

Designing Retro-Fit Power Access for Sofas

Theo Bengtsson Übelacker and Oskar Troell

DIVISION OF INNOVATION | DEPARTMENT OF DESIGN SCIENCES
FACULTY OF ENGINEERING LTH | LUND UNIVERSITY
2026

MASTER THESIS



Designing Retro-Fit Power Access for Sofas

for IKEA of Sweden AB

Theo Bengtsson Übelacker

Oskar Troell



Lund University

June 9, 2026

Supervisor: Per Kristav

Department of Design Sciences

Designing Retro-Fit Power Access for Sofas

for IKEA of Sweden AB

Copyright © 2026 Theo Bengtsson Übelacker and Oskar Troell

Published by

Department of Design Sciences

Faculty of Engineering LTH, Lund University

P.O. Box 118, SE-221 00 Lund, Sweden

Subject: Technical Design (MMKM10)

Division: Innovation

Supervisor: Per Kristav

Examiner: Axel Nordin

Abstract

This thesis presents the development of a prototype for a concealed power strip integrated into the underside of a sofa. The aim is to improve accessibility to electrical outlets while maintaining a clean and unobtrusive appearance in the living environment. The solution is designed to both hide cables and allow convenient access to power when seated, while ensuring sufficient ground clearance for robot vacuum cleaners.

The project followed an iterative design process, where multiple concepts were generated, evaluated, and prototyped. Key challenges included achieving a compact and discreet form, ensuring ease of installation, and creating a solution compatible with a wide range of furniture. Several concepts were explored before a final design based on a spring-loaded leg mechanism was selected. This concept utilizes an existing attachment interface to simplify installation and improve compatibility.

The resulting prototype demonstrates that it is possible to combine concealed cable management, user accessibility, and compatibility with automated cleaning systems in a single solution. While further development is required for production implementation, the concept provides a feasible direction for integrating power access into furniture in a more discreet and user-friendly way.

Keywords: *mechanical design, product development, prototyping, modular systems, IKEA, fastening interface (M8), design for assembly, user interaction, cable management, integrated power solutions.*

Sammanfattning

Detta examensarbete presenterar utvecklingen av en prototyp för ett dolt grenuttag integrerat på undersidan av en soffa. Syftet är att förbättra tillgängligheten till eluttag samtidigt som ett rent och diskret uttryck i boendemiljön bibehålls. Lösningen är utformad för att både dölja kablar och möjliggöra enkel åtkomst till el-uttag när användaren sitter i soffan, samtidigt som tillräcklig markfrigång säkerställs för robotdammsugare.

Projektet följde en iterativ designprocess där flera koncept genererades, utvärderades och prototypades. Centrala utmaningar var att uppnå en kompakt och diskret form, säkerställa enkel installation samt skapa en lösning som är kompatibel med ett brett urval av möbler. Flera koncept undersöktes innan en slutlig design baserad på en fjäderbelastad benmekanism valdes. Detta koncept använder ett befintligt fästgränssnitt för att förenkla installationen och förbättra kompatibiliteten.

Den framtagna prototypen visar att det är möjligt att kombinera dold kabelhantering, användartillgänglighet och kompatibilitet med automatiserade städsystem i en och samma lösning. Även om ytterligare utveckling krävs för implementering i produktion, erbjuder konceptet en genomförbar riktning för att integrera åtkomst till ström i möbler på ett mer diskret och användarvänligt sätt.

Nyckelord: mekanisk konstruktion, produktutveckling, prototypframtagning, modulära system, IKEA, fästgränssnitt (M8), monteringsanpassad design, användarinteraktion, kabelhantering, integrerade strömlösningar.

Acknowledgements

This thesis was carried out within the Department of Design Sciences at Lund University, Faculty of Engineering, with IKEA of Sweden AB as the collaborating company. We are grateful for the opportunity to work on this project and for the support provided throughout the process.

We would like to express our appreciation to Per Kristav, our supervisor at LTH, for his guidance, feedback and academic support during the thesis. We are also grateful to Erik Hult, our supervisor at IKEA of Sweden AB, for sharing his experience, providing valuable input and contributing with an industrial perspective on the project.

The practical realization of the project was supported by several people at LTH. We would like to thank David Andersson for his assistance with the 3D printing process and for sharing his knowledge in this area. We would also like to thank the technicians at the IKDC workshop for their support and guidance during the manufacturing of the metallic parts.

Lastly, we would like to thank everyone who contributed to the project through discussions, advice or practical support.

