experienced noise rather is dependent on the type of noise and its frequency. There is also no consistent relationship between the values of the measured noise and the measured vibration. For example, does not a low vibration imply a low decibel and vice versa. Due to those reasons, the concepts selected for further development are mainly based on the subjective evaluation presented in Table 6.3.

6.4.1 **Selected Concepts**

The concepts marked in green in Table 6.3 are the concepts selected for further development. Those are the concepts that the design team considered being the most potential concepts for the sought solution. The evaluation and selection of the concepts are as discussed in section 6.4 mainly based on the subjective evaluation. The concepts that were chosen as the concepts to investigate and/or further develop are Concept B.5, Concept C.1, Concept I.3 and Concept N.

6.5 Further Development

Further development of the selected concepts is considered before further evaluation in section 7. The development is based on previously tests and experiences.

6.5.1 **Concept B.5**

The concept implied an improved stability of the wheels since the increased inner diameter decreases the maximum angle that the wheel can wobble. Although, the quality of the handmade prototype affected the fitting of the wheels and must therefore be further optimized. By optimizing the fitting of the wheels, the wobbling may be increased even more. Due to time limitations and manufacturing possibilities, the current prototype shown in Figure 6.4 is unchanged and used for further examination.

6.5.2 **Concept C.1**

The concept generated a more comfortable noise compared to the original roller slide. The noise was considered being more pleasant since the sound was muffled. As a further development, Concept C.1+ was generated. Although, this concept is of interest since it represents a certain contact surface between the wheels and the plates. It is also of interest since it is a quite simple and cheap modification of the original roller slide. The current prototype presented in Figure 6.5 is unchanged and used for further examination.

6.5.3 **Concept C.1+**

By replacing the fixed wheels on the drawer in Concept C.1 with plastic blocks made in POM, Concept C.1+ was developed. The design of the blocks was discussed with F. Wallis, who has investigated similar solutions before, and suggested therefore a specific design. To minimize the friction and maintain the stability, the blocks were designed as presented in Figure 6.19-Figure 6.20. The general design of the blocks was based on the dimensions of the original drawer wheels in order to maintain the original design of the roller slide. The manufactured prototype which is used in further examination is presented in figure Figure 6.21-Figure 6.22.

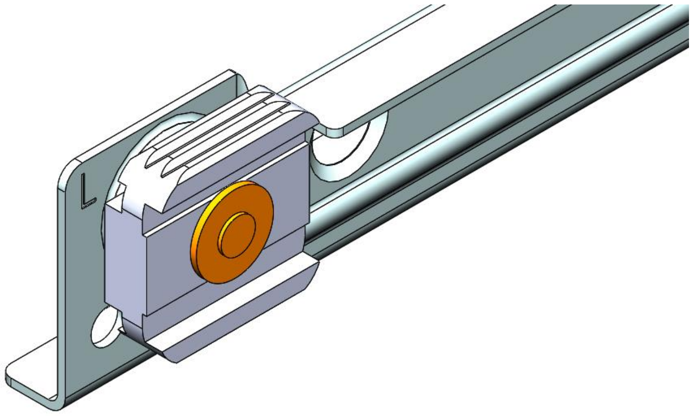


Figure 6.19 CAD-model of Concept C.1+.

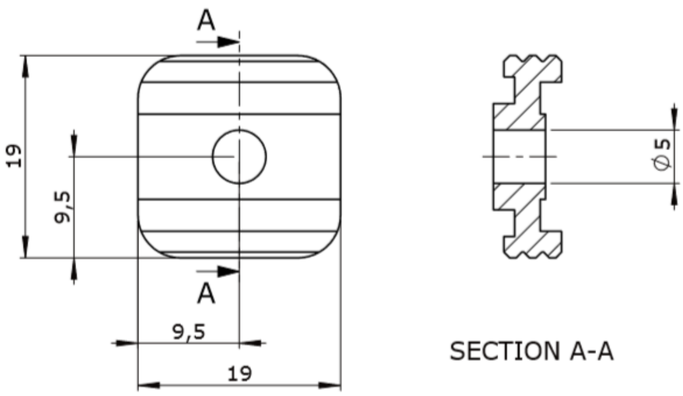


Figure 6.20 General design of the POM blocks in Concept C.1+.

Figure 6.21 Concept C.1+ mounted on a drawer.

Figure 6.22 The plastic blocks of Concept C.1+ in detail.

6.5.4 **Concept I.3**

A potential improvement of this concept would be to optimize the fitting between the bushings, wheels and rivets. The current prototype was manufactured in a way that made it difficult to achieve an optimal fitting. Although, the design team considered the concept being a potential solution due to its improved stability and the concept will therefore be further investigated. The current prototype presented in Figure 6.13 is unchanged and used for further examination.

6.5.5 Concept N

This concept is not further developed but was selected for further investigation due to the interest of examining the impact of the unstable drawer. The design team considered it being important to conclude all type of factors impacting the stability and the generated noise. By further examining this fixed drawer, it might be concluded whether it is most efficient to improve the roller slide or instead focus on improving the stability of the drawer. The current prototype is unchanged and is used during further investigation, see Figure 6.18.

7 Concept Testing

This section contains the Blind Test performed on the further examined concepts and the results from the test.

7.1 Method

Since the perceived quality is subjective and differs individually, the design team together with supervisors concluded that the evaluation of the concept should be based on a number of individual experiences. A *Blind Test* was performed by 25 co-workers at IKEA Components. The test persons were randomly selected to achieve a broad perspective and evaluation of the final concepts. Each test person performed the test separately in order to not impact each other's experiences. The *Blind Test* was performed by mounting the prototypes of the final concepts in a MALM-dresser. The test persons were not aware of which concept that was mounted in the different drawers. The test persons were allowed to open and close the drawers as many times as they wanted to. Based on the experience, the test person selected their top three favorite concepts. These top three concepts where then ranked from 1 to 3, where 1 represented the most favorable solution followed by the second and the third favorable solution. The test person was also allowed to comment and review their experiences both written and oral. Conclusions based on the result could then be drawn.

7.2 Blind Test

The *Blind Test* was performed in the conference room KÖXHULT at IKEA DC South and the 25 randomly selected test persons were IKEA co-workers with a broad variation of responsibilities, educations and knowledge of the Roller Slide. The test objects were mounted in two MALM-dressers and the six drawers were numbered as shown in Figure 7.1. All six drawers were empty in order to correspond to the in-store situation when the consumer is about to try the dresser. The test persons were neither aware of which concepts that were about to be tested nor whether or where the original roller slide was mounted. In the six dressers, the concepts were positioned in the following randomly selected order:

1. Concept B.5
2. Original Roller Slide
3. Concept C.1
4. Concept N
5. Concept C.1+
6. Concept I.3

Figure 7.1 The six test objects mounted in two MALM-dressers.

The results of the *Blind Test* are presented in two diagrams along with a summary of comments and reviews for each concept. The ranking of the concepts, based on the test persons' evaluation, are summarized in Figure 7.2 by presenting how many times respectively concept was ranked as first, second or third choice. Additionally, Figure 7.3 indicates how many times each concept was selected as one of the top three solutions.

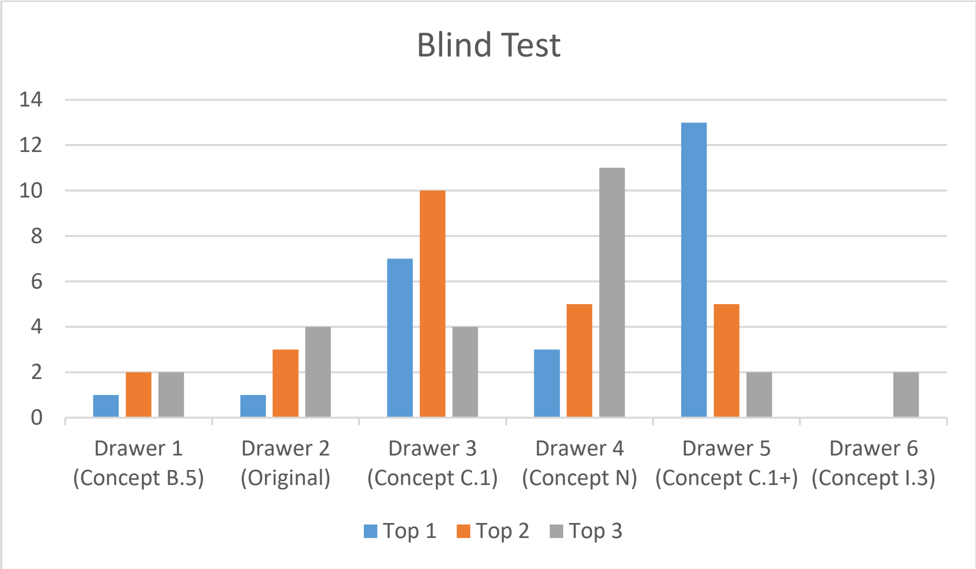


Figure 7.2 The result from the *Blind Test* showing the ranking of the top three favorite concepts.

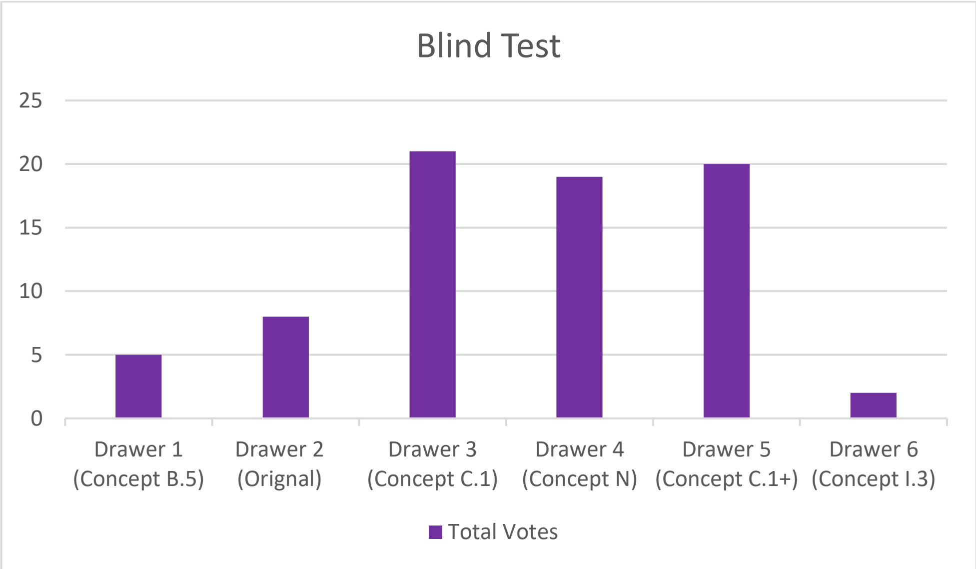


Figure 7.3 The result from the *Blind Test* showing all votes summarized.

7.2.1 Summary of the Written and Oral Reviews

The oral and written comments and reviews of each concept are summarized and presented below. It was not compulsory to comment during the test but in the cases when the test persons did, the design team collected the notes alternatively wrote down their comments.

7.2.1.1 Drawer 1 – Concept B.5

Generally, the test persons perceived this drawer being stable but difficult to open due to high friction. Some argued that the inert movement of the drawer adds a sense of quality but most of the test persons considered the drawer being too heavy to open, especially when adding weight to the drawer.

7.2.1.2 Drawer 2 – Original Roller Slide

This drawer was considered being easy to open, unstable, cheap and generated an unpleasant noise.

7.2.1.3 Drawer 3 – Concept C.1

This drawer was considered being stable and silent. A number of comments mentioned that this drawer was similar to drawer number 5 apart from that this drawer was easier to open. When summarizing all votes, this concept got the highest score but was mainly chosen as second favorite of the top three favorable solutions.

7.2.1.4 Drawer 4 – Concept N

Drawer 4 was one of the top three favorites and was mainly chosen as the third most favorable solution. The test persons experienced the drawer being easy to open and more stable than drawer 2 (the original roller slide). Some test persons consider the drawer being noisy, but the type of generated noise was not unpleasant.

7.2.1.5 Drawer 5 – Concept C.1+

This drawer was one of the most attractive concepts and was mainly selected as the most favorable solution. The test persons considered the drawer being stable and generating a low pleasant noise. The friction is a bit higher but still easy to open and close. One of the test persons noted that the drawer “bounces back” when closing the drawer which must be taken into consideration when improving the design.

7.2.1.6 Drawer 6 – Concept I.3

This drawer only got two votes. A scraping sound occurred during use which generated an unpleasant noise. Compared to drawer 2 and 4, the drawer was experienced being stable but not as stable as drawer 1, 3 and 5.

7.3 Conclusions from the Blind Test

The results of the *Blind Test* indicated that drawer 3, 4 and 5 were the most preferable solutions. The concept related to drawer 4 was mainly investigated in order to neglect other aspects that might affect the generated noise and vibration during use. The concept itself is not an improvement of the roller slide but rather an indication that the perceived quality of the drawers is not only dependent on the roller slide. Concept N will therefore not be a part of the upcoming recommendation to IKEA Components.

Concept C.1 and Concept C.1+ are the ones related to drawer 3 and 5. Those are, based on the test, the two most favorable concepts and will therefore represent the two final concepts.

8 Final Concepts

This section contains the detailed design of the final concepts including specified parts, material selection, manufacturing etc.

8.1 Concept C.1

Concept C.1 is based on the original roller slide where the wheels mounted on the drawer slides, DL and DR, are unable to rotate. The wheels mounted on the cabinet slides, CL and CR, are able to rotate. The fixed wheels improve the stability and entails a more pleasant noise while the rotating wheels enables smooth opening and closing of the drawer.

8.1.1 **Design of the Parts**

All the included parts of concept C.1 are identical to the original parts of the roller slide. A slide set consist of four slides, CL, DL, CR and DR where the wheels attached to the DL and DR are non-rotational. The wheels attached to the CL and CR are rotational, see Figure 8.1-Figure 8.2 for explanation. The detailed design of each part is described in chapter 3. The only difference between the original design and Concept C.1 is regarding the assembling of the drawer slides. The four wheels are attached to the plates with the original rivets and washers.

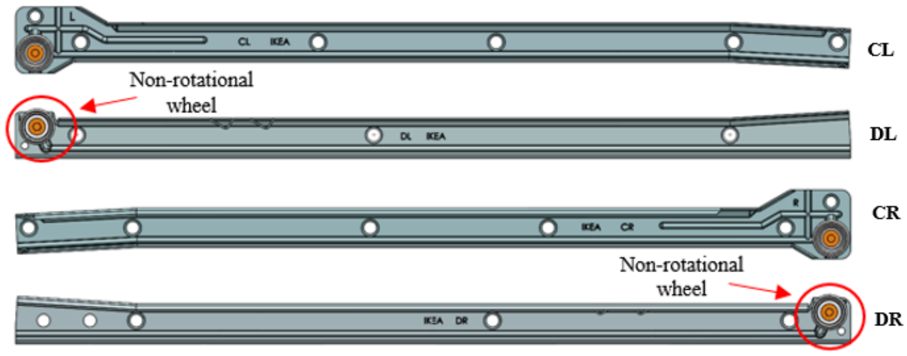


Figure 8.1 A set of slides for Concept C.1.

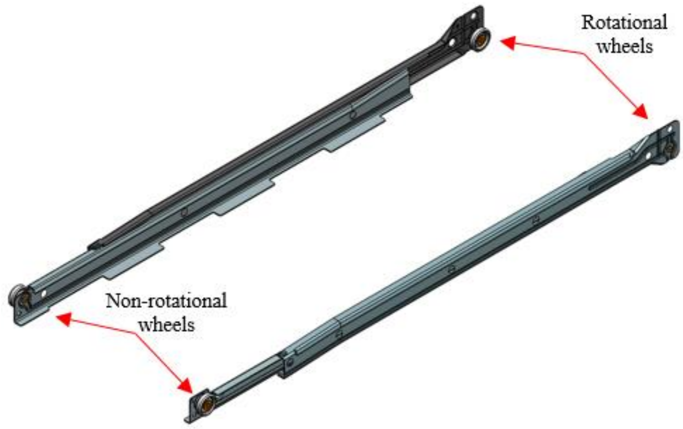


Figure 8.2 Position of the non-rotational and the rotational wheels.

8.1.2 Manufacturing and Assembling

All the included parts of this concept are manufactured using the same methods as mentioned in chapter 3. regarding the original design. The only difference is the assembling of the wheels mounted on the drawer plates which are fixed attached in order to prevent the wheels from rolling. There are different manufacturing methods to enable the fixed joint between the wheel and the plate. The current manufacturing method, riveting, are probably the most suitable alternative through an economical perspective. This since IKEA Components already have suppliers and subcontractors providing this manufacturing process. Compared to the current riveting process, a higher pressure during the riveting is necessary in order to fix the drawer wheels and thereby prevent the rotation.

8.1.3 **Cost Analysis**

The concept does most likely not exceed the current material and manufacturing costs. The material specification of the original roller slide as well as the current manufacturing process can be applied for this concept and the cost will therefore probably not be affected. Additionally, the current suppliers can be contracted, and no additional costs related to contracting will be applied.

8.2 Concept C.1+

Concept C.1+ are similar to Concept C.1 apart from that the drawer wheels have been further developed. The fixed, non-rotational wheels mounted on the drawer plates are replaced by plastic blocks. The design of the plastic blocks enables low friction and stable sliding of the drawer. The combination of non-rotational blocks on the drawer slides and the rotational wheels on the cabinet slides, as seen in Figure 8.3, provides a low generated noise as well as an improved perceived quality of the drawer.

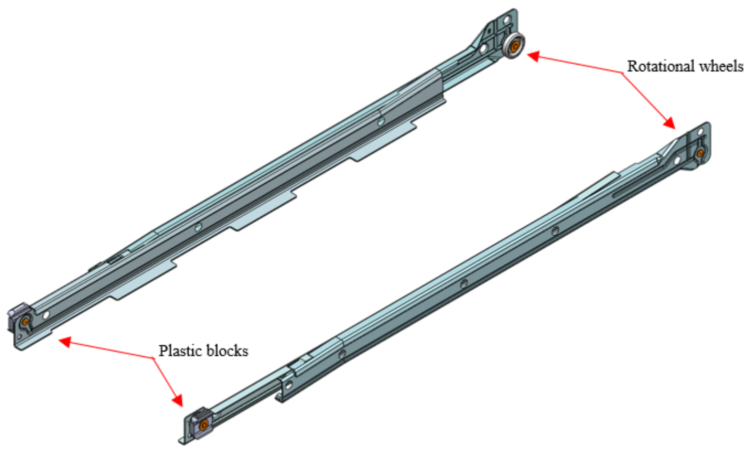


Figure 8.3 Position of the plastic blocks and the rotational wheels.

8.2.1 Design of the Parts

The plates for this concept are identical to the plates of the original roller slide. The wheels attached to the cabinet slides are also identical to the ones attached to the original roller slide. A detailed description of the plates and the cabinet wheels can be found in chapter 3. The plastic blocks attached to the drawer slides, as shown in Figure 8.4, are designed by the design team together with F. Wallis at the IKEA prototype workshop. The design aims to decrease the friction between the block and the plate while enable stable and silent sliding of the drawer. The grooves on the plastic blocks, as shown in Figure 8.5, are designed to decrease the contact surface and thereby optimize the sliding. The material selection of the plastic blocks was set to POM. Mainly, POM was selected since this material is currently used for the wheels. By selecting POM, the design team argued that the durability of the slides therefore would be fulfilled. Additionally, POM was the material that the prototype workshop could offer. The plastic blocks and the wheels are attached to the plates with the original rivets and washers.