June 9, 2026

Oskar Troell & Theo Bengtsson Übelacker

Contents

Abstract	i
Sammanfattning	ii
Acknowledgements	iii
1 Introduction	1
1.1 Background	1
1.1.1 Company Background	2
1.2 Problem Description	2
1.3 Delimitations	3
1.4 Goals	4
1.5 Key People	4
1.6 Use of AI tools	4
2 Methodology	5
2.1 Planning	5
2.2 Methods Applied in the Project	5
2.2.1 Product Development Process - Ulrich & Eppinger	6
2.2.2 IKEA Democratic Design	7
2.2.3 Circular IKEA	9
2.2.4 Design of Everyday Things - Don Norman	10
2.3 Risk Analysis	12
2.4 Division of Work	13
3 Research	14
3.1 Patent Search	14
3.2 IKEA Search	15
3.3 External search	15
3.3.1 3D-Printed alternatives	16
3.3.2 Online retailers	16
4 Specifications	17
4.1 Preparing Metrics	17
4.1.1 The Koppla Socket	18
4.1.2 Connector Specifications	18
4.1.3 Furniture Specifications	22
4.2 Benchmark competitors	25
4.2.1 DIY	25

4.2.2	Products	26
4.3	Set ideal and marginal values	29
5	Concept Generation	31
5.1	Internal search	31
5.2	Subproblem breakdown	32
5.3	Concept combination	32
5.4	List of Concepts	33
6	Concept Selection	37
6.1	First Screening	37
6.1.1	Remaining concepts	40
6.2	Low-Fi Prototyping	42
6.2.1	Prototype Creation	42
6.2.2	Prototype Evaluation	43
6.3	Selection Decision	49
7	Concept Validation	51
7.1	Risk Analysis	51
7.1.1	Concept Risk Analysis	51
7.1.2	Initial Risk Mitigation	55
7.2	Mid-Fi Prototyping	60
7.2.1	BANKABY as a Starting Point	60
7.2.2	Initial Slot-Based Mechanism	61
7.2.3	Arm and Socket Attachment	63
7.2.4	Guide Path and Structural Issues	67
7.2.5	Installation and Orientation Challenges	68
7.2.6	Simplified Hollow Pillar Design	70
7.2.7	Final Mid-Fi Prototype Configuration	73
7.2.8	Final Prototype	76
7.3	System Level Design	78
7.3.1	Material & Manufacturing Suggestions	78
7.3.2	Assembly	83
7.3.2.1	Factory assembly	84
7.3.2.2	Home assembly and installation	87
7.4	Feasibility	88
7.4.1	Economic Feasibility	89
7.4.2	Ethical Feasibility	89
7.4.2.1	Democratic Design Alignment	90
7.4.2.2	Environmental Assessment	92

7.5	Usability Tests	93
7.5.1	Product Installation Tests	93
7.5.2	Product Operation Tests	94
7.6	Updated Specifications	94
8	Results	96
8.1	Final Concept	96
9	Discussion	98
9.1	Planning and Theory	100
9.2	Further Development Suggestions	101
9.2.1	User Research	102
9.2.2	Parts refining	102
9.2.2.1	Functional refinements	103
9.2.2.2	Existing Ergonomical refinements	105
9.2.2.3	Manufacturability refinements	107
9.2.3	Simulations and Lab Testing	109
9.2.4	Modularity	111
10	Conclusion	112
	References	113
Appendix:		
A	WBS	119
B	GANTT	122
C	Updated GANTT	122
D	Core Statements of the Democratic Design Manifesto	122
E	Benchmarking of existing power strip mounting solutions	124
F	Weighted Scores	125

1. Introduction

This chapter establishes the background of the project, followed by the problem description. This is followed by the delimitations and goals set for the project to make it manageable given the timeline.

1.1. Background

The concept presented in this project originates from a specific practical situation rather than from a generalized problem formulation. In a domestic setting, we identified a need to provide accessible power for devices such as phones and tablets while seated on a sofa. At the same time, cables and power strips were perceived as visually intrusive and were therefore placed under the sofa to reduce their impact on the living environment.

This arrangement created conflicts with the use of a robotic vacuum cleaner, as cables and power strips placed on the floor interfered with its operation. As an immediate response, we developed a simple practical solution where a power strip was mounted to a hinged board attached on the inside of the sofa. This lifted the cables off the ground while keeping them accessible (see Figure 1).

This solution was not developed as a complete product, but it demonstrated clear potential. The combination of improved accessibility, reduced visual impact, and compatibility with robotic cleaning systems suggested that the idea addressed a broader need. Based on this identified problem and an initial proposed solution direction, IKEA was contacted with the aim of exploring whether the idea could be further developed as a master thesis project.