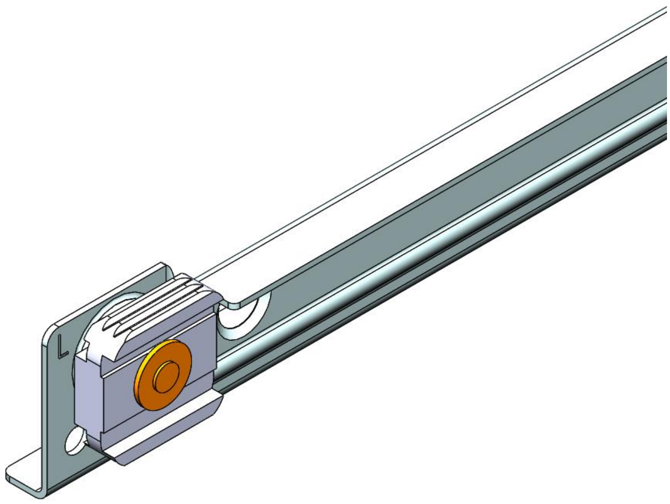


Figure 8.4 The plastic block attached to the drawer slide.

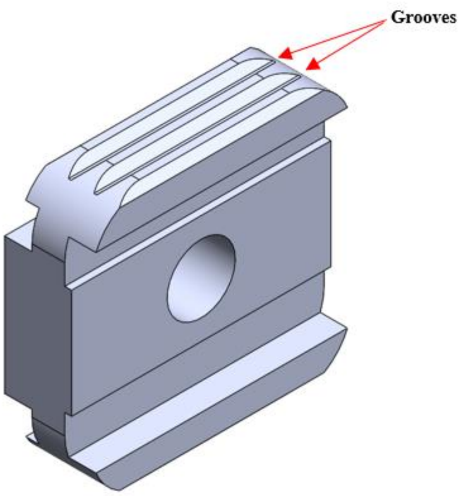


Figure 8.5 Design of the plastic block.

8.2.2 Manufacturing and Assembling

Apart from the plastic blocks, all the included parts in this concept applies the same manufacturing processes as the ones mentioned in chapter 3 regarding the original roller slide. The assembling of the plastic blocks applies the same riveting method as used for the wheels. Although, the settings of the riveting might have to be adjusted to fit the new design. The riveting implies that the blocks are still able to tilt which is preferable in order to make the block follow the angled cabinet plate.

There are many possible manufacturing methods regarding the production of the plastic blocks. Mainly two aspects were considered regarding the selection of manufacturing method for the POM blocks. The manufacturing method must both be applicable for POM and enable mass production in an efficient and economical way. POM can be manufactured by either injection molding or extrusion. Due to mass production of the blocks as well as the design of the blocks, injection molding is considered being the most efficient manufacturing method. Injection molding is used for the manufacturing of the original wheels and would thereby allow IKEA Components to keep their current suppliers. To enable injection molding as a manufacturing method for the plastic blocks, a new mold must be designed.

8.2.3 Cost Analysis

The new mold required for the production of the plastic blocks implies an additional cost. The investment of a new mold causes an initial cost and the manufacturing of the mold might be expensive. Although, this potentially high investment is most likely over time a relatively low cost, especially in combination with the high production volume. Regarding the material consumption is the volume of the bock compared to the volume of the drawer wheel, increased with about 26%. The increased amount of material implies a higher total material cost for the slides. Apart from the plastic blocks, no additional costs are incurred compare to the original roller slide since the current material and manufacturing methods can be used.

9 Results

This chapter covers the results of this Master Thesis including an evaluation of how well the recommended concepts fulfills the target specification and the Democratic Design.

9.1 Final Recommendation

The design team has, based on the investigation performed during this Master Thesis, concluded a final recommendation to IKEA Components regarding the improvement of the current roller slide mounted in the MALM-dresser. The recommendation covers two concepts where one of the concepts is a development of the other. The two concepts, called Concept C.1 and Concept C.1+, are developed throughout this thesis and the finalized designs are described in chapter 8. Concept C.1 is presented in Figure 9.1and Concept C.1+ is presented in Figure 9.2.

Figure 9.1 Concept C.1.

Figure 9.2 Concept C.1+.

9.1.1 **Target Specification**

To investigate how well the recommended concepts fulfills the target specification, each concept has been evaluated in relation to each metric in Table 4.1. The evaluation of the subjective specifications has been performed by the design team.

9.1.1.1 Concept C.1

As presented in Table 9.1 fulfills Concept C.1 the majority of the specifications. The two metrics which are not met, “Environmentally friendly” and “Damping”, are of low importance and are therefore not of high priority to fulfill. The material cost as well as the total cost for the concept were difficult to determine due to lack of information. The number of man-hours as well as manufacturing and transportation costs were to the design team unknown. Although, the design team argues that the cost of the concept should not exceed the current cost of the roller slide. The metrics “Volume of noise during sliding” and “Vibration during sliding” have no margin value assigned since such values have not been determined by IKEA Components before. The design team still considered the metrics being fulfilled based on their subjective evaluation in combination with the results of the *Blind Test.*

Table 9.1 Evaluation of how well Concept C.1 fulfills the target specification.

No.	Metric	Importance factor (1-5)	Unit	Margin value	Ideal value	Fulfilled
1	Volume of noise during sliding	5	dB	-	0	Yes
2	Vibration during sliding	5	mm/s^2	-	0	Yes
3	Stability	4	Subj.	-	-	Yes
4	Material cost	4	SEK	-	-	Yes*
5	Total Cost	4	SEK	-	-	Yes*
6	Easy to install	2	Subj.	-	-	Yes
7	Changes of existing tolerances of the MALM-dresser	4	Binary	No	No	Yes
8	Dismountable	2	Binary	Yes	Yes	Yes
9	Easy to dismount	2	Subj.	-	-	Yes
10	Smooth sliding	5	Subj.	-	-	Yes
11	Environmentally friendly	3	Binary	No	Yes	No
12	Damping	1	Binary	No	Yes	No
13	Few tools needed when installing	1	Subj.	3	0	Yes
14	Few changes on existing roller slide	2	Binary	Yes	No	Yes
15	Initiative for the user	3	Subj.	-	-	Yes
16	Appealing to the user	3	Subj.	-	-	Yes

* Exact value could not estimate but with respect to the relatively small adjustments compare the original roller slide, the costs should not exceed the current cost.

9.1.1.2 Concept C.1+

The majority of the metrics in the target specification are fulfilled as presented in Table 9.2. The concept implies a higher material cost compared to the original design and thereby also a higher total cost. Whether the increased costs are too expensive or not are difficult for the design team to evaluate since no margin values have been concluded by IKEA Components. The design team also lacked information regarding current costs which made it difficult to calculate the costs of Concept C.1+. The design team could therefore not determine whether the metrics are fulfilled or not. The metrics “Environmentally friendly” and “Damping” are not fulfilled but as discussed regarding Concept C.1 are those metrics not of high importance.

Table 9.2 Evaluation of how well Concept C.1+ fulfills the target specification.

No.	Metric	Importance factor (1-5)	Unit	Margin value	Ideal value	Fulfilled
1	Volume of noise during sliding	5	dB	-	0	Yes
2	Vibration during sliding	5	mm/s^2	-	0	Yes
3	Stability	4	Subj.	-	-	Yes
4	Material cost	4	SEK	-	-	Cannot know*
5	Total Cost	4	SEK	-	-	Cannot know*
6	Easy to install	2	Subj.	-	-	Yes
7	Changes of existing tolerances of the MALM-dresser	4	Binary	No	No	Yes
8	Dismountable	2	Binary	Yes	Yes	Yes
9	Easy to dismount	2	Subj.	-	-	Yes
10	Smooth sliding	5	Subj.	-	-	Yes
11	Environmentally friendly	3	Binary	No	Yes	No
12	Damping	1	Binary	No	Yes	No
13	Few tools needed when installing	1	Subj.	3	0	Yes
14	Few changes on existing roller slide	2	Binary	Yes	No	Yes
15	Initiative for the user	3	Subj.	-	-	Yes
16	Appealing to the user	3	Subj.	-	-	Yes

* Due to the increased material volume and the required manufacturing mold, both the material cost and the total cost will increase but if the increased costs are too expensive cannot be evaluated by the design team.

9.2 Democratic Design

To make sure the two final concepts corresponds to the Democratic Design, the design team evaluated the concepts based on the five included dimensions. The Democratic Design is the design model which IKEA applies for all development processes. Since the concepts are similar, they are evaluated together.

9.2.1 **Form**

The two concepts are initiative for the end consumer to both install and use. The design of the concepts are not disturbing since the slides are positioned in a discreet way.

9.2.2 **Function**

The usage of the concepts are initiative and does not differ from the current solution.

9.2.3 **Quality**

The concepts are in an initial phase of the development process and the durability has therefore not been concluded. The two concepts are based on the same materials as the original roller slide and should therefore most likely fulfill the requirements. Although, it must be examined whether the non-rotational wheels and the plastic blocks withstands the loads over time.

9.2.4 **Sustainability**

Through a sustainability perspective, it would be advantageously to enable dismounting of all the included parts of the concepts. If each part were separable, it would improve the recycling process. In this case, due to the riveting, the wheels are non-separable which complicates the recycling process. Although, compared to the current solution, the recyclability is unchanged.

9.2.5 **Price**

Concept C.1 does not necessary imply a higher price for the end consumer since the production costs does most likely not exceed the current costs of the original roller slide. The plastic blocks of Concept C.1+ requires a new manufacturing mold and will thereby affect the production costs. As a results, the end-price can possibly increase.

9.3 Further Development

In order to implement the final concepts, a number of considerations and aspects have to be investigated. Generally, the two concepts must be tested with respect to the IKEA standard test requirements. Those tests evaluates the durability and the quality of the slides and such tests have not been performed by the design team. It is of high importance to conclude whether the concepts meets the requirements or not before implementation. A detailed cost analysis for the two concepts must be performed in order to evaluate if the end-price of the slides are too expensive. The costs of Concept C.1 is probably unchanged whereas the costs of Concept C.1+ increases compared to the original roller slide.

It is also of interest to investigate the manufacturing methods of each concept. With respect to Concept C.1, there might be alternative joining methods regarding the attachment of the non-rotational wheels. If the current riveting method is used, the settings must probably be adjusted in order to achieve accurate fitting of the wheels. Due to the plastic blocks of Concept C.1+, the riveting settings for this concept must as well be adjusted. This in order to make sure that the tilting of the blocks works properly. If the riveting is performed with a too high pressure, the blocks might not be able to tilt and thereby cannot follow the angled cabinet plates. The manufacturing method of the blocks must also be further examined, mainly with respect to the required mold. The mold and the design of the plastic blocks must be optimized in order to achieve an efficient production process. The design team has not further evaluated whether the design of the plastic blocks meet the general construction rules regarding the plastic design. For example no sharp corners are acceptable and the position of the injection is of high importance to maintain durability.

The currently recommended method, injection molding, is based on the selected POM material and in case the material changes, other manufacturing processes might be more suitable. The material selection of the plastic blocks are possible to examine in order to improve the properties of the blocks. By using PTFE as an additive, the friction properties, and thereby the sliding, might be improved. Other plastic materials have not been examined by the design team due to time limitations and it might be of interest to investigate if other materials meets the requirements. From an environmentally friendly perspective, it would be of high interest to investigate bioplastic materials as an option.

The implementation of Concept C.1+ requires an even further design investigation in order to optimize the sliding function of the blocks.

The design of Concept C.1+ can be further optimized, especially with respect to the plastic blocks. To achieve a good sliding with low friction, the design of the grooves have to be examined. The number and the design of the grooves as well as their position on the block are of interest to improve. The current design of the blocks are based on the dimensions of the original drawer wheels. The outer dimension of the blocks might therefore be able to decrease, which in turn would result in a lower material cost. Additionally, all the chamfers integrated in the design of the block might be able to optimize. Through a manufacturing aspect, it is important to design the block in a way that enables production in a cost efficient way. A too complex geometry could result in an expensive mold since cores might be necessary.

To improve the design even further, it would be of interest to investigate the interaction between the blocks and the plates. The plates have not been modified in any of the final concepts but they can possibly have an impact on the stability and the perceived quality during use. Especially regarding Concept C.1+, the interaction between the plates and the blocks can be further stabilized by improving the design and the contact surface.

10 Discussion and Conclusion

This section covers thoughts and reflections about the project expressed by the design team. The discussion is followed by a summary of the conclusions.

10.1 Discussion

The goal with this Master Thesis was to study potential modifications of the roller slide with the aim to improve the perceived quality. The expected outcome was to present a recommendation regarding the impact of tested modifications. After finalizing the project, we have recommended two concepts which fulfills the aim and the goal, thereby is the thesis finished. We decided to investigate the problem through a broad perspective in order to examine as many solutions as possible. This resulted in a high number of prototypes which were very time consuming. If we were able to redo it, we would have screened the potential concepts more strictly in order to both save time and being able to focus on developing the final concepts in detail. In the beginning of the project we were interested in redesigning the roller slide more extensively but we were requested by the supervisors to instead focus on adjustments of the roller slide. This in combination with the cost limitations, all the new design solutions were discarded.

As a method for this Master Thesis, the Ullrich and Eppinger product development process was adopted and adjusted. The performed modifications of the process ended up being suitable for this project since the adjusted model could be followed. Although, the time schedule for some activities had to be adjusted. This since some activities were more time consuming than predicted and since some activities overlapped each other. Especially the product development phase had to be modified since the activities took longer time than expected. Although the two following phases took shorter time to perform and the overall time frame could be kept.

The pre-stated delimitations were useful in order to get an overview of the extent of the project and to conduct a relevant time schedule. As time went by, new limitations were detected and necessary in order to focus the content of the project. In an early stage of the project, we decided to only make use of the MALM-dresser and not include other dressers involving the roller slide. This was an advantage due to many reasons. First of all, it saved us a lot of time since we only had to try the concepts in one type of dresser. Secondly, it made it easier for us to rather focus on the development of the concepts than adapting the concepts into the many dressers. On the other hand, this limitation implies that the final concepts are not tested in other dressers. It would have been of interest to try the two concepts in for example a HEMNES-dresser in order to verify the concepts. Another limitation was regarding the discarding of the new design solutions. This limitation affected the project in different ways. It made it easier for us to develop a fewer number of concepts in a more extensively way. If we would have focused on both modifications and new design solutions, it would have been very time consuming and the concepts might not have been fully developed and tested. The limitation was not only based on our time perspective but it was also a request from supervisors. A consequence of this is that a high number of ideas generated by us were not investigated and potentially suitable solutions were discarded at an early stage. A delimitation that would have been an advantage to state in the beginning of the project is regarding the complexity of modifying the roller slide. It would have been preferable if we were informed about certain limitations regarding the design of the roller slide. In that case we could have focused on modifications that are actually possible to implement.

The establishment of the target specification were difficult and mainly performed based on our preferences combined with the Democratic Design of IKEA. The metrics had to be estimated since the target with the roller slide was abstract and subjective. It was also difficult to evaluate what type of values that corresponds to an actual improvement due to the subjective evaluation. Additionally, similar tests regarding noise and stability have not been performed by IKEA before and therefore no references existed. Many of the metrics in the target specification where subjective which implies a highly individual evaluation. The experience of each concept differs from person to person and what is considered being good or bad is rather a question of preferences. The economic metrics were also difficult to evaluate since no stated cost interval were pin pointed regarding how much the improvement were allowed to cost. In addition, we decided to add a metric with respect to the environment since we personally considered it being an important aspect.

The concept generation, which resulted in a high number of established concepts, could have been performed in a more efficient way. Afterwards, it was clear that some of the concepts were unrealistic or not likely to have a positive impact on the roller slide. This could have been avoided by consulting supervisors and co-workers in a more efficient way. Although, the priority of generating the high number of concepts were based on our theory of testing as many modifications as possible. As a result of the many established concepts, a lot of prototypes were necessary to be produced. This was very time consuming and affected the development process since tests could not be performed continuously. Additionally, the quality of the prototypes differed a lot which made it difficult to evaluate each concept properly.

If we would have known that these many prototypes were needed, we together with IKEA Components would have preferred to consult an extern prototype workshop. This since Pattern Shop at IKEA had a heavy workload and by consulting another workshop, the quality might have been more consistent and thereby easier to compare.

The benchmarking included in the concept generation, could in some extent been broader and better applied during the project. In relation to the available information relevant to this project, our external benchmarking covers a relatively small area. By extending the information search, a broader perspective and potentially a higher number of ideas could have been generated. Although, this would also result in a more time consuming process and the risk of not developing each concept as extensively as we did, would have increased. The performed benchmarking gave us a better knowledge within relevant subjects but the knowledge might not have been applied as predicted. In the beginning we planned to find substitutes to the current mechanism and the material of the roller slide but later on, we realized how difficult those types of replacements would be. The replacements would either be too expensive or too difficult in order to meet the requirements, especially due to durability. Even though we for example found potential noise damping materials, those were not further examined. This since we were told that adding softer materials on the wheels implies some complications, such as poor durability.

Our method for evaluating the many concepts included the three steps, the *Noise and Vibration Test*, our subjective evaluation and the *Blind Test*. Since IKEA did not have any pre-developed noise or vibration tests, we had to invent a test on our own. After performing a number of tests, we realized that the quantitative results did not match the subjective experiences. We decided either way to complete the tests and argued that it in the future, it is of interest for IKEA Components to improve the test in order to make it more useful. Additionally, we considered it interesting to have numerical values referring to all the concepts. Potentially, we could have put some more effort while developing the test and thereby make sure the test were more useful than it turned out to be. Since we did not achieve useful results from the *Noise and Vibration Test*, the first selection of the concepts were mainly based on our subjective experiences. Due to those highly individual experiences, this step of the selection is based on personal preferences. Since the design team only consisted of two persons, this step of the process could have been improved by involving a higher number of test persons. On the other hand, we claimed that at this stage of the concept selection, a quite rough screening was necessary. The final selection of the concepts consisted of the *Blind Test*. The idea with the *Blind Test* was to verify the concepts based on many persons preferences. The performance turned out to be both rewarding for the project and appreciated by the co-workers at IKEA. During the *Blind Test* we realized some defects with the method which might have affected the results. For example were the test persons told to evaluate their first impression with respect to noise and stability. As a consequence, some test persons tried the drawers very harshly in order to test the stability. Potentially they would have done the same in a real warehouse but if the instruction would have focused more clearly on only evaluating the first impression, this might have been avoided. In order to even better match the consumers' situation when buying a new furniture, the test could have been performed in a real IKEA warehouse with real customers as test persons. Although, this would have required that the prototypes were optimal manufactured to avoid concepts being discarded due to poor fittings. Another potential improvement of the *Blind Test* would be to involve a higher number of test persons since this would represent a broader spectra of customers.

The tests of the many modifications of the roller slide resulted not only with the two recommended concepts but also with other findings. Due to the varied quality of the prototypes, it was concluded that the fitting of the wheels had a great impact on mainly the stability but also on the generated noise. During the tests we identified a relationship between how well the wheels were riveted to the plates and the generated wobbling. A loose fitting, resulted in high wobbling of the wheels and thereby an unstable design as well as a high generated noise. On the other hand, when the wheels were riveted close to the plates, the wobbling decreased and the stability was improved. As a conclusion it would be of interest for IKEA Components to examine if the stated tolerances of the riveting and the including parts are fulfilled. Even though this relationship is identified based on our prototypes with poor quality, similar variations have been found regarding the original roller slides. Since IKEA Components strives for a cheap solution, it might be an option to investigate how well the tolerances are fulfilled today.

The outcome of the Master Thesis is a recommendation of two potential concepts that fulfills the requirements of the sought solution. Throughout the project, many concepts have been discarded and even though the selection have indicated that those concepts in one way or another have not met our demands, some of the concepts might still be of interest. We still believe that for example using bushings potentially can improve the stability and it might therefore be interesting for IKEA Components to investigate this solution even further. In addition, we also think it would be of interest to combine bushings with the two final recommended concepts. Another idea that still can be valuable for IKEA Components is to investigate if the material samples of TPE-E from Hexpol TPE AB can be applied in an efficient way. This since the advisor from Hexpol TPE AB was convinced that the material would have had a positive impact on the generated noise.

10.2 Conclusion

Generally, it is concluded that modifications of the roller slide have an impact on the perceived quality. The Master Thesis ended up with two recommended concepts where both represents a potential improvement of the current roller slide. The two concepts makes up a pre-study and before implementation they have to be further optimized. There are advantages and disadvantages with both of the concepts and it is up to IKEA Components to consider if the concepts meet their needs and wishes.

The project proved the complexity of how difficult and time consuming it is to perform changes at such an optimized product. Despite the difficulties, the thesis resulted in lots of useful and valuable knowledge for both IKEA Components and the design team.

References

[1] Inter IKEA Systems B.V. (c. 1999). Vårt arv, Retrieved January 18, 2019, from: https://m2.ikea.com/se/sv/this-is-ikea/about-us/vart-arv-pub4f9ca8d7

[2] Inter IKEA Systems B.V. (c. 1999). Vision and business idea, Retrieved January 18, 2019, from: https://www.ikea.com/ms/en_US/this-is-ikea/company-information/index.html

[3] Inter IKEA systems B.V. (c 1999). *Product Catalogue*, Retrieved March 13, 2019, from: https://www.ikea.com/se/sv/catalog/products/40214551/

[4] Inter IKEA systems B.V. (c 1999). *Product Catalogue*, Retrieved March 14, 2019, from: https://www.ikea.com/se/sv/catalog/products/90374274/

[5] Inter IKEA systems B.V. (c 1999). *Product Catalogue*, Retrieved March 14, 2019, from: https://www.ikea.com/se/sv/catalog/products/50324511/

[6] Ulrich, K. T. & Eppinger, S. D. (2012). *Product Design and Development* (fifth edition.). New York, USA: McGraw-Hill.

[7] Inter IKEA systems B.V. (c 1999). *This is IKEA*, Retrieved 20 February, 2019 from: https://www.ikea.com/gb/en/this-is-ikea/democratic-design-en-gb/

[8] Inter IKEA systems B.V. (c 1999). *Product Catalogue,* Retrieved March 4, 2019, from: https://www.ikea.com/se/sv/catalog/products/10391324/

[9] Inter IKEA systems B.V. (2018). *Assembly instructions Tyssedal,* Retrieved March 4, 2019, from:https://www.ikea.com/se/sv/assembly_instructions/tyssedal-byra-med-lador__AA-2004825-3_pub.pdf

[10] Inter IKEA systems B.V. (c 1999). *Product Catalogue*, Retrieved March 4, 2019, from: https://www.ikea.com/se/sv/catalog/products/50374332/

[11] Inter IKEA systems B.V. (2018). *Assembly instructions Vadholma*, Retrieved March 4, 2019, from: https://www.ikea.com/se/sv/assembly_instructions/vadholma-ladsektion__AA-2030245-3_pub.pdf

[12] [Assembly instructions for the bedside table ELVIRA at Mio]. (2015). Retrieved March 15, 2019, from: https://static.mio.host/documents/30444.pdf

[13] [Assembly instructions for the dresser NORDBY at Jysk]. (2018). Retrieved March 15, 2019, from: https://cdn4.jysk.com/ttr/ai/1374677.pdf

[14] Rivets information, (2019). Retrieved February 25, 2019, from: https://www.globalspec.com/learnmore/mechanical_components/mechanical_fasteners_hardware/rivets

[15] Cullum, R. D. (1998). *Handbook of Engineering Design*. Butterworth and Co. https://books.Handbook-of-Engineering-Design

[16] Dr. Hijazi, A. (n.d.) *Mechanical Fasteners*. Retrieved February 25, 2019, from: https://studylib.net/doc/18252207/mechanical-fasteners

[17] Bearings. (n.d.) Retrieved March 1, 2019 from: https://www.ggbearings.com/en/bearings

[18] Slide Bearings. (n.d.) Retrieved March 1, 2019 from: https://debearings.com/tech/slide-bearings/

[19] Sliding material and bushing type selection guide. (n.d.) Retrieved March 15, 2019 from: https://www.skf.com/group/products/bearings-units-housings/plain-bearings

[20] Lubrication. (n.d.). Retrieved March 6, 2019 from: https://debearings.com/tech/lubrication/

[21] Lubrication. (n.d.). Retrieved March 6, 2019 from: https://www.skf.com/group/products/bearings-units-housings/plain-bearings/lubrications

[22] Bruder, U. (2014). *User's guide to plastic* (Second printing) Karlskrona Sweden: Bruder Consulting AB.

[23] Nationalencyklopedin. (n.d.). *ljud*, Retrieved March 1, 2019 from: http://www.ne.se/uppslagsverk/encyklopedi/enkel/ljud

[24] Akay, A. (2002). *Acoustic of friction*. Acoustical Society of America. Retrieved March 1, 2019, from: https://www.imperial.ac.uk/media/imperial-college/research-centres-and-groups/dynamics/Akay-Acoustics-of-friction.pdf

[25] Marques, F., Flores, P., Pimenta Claro, J.C., Lankarani, H. M. (2016, August 9). *A survey and comparison of several friction force models for dynamic analysis of multibody mechanical systems.* Springer Science+Business Media Dortrecht 2016.

[26] PRV. (n.d.). *Conditions for a patent.* Retrieved April 12, 2019 from: https://www.prv.se/en/patents/applying-for-a-patent/before-the-application/conditions-for-a-patent/

[27] Espacenet Patent Search, Retrieved April 18, 2019 from: https://worldwide.espacenet.com/advancedSearch?locale=en_EP

[28] Andersson, B. (2018). *A drawer, and a drawer sliding system for such drawer*. Patent EP 3346874.

[29] Nolte, F., Dowe, M., Montecchio, A., Feld, S. (2013). *Roller, particularly for sliding door or sliding door fitting, particularly for furniture, has rotary bearing with inner ring and outer ring, between which multiply rolling elements are arranged.* Patent DE 102012105182.

[30] Hugo Willach & Soehne. (1953). *Rollenbeschlag fuer Schiebetueren.* Patent DE 899015.

[31] Gretsch Unitas GMBH. (1936). *Schiebetuerrolle mit als Ring ausgebildeter, schalldaempfender Zwischenlage.* Patent DE 636859.

Appendix A Work Distribution and Time Plan

This section includes the work distribution and the time plans presented as Gantt-Schedules for this project. The first Gantt-Schedule represent the time plan made by the design team in the beginning of the project and the second version represent the correct version with the actual times durations.

A.1 Work Distribution

The work has been distributed equally among the team members through this Master Thesis. Both team members have participated and been involved in all activities, discussions and conclusions.

A.2 Time Plan

The Gantt-Schedule in Figure A. 1 shows the time plan made by the design team in the beginning of this Master Thesis. During the project, the time plan has been updated with the correct time duration and is presented in the Gantt-schedule in Figure A. 2. The different colors represents the different phases, activities and their duration time.

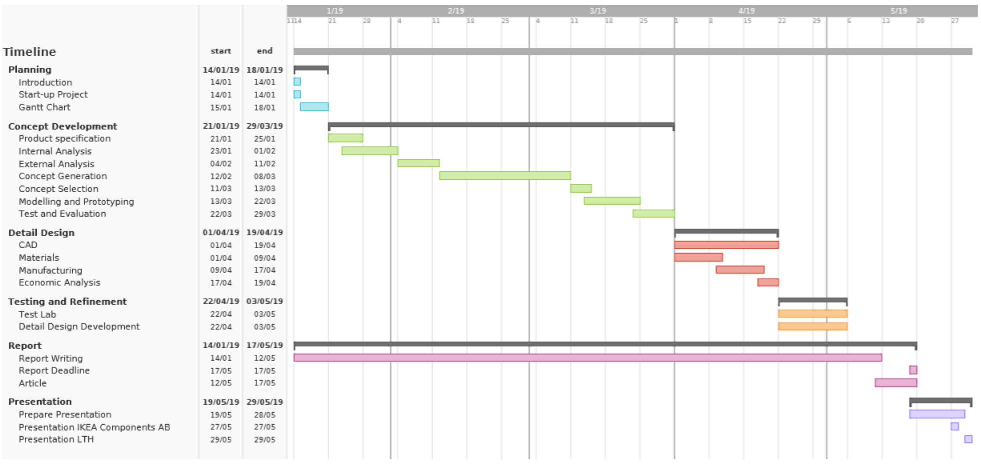


Figure A. 1 The first Gantt-Schedule established in the beginning of the project.

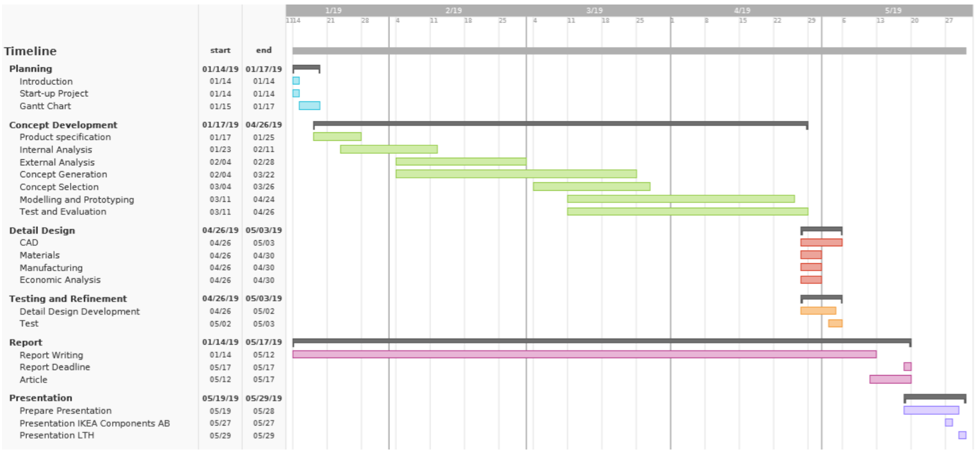


Figure A. 2 The updated Gantt-Schedule representing the actual time durations.

Appendix B Results from the Noise and Vibration Test

The complete results from the Noise and Vibration Test including the reference values and the results from the developed concepts.

B.1 Reference Values

The results from the *Noise and Vibration Test* performed on the original roller slide, BEACH POM and BEACH BEARING are presented in Table B. 1-Table B. 2.

Table B. 1 The noise results from the *Noise and Vibration Test.*

The Noise and Vibration Test - Noise [dB]						
	Type of slide					
	Original		BEACH BEARING		BEACH POM	
Test	Noise Total [dB]	**Noise Slide [dB]**	Noise Total [dB]	**Noise Slide [dB]**	Noise Total [dB]	**Noise Slide [dB]**
Background	*29,4*		*24,1*		*24,5*	
1	39,5	**10,1**	41,3	**17,2**	42,1	**17,6**
2	40,5	**11,1**	42,2	**18,1**	43,6	**19,1**
3	40,8	**11,4**	42,6	**18,5**	44,3	**19,8**
4	39,4	**10**	42,7	**18,6**	43,8	**19,3**
5	39,5	**10,1**	41,5	**17,4**	43,4	**18,9**
6	40,5	**11,1**	42,7	**18,6**	45,4	**20,9**
7	42,5	**13,1**	42	**17,9**	44	**19,5**
8	39	**9,6**	42,5	**18,4**	43	**18,5**
9	41,1	**11,7**	42,9	**18,8**	43,1	**18,6**
10			42,5	**18,4**	43,1	**18,6**
Average		**9,82**		**18,19**		**19,08**
Min		9,6		17,2		17,6
Max		13,1		18,8		20,9

Table B. 2 The vibration results from the *Noise and Vibration Test*.

The Noise and Vibration Test - Vibration [mm/s^2]

Test	Original: Vibration Total [mm/s^2]	Original: **Vibration Slide [mm/s^2]**	BEACH BEARING: Vibration Total [mm/s^2]	BEACH BEARING: **Vibration Slide [mm/s^2]**	BEACH POM: Vibration Total [mm/s^2]	BEACH POM: **Vibration Slide [mm/s^2]**
Background	*4,01*		*3,85*		*3,85*	
1	192	**187,99**	243	**239,15**	305	**301,15**
2	219	**214,99**	288	**284,15**	361	**357,15**
3	243	**238,99**	295	**291,15**	331	**327,15**
4	212	**207,99**	305	**301,15**	340	**336,15**
5	169	**164,99**	266	**262,15**	328	**324,15**
6	213	**208,99**	281	**277,15**	382	**378,15**
7	207	**202,99**	268	**264,15**	335	**331,15**
8	197	**192,99**	262	**258,15**	297	**293,15**
9	228	**223,99**	289	**285,15**	328	**324,15**
10			284	**280,15**	292	**288,15**
Average		**184,391**		**274,25**		**326,05**
Min		164,99		239,15		288,15
Max		238,99		301,15		378,15

B.2 Results Based on the Developed Concepts

The results from the *Noise and Vibration Test* performed on the developed concepts are presented in Table B. 3-Table B. 9.

Table B. 3 The results from the *Noise and Vibration Test* for concept B.2 and B.5.

The Noise and Vibration Test

Test	Concept B.2 – *Measured values*: Noise [dB]	Concept B.2 – *Measured values*: Vibration [mm/s^2]	Concept B.2 – *Without background*: **Noise Slide [dB]**	Concept B.2 – *Without background*: **Vibration Slide [mm/s^2]**	Concept B.5 – *Measured values*: Noise [dB]	Concept B.5 – *Measured values*: Vibration [mm/s^2]	Concept B.5 – *Without background*: **Noise Slide [dB]**	Concept B.5 – *Without background*: **Vibration Slide [mm/s^2]**
Background	29,6	4,24			29,1	3,9		
1	32,7	99,3	**3,1**	**95,06**	42,7	319	**13,6**	**315,1**
2	46,4	752	**16,8**	**747,76**	41,2	358	**12,1**	**354,1**
3	46	748	**16,4**	**743,76**	43,6	404	**14,5**	**400,1**
4	47,2	619	**17,6**	**614,76**	42,9	389	**13,8**	**385,1**
5	46,4	643	**16,8**	**638,76**	41,7	348	**12,6**	**344,1**
6	46,5	689	**16,9**	**684,76**	42,6	404	**13,5**	**400,1**
7	48,9	906	**19,3**	**901,76**	40,2	356	**11,1**	**352,1**
8	45	620	**15,4**	**615,76**	44	469	**14,9**	**465,1**
9	46,8	684	**17,2**	**679,76**	46,7	594	**17,6**	**590,1**
10	46,9	652	**17,3**	**647,76**	47,9	641	**18,8**	**637,1**
Average			**15,68**	**636,99**			**14,25**	**424,3**
Min			3,1	95,06			11,1	315,1
Max			19,3	901,76			18,8	637,1

Table B. 4 The results from the *Noise and Vibration Test* for concept C.1 and C.2.

The Noise and Vibration Test

	Type of concept							
	Concept C.1				Concept C.2			
	Measured values		*Without background*		*Measured values*		*Without background*	
Test	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**
Background	29,7	3,92			27	3,95		
1	37,6	206	**7,9**	**202,08**	44,9	795	**17,9**	**791,05**
2	37	216	**7,3**	**212,08**	45,4	793	**18,4**	**789,05**
3	39,9	296	**10,2**	**292,08**	43,1	454	**16,1**	**450,05**
4	39,8	296	**10,1**	**292,08**	45,1	607	**18,1**	**603,05**
5	39,4	279	**9,7**	**275,08**	44,3	574	**17,3**	**570,05**
6	39,2	273	**9,5**	**269,08**	44,6	431	**17,6**	**427,05**
7	39,1	274	**9,4**	**270,08**	44,1	419	**17,1**	**415,05**
8	39,7	279	**10**	**275,08**	42,9	434	**15,9**	**430,05**
9	39,4	267	**9,7**	**263,08**	42	429	**15**	**425,05**
10	39,2	250	**9,5**	**246,08**	41,9	490	**14,9**	**486,05**
Average			**9,33**	**259,68**			**16,83**	**538,65**
Min			7,3	202,08			14,9	415,05
Max			10,2	292,08			18,4	791,05

Table B. 5 The results from the *Noise and Vibration Test* for concept D and G.3.

The Noise and Vibration Test

	Type of concept							
	Concept D				Concept G.3			
	Measured values		*Without background*		*Measured values*		*Without background*	
Test	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**
Background	26,9	3,96			24,7	3,98		
1	31,3	85,6	**4,4**	**81,64**	37,6	186	**12,9**	**182,02**
2	33,8	135	**6,9**	**131,04**	37	186	**12,3**	**182,02**
3	33,3	120	**6,4**	**116,04**	37,9	208	**13,2**	**204,02**
4	32,5	111	**5,6**	**107,04**	39,3	265	**14,6**	**261,02**
5	33,8	129	**6,9**	**125,04**	37,6	199	**12,9**	**195,02**
6	34,2	112	**7,3**	**108,04**	38,9	211	**14,2**	**207,02**
7	31,8	79,8	**4,9**	**75,84**	38,6	209	**13,9**	**205,02**
8	34,2	101	**7,3**	**97,04**	37,8	175	**13,1**	**171,02**
9	32	81,1	**5,1**	**77,14**	38,2	209	**13,5**	**205,02**
10	33,9	114	**7**	**110,04**	39,7	243	**15**	**239,02**
Average			**6,18**	**102,89**			**13,56**	**205,12**
Min			4,4	75,84			12,3	171,02
Max			7,3	131,04			15	261,02

Table B. 6 The results from the *Noise and Vibration Test* for concept H.1 and H.2.

The Noise and Vibration Test

	Type of concept							
	Concept H.1				Concept H.2			
	Measured values		*Without background*		*Measured values*		*Without background*	
Test	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**
Background	26,8	4,61			32	3,97		
1	42,3	307	**15,5**	**302,39**	44,7	677	**12,7**	**673,03**
2	41,4	259	**14,6**	**254,39**	47,9	517	**15,9**	**513,03**
3	40,7	274	**13,9**	**269,39**	46,9	557	**14,9**	**553,03**
4	41,1	310	**14,3**	**305,39**	47,6	534	**15,6**	**530,03**
5	40,5	259	**13,7**	**254,39**	469	528	**437**	**524,03**
6	42,6	329	**15,8**	**324,39**	47,1	604	**15,1**	**600,03**
7	40,5	264	**13,7**	**259,39**	46,2	516	**14,2**	**512,03**
8	40,8	265	**14**	**260,39**	47,7	458	**15,7**	**454,03**
9	42,3	318	**15,5**	**313,39**	44,4	413	**12,4**	**409,03**
10	39,8	257	**13**	**252,39**	45,3	518	**13,3**	**514,03**
Average			**14,4**	**279,59**			**56,68**	**528,23**
Min			13	252,39			12,4	409,03
Max			15,8	324,39			437	673,03

Table B. 7 The results from the *Noise and Vibration Test* for concept I.1 and I.2.

The Noise and Vibration Test

	Type of concept							
	Concept I.1				Concept I.2			
	Measured values		*Without background*		*Measured values*		*Without background*	
Test	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**
Background	26,8	6,22			29,5	4,97		
1	48,3	564	**21,5**	**557,78**	40,8	247	**11,3**	**242,03**
2	49,6	564	**22,8**	**557,78**	42,2	270	**12,7**	**265,03**
3	49,3	548	**22,5**	**541,78**	40,6	239	**11,1**	**234,03**
4	49,9	600	**23,1**	**593,78**	39,7	231	**10,2**	**226,03**
5	51,7	864	**24,9**	**857,78**	41,5	243	**12**	**238,03**
6	49,1	544	**22,3**	**537,78**	41	256	**11,5**	**251,03**
7	51	779	**24,2**	**772,78**	40,3	234	**10,8**	**229,03**
8	52,2	889	**25,4**	**882,78**	40	192	**10,5**	**187,03**
9	49,7	665	**22,9**	**658,78**	41	243	**11,5**	**238,03**
10	49,8	635	**23**	**628,78**	40	228	**10,5**	**223,03**
Average			**23,26**	**658,98**			**11,21**	**233,33**
Min			21,5	537,78			10,2	187,03
Max			25,4	882,78			12,7	265,03

Table B. 8 The results from the *Noise and Vibration Test* for concept I.3 and N.

The Noise and Vibration Test

	Type of concept							
	Concept I.1				Concept I.2			
	Measured values		*Without background*		*Measured values*		*Without background*	
Test	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**
Background	26,8	6,22			29,5	4,97		
1	48,3	564	**21,5**	**557,78**	40,8	247	**11,3**	**242,03**
2	49,6	564	**22,8**	**557,78**	42,2	270	**12,7**	**265,03**
3	49,3	548	**22,5**	**541,78**	40,6	239	**11,1**	**234,03**
4	49,9	600	**23,1**	**593,78**	39,7	231	**10,2**	**226,03**
5	51,7	864	**24,9**	**857,78**	41,5	243	**12**	**238,03**
6	49,1	544	**22,3**	**537,78**	41	256	**11,5**	**251,03**
7	51	779	**24,2**	**772,78**	40,3	234	**10,8**	**229,03**
8	52,2	889	**25,4**	**882,78**	40	192	**10,5**	**187,03**
9	49,7	665	**22,9**	**658,78**	41	243	**11,5**	**238,03**
10	49,8	635	**23**	**628,78**	40	228	**10,5**	**223,03**
Average			**23,26**	**658,98**			**11,21**	**233,33**
Min			21,5	537,78			10,2	187,03
Max			25,4	882,78			12,7	265,03

Table B. 9 The results from the *Noise and Vibration Test* for concept M.1 and M.2.

The Noise and Vibration Test

	Type of concept							
	Concept M.1				Concept M.2			
	Measured values		*Without background*		*Measured values*		*Without background*	
Test	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**	Noise [dB]	Vibration [mm/s^2]	**Noise Slide [dB]**	**Vibration Slide [mm/s^2]**
Background	34	3,88			29,5	4,44		
1	42,7	446	**8,7**	**442,12**	36,6	152	**7,1**	**147,56**
2	44,1	522	**10,1**	**518,12**	37,8	137	**8,3**	**132,56**
3	44,4	541	**10,4**	**537,12**	39,6	182	**10,1**	**177,56**
4	43,6	489	**9,6**	**485,12**	38,2	185	**8,7**	**180,56**
5	45	501	**11**	**497,12**	38,9	182	**9,4**	**177,56**
6	48,3	832	**14,3**	**828,12**	40,1	184	**10,6**	**179,56**
7	48	877	**14**	**873,12**	38,7	166	**9,2**	**161,56**
8	48,2	928	**14,2**	**924,12**	40,1	220	**10,6**	**215,56**
9	45,6	585	**11,6**	**581,12**	41,2	203	**11,7**	**198,56**
10	45,1	605	**11,1**	**601,12**	41,7	215	**12,2**	**210,56**
Average			**11,5**	**628,72**			**9,79**	**178,16**
Min			8,7	442,12			7,1	132,56
Max			14,3	924,12			12,2	215,56

Appendix C Explanation of the Target Specification

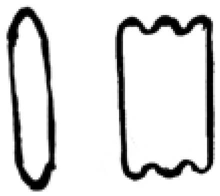
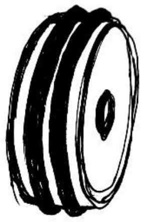
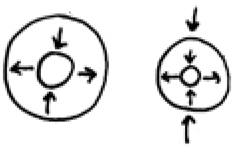
Explanation of the metrics in the target specification.

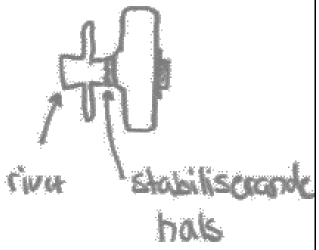
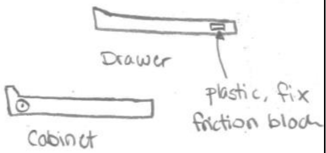
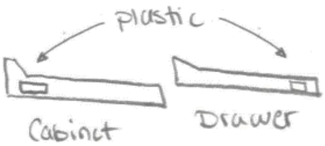
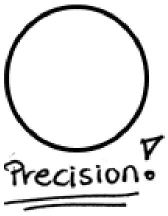
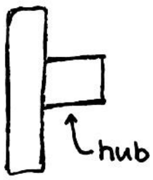
No.	**Metric**	**Explanation**
1	Volume of noise during sliding	The decibel measured during the *Noise and Vibration Test.*
2	Vibration during sliding	The vibration measured during the *Noise and Vibration Test.*
3	Stability	The perceived stability of the drawer during sliding in the MALM-dresser.
4	Material cost	The total material cost for the roller slide.
5	Total Cost	An estimated total cost of the roller slide based on manufacturing and material aspects.
6	Easy to install	How easy it is to assembly a dresser where the roller slide is included. The criteria is subjective and must be experienced in real life.

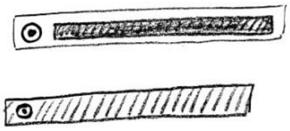
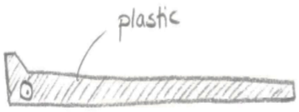
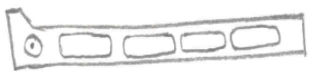
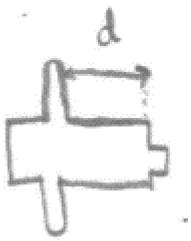
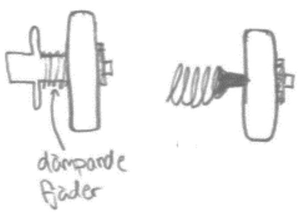
7	Changes of existing tolerances of the MALM-dresser	How much the tolerances of the MALM-dresser needs to be adjusted due to the changed roller slide.
8	Dismountable	The roller slide must be able to dismount from the dresser.
9	Easy to dismount	How easy it is to dismount the roller slide from the dresser. The criteria is subjective and must be experienced in real life.
10	Smooth sliding	Refers to the perceived experience during opening and closing of the dresser. The criteria is subjective and must be experienced in real life.
11	Environmentally friendly	Refers to if changed or added materials affects the recycling possibilities of the roller slides.
12	Damping	Refers to if the roller slide is closed softly.
13	Few tools needed when installing	The increased number of tools necessary for the end consumer to install the roller slide.
14	Few changes on existing roller slide	The extent of changes of the roller slide where large changes implies higher production and development costs.
15	Initiative for the user	The way of mounting the roller slide shall be easy for the end consumer to figure out.
16	Appealing to the user	The design of the roller slide shall during use not be disturbing for the end consumer.

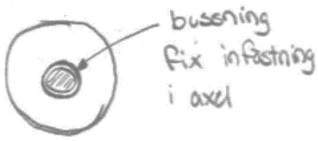
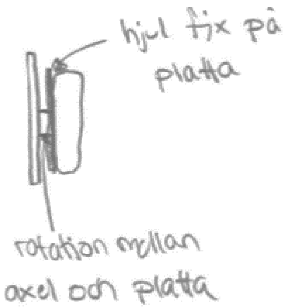
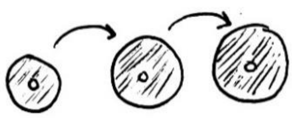
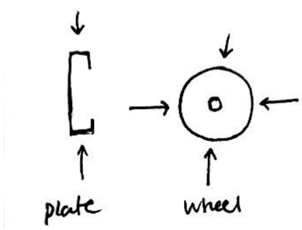
Appendix D Brainstorming Ideas

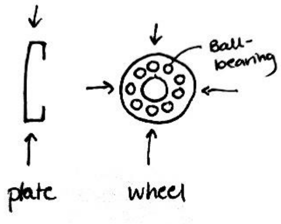
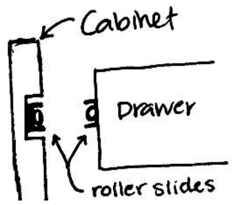
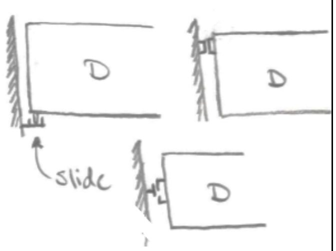
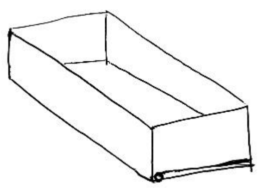
Ideas generated by the design team during the brainstorming session including description, picture and reason of eventual dismissal for each idea.

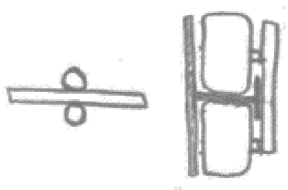
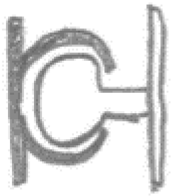
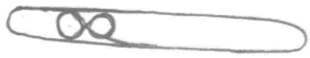
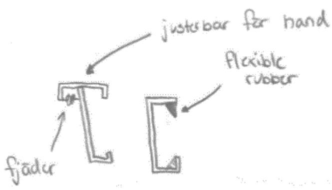
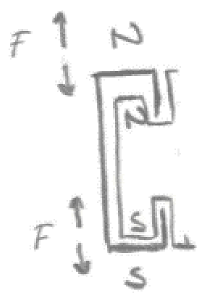
Name of idea	Picture	Description	Reasons for dismissal
1 Wheels			
1.1 Wheel Profile		Different wheel profiles may have an impact on the stability of the wheels, the vibration and the noise.	Not dismissed.
1.2 Soft Layer		Apply a soft layer of material i.e. rubber on the wheels for a damping effect and to reduce friction.	Not dismissed.
1.3 Dimensions		Investigate different dimensions of the wheels by decreasing and increasing both the inner and the outer diameter.	Not dismissed.

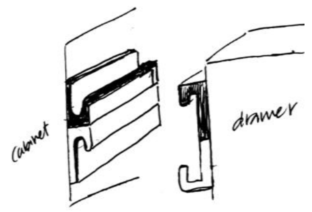
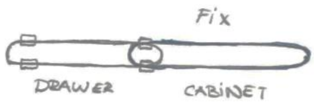
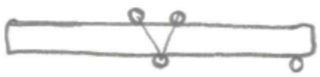
1.4 Stable Throat		Use a more stable throat on the wheels to prevent the wheels from wobbling. The throat can be made in i.e. rubber, plastics etc.	It was concluded that it will not have an impact on the noise and perceived quality.
1.5 Wheel and Block		Using two wheels and two fixed blocks to achieve a more stable design.	Not dismissed.
1.6 Blocks		Replacing the wheels with four fixed plastic blocks.	Not dismissed.
1.7 Turning Wheel		Investigate the impact of the precision of the cylindrical shape by manufacturing a wheel using turning as a method.	Not dismissed.
1.8 Longer Hub		With a longer wheel hub, the aim is to investigate eventual improvement concerning the stability and wobbling of the wheel.	Not dismissed.
2 Plates			

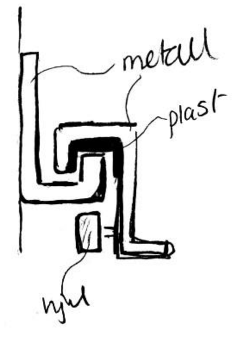
2.1 Isolators		Apply different kinds of isolators i.e. coating, rubber, plastic, fabric, foam and silicon to decrease the noise during sliding.	Not dismissed.
2.2 Plastic Plate		Use plastic material instead of steel to decrease the noise during sliding.	Dismissed due to poor durability.
2.3 Topology		Remove material in order to decrease the noise propagation during sliding.	Not dismissed.
2.4 Tolerances		With decreased tolerances, the wobbling may reduce and a more stable design will be achieved.	The variations of the MALM-dressers is too large.
3 Attachment			
3.1 Slim Rivet		Investigate if a smaller rivet will result in less wobbling.	The tolerances of the rivet is already optimized.
3.2 Spring		Integrate a spring to the wheels in order to work as a damper in the horizontal direction.	Due to small tolerances and economical aspects, this solution was concluded hard to implement.

3.3 Bushing		Integrate bushings to the wheels.	Not dismissed.
3.4 Plate Rotation		Mounting the wheels to a circular rotating plate. Prevents the wheels from wobbling.	Dismissed since it is difficult to enable rotation between the sliding plate and the shaft.
3.5 Washer Dimension		Increase the diameter of the washer.	Not dismissed.
4 *Other*			
4.1 BEACH POM		One of the prototypes developed by IKEA Components. For detail information, see 3.2	Used as inspiration and reference.

4.2 BEACH BEARING		One of the prototypes developed by IKEA Components. For detail information, see 3.2	Dismissed since ball-bearing is too expensive. However, the prototype is used as a reference.
4.3 Integrated Slide		Integrated roller slide in the cabinet with the aim to reduce the noise propagation.	Not dismissed.
4.4 Slide Position		Investigate how different positions of the roller slide will impact the stability and the perceived quality.	It was concluded that the position of the slide used today is the most optimal and other positions will not improve the perceived quality.
4.5 Fixed Drawer		Investigate the impact regarding the stability of the drawer by stabilizing the drawer.	Not dismissed.
5 *New Designs Solutions*			
5.1 Hanging Wheel		Changing the mounting of the wheels. The wheels are stabilized by the added metal arc.	Dismissed due to economical and time aspects.

5.2 Double Wheel		Using two vertical wheels on the drawer slides in order to improve the stability. The wheels "clamps" against the cabinet plates.	Dismissed due to economical and time aspects.
5.3 Ball Slider		A design where a curved plate is mounted on the cabinet. On the drawer, a plate with a ball is mounted. By using coatings of the plates and material of the ball with good sliding properties, the ball will slide in the curved plate.	Dismissed due to economical and time aspects.
5.4 Wire		Instead of using wheels a wire will enable the open and close mechanism.	Dismissed due to economical and time aspects.
5.5 Adjustable Guide		Adjustable guides that either can be adjustable by hand or flexible, by using a rubber or a spring that keeps the wheels in place.	Dismissed due to economical and time aspects.
5.6 Magnetic Slide		The drawer slides by using magnetic forces.	Dismissed due to economical and time aspects.

5.7 Clamp Slide		With this design, the slides mounted on the cabinet and the drawer is clamped together. By using relevant plastic material and coatings, a smooth sliding will be achieved.	Dismissed due to economical and time aspects.
5.8 Wire Slide		Using wires to achieve sliding mechanism.	Dismissed due to economical and time aspects.
5.9 Elastic Slide		Using a spring or an elastic band between the wheels to keep the wheels against the plate.	Dismissed due to economical and time aspects.
5.10 Three Wheels		Using three wheels in a triangle design on one of the plates to improve the stability.	Dismissed due to economical and time aspects.
5.11 Groove Rails		Adding tracks to the wheels and the plates in order to prevent wobbling.	Dismissed due to economical and time aspects.

5.12 Slide Wheel		The idea is to make use of low friction between the plates. The wheel is used in order to maintain the stability.	Dismissed due to economical and time aspects.

Appendix E Operating Characteristics According to SKF

	Plain bearing types and materials						
Operating characteristics	Solid bronze	Sintered bronze	Wrapped bronze	PTFE composite	POM composite	PTFE polyamide	Filament wound
Self-lubricating performance	not suitable	good	not suitable	excellent	good	excellent	excellent
Maintenance-free operation	not suitable	good	suitable	excellent	good	excellent	excellent
Dirty environments	good	suitable	excellent	not suitable	suitable	not suitable	good
Corrosion resistance	good	suitable	good	suitable	suitable	excellent	excellent
High temperatures	good	not suitable	good	excellent	suitable	suitable	good
Heavy loads	suitable	not suitable	suitable	good	excellent	suitable	good
Shock loads/vibrations	good	suitable	good	suitable	suitable	not suitable	excellent
High sliding velocity	not suitable	excellent	suitable	good	good	suitable	not suitable
Low friction	not suitable	good	not suitable	excellent	excellent	suitable	excellent
Poor shaft surface finish	good	not suitable	suitable	not suitable	suitable	suitable	suitable
Small operating clearance	not suitable	suitable	suitable	excellent	good	suitable	not suitable
Insensitive to misalignment	good	suitable	suitable	not suitable	suitable	suitable	good

Appendix F Material Specification

The material specification of TPE-E provided from the retailer Hexpol TPE AB.

Dryflex®
TPE

Reg.nr:	500805
Utgåva	1
Validerad	30.04.2015
Utfärdare	PO
Produktionsställe	HEXPOL TPE AB

500805

Allmänt

Dryflex 500805	Termoplastisk Elastomer
Basmaterial	TPS-SEBS
Hårdhet	80 Shore A (4mm)
Användningstemperatur	-50 -- +130 °C (Obelastat material)
Färg	Translucent, men kan även infärgas i annan kulör.
Fysisk form	Granulat färdiga för bearbetning utan förtorkning vid lagring under normala förhållanden.
Väderresistens	Utmärkt
Kemikaliebeständighet	God (undantag: organiska lösningsmedel, aromatiska och vegetabiliska oljor).
Återvinning	100% återvinningsbar.

Bearbetning

Materialet har mycket goda processegenskaper och är främst avsedd för formsprutning och extrudering. Materialet kan formsprutas eller extruderas i standardutrustning avsedd för termoplaster.

Bearbetningstemperatur	Formsprutning	Extrudering
Cylindertemperatur °C	180 - 210	150 - 210
Formtemperatur °C	30 - 60	

Fysikaliska egenskaper

Egenskap	Enhet	Värde	Testmetod
Hårdhet	Shore A (4mm)	80	ASTM D 2240
Densitet	g/cm³	0,89	ASTM D 792
Draghållfasthet	MPa	14	ASTM D 638
Rivhållfasthet	kN/m	43	ASTM D 624
E-100%	MPa	3,0	ASTM D 638
E-300%	MPa	5,0	ASTM D 638
Brottöjning	%	700	ASTM D 638
Smältindex	g/10 min 190°C/5kg	10	ASTM D 1238

HEXPOL TPE

info@hexpolTPE.com
www.hexpolTPE.com