Figure 1: Power strip attached to a hinged board with magnets to hold it in place

1.1.1. Company Background

IKEA was founded by Swedish businessman Ingvar Kamprad in 1943, finding early success selling pens through mail order before pivoting towards furniture in the late 1940s. [1]

With the motto "To create a better everyday life for the many people - by offering 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", the company has become one of the worlds largest furniture retailers.[2]

1.2. Problem Description

Technical developments and the increasing number of electronic products in domestic environments have led to a growing need for power access in living spaces. Devices such as robot vacuums, speakers, computers, and gaming consoles must coexist with furniture, often resulting in visible cables that negatively affect both aesthetics and cleanliness. In particular, robot vacuum cleaners frequently struggle to navigate around exposed cables, reducing their effectiveness.

This project explores the problem of providing accessible power outlets for sofas while maintaining a discreet design that does not interfere with the furniture's appearance or obstruct the operation of robotic vacuum systems.

While some new furniture designs address these problems, the available models are limited. Therefore, a retro-fit solution for existing furniture could better satisfy the need for electricity while leaving the aesthetic choices to the consumer.

1.3. Delimitations

Due to the nature of the project, certain limitations needed to be established to ensure that the goals of the project could be met. These were discussed in conjunction with our supervisor Erik Hult at IKEA of Sweden AB.

Firstly, it was decided that the installation of the product should be feasible on furniture comparable to reference models representing popular furniture categories at IKEA. These models will be decided upon during the early phases of the project but may change if discoveries are made that would favour alternatives. The product should also focus on just one market, in this case the European Union - EU, when designing for different regulations. The product should be designed for indoor use and should not be marketed as a product for children.

From the time schedule and from the internal design process at IKEA it was decided that the project should end before the Hi-Fi prototype stage since reaching this stage would not be feasible. The types and scale of the prototypes delivered during the project are also limited by the available equipment and time at IKEA of Sweden and LTH:s workshops and the projects limited budget. Advanced software simulations are left to further development, should the given final concept be deemed worthy to explore further. The manufacturing methods and materials suggested in the project will thus be based on the final concept and and prototype and further testing might reveal the need for design reconsideration.

1.4. Goals

The goals of the project is to find a retro-fit cable management/cable extension lead solution for area seating which allows for charging portable devices in connection with the furniture. This solution should free up the floor space to allow for a robot vacuum to clean under the furniture unobstructed. The solution should leave the aesthetics and impression of the furniture unchanged. The project deliverables include a 3D-CAD model and technical drawings of the final suggested concept, along with a functional prototype, which combined with this report contains all insights made for the design space.

1.5. Key People

- Per Kristav (PhD) Department of Design Sciences, LTH
Supervisor at LTH.
- Erik Hult (Design Engineer) IKEA of Sweden AB
Supervisor at IKEA
- Johan Rice Svensson (Product Engineering Manager/Team Manager) IKEA of Sweden AB
Initial contact with IKEA

1.6. Use of AI tools

During the thesis process, AI tools were used for language support, including spelling and grammar correction. The same tools were also used as a search aid during the literature review.

2. Methodology

This chapter presents the methodology used in the project and describes how the work was planned and conducted. First, the project planning is outlined, including how the scope, goals and deliverables were defined, as well as how the project was scheduled. The chapter then presents the methods applied during the project, with particular focus on the product development process by Ulrich and Eppinger, which served as the framework for the thesis. Finally, the adapted process used in the project is described in relation to the specific context and conditions of IKEA.

2.1. Planning

The planning of the project started with a meeting in Älmhult to present and analyze the problem. This was done to be able to get an initial impression of the delimitations and scope of the project as well as to establish the goals and deliverables. The meeting was conducted together with our supervisor Erik Hult at IKEA and after the meeting we were tasked with creating a Work Breakdown System - WBS for the project as well as a GANTT-chart. The WBS breaks down the project into more manageable tasks and worked as an aid when structuring the GANTT-chart. The initial chart, based on said WBS, is shown in appendix A. The running time of the project was one standard semester of 20 weeks and the GANTT-chart illustrates the order and duration of the different project steps. At the end of the project, a revised chart was created to illustrate the actual time taken at each step as well as what steps were cut due to the project scope. This chart is shown in appendix C and discussed under section 9.1.

2.2. Methods Applied in the Project

Several methodologies and design frameworks were applied throughout the project. *Product Design and Development* by Ulrich and Eppinger [3] formed the foundation of the development process, while *IKEA Democratic Design* [4] and *Circular IKEA* [5] were used to guide concept generation and design decisions. *The Design of Everyday Things* by Don Norman [6] complemented these frameworks by providing principles related to usability and user interaction.

2.2.1. Product Development Process - Ulrich & Eppinger

As a theoretical base and framework for our development process we have opted to use Karl T. Ulrich and Steven D. Eppingers book "Product design and development" [3]. Their concept development process is split into 7 sequential stages, however the authors of the book note that these stages may overlap or certain stages may be iterated. The seven stages can be viewed in Figure 2 and are described as following;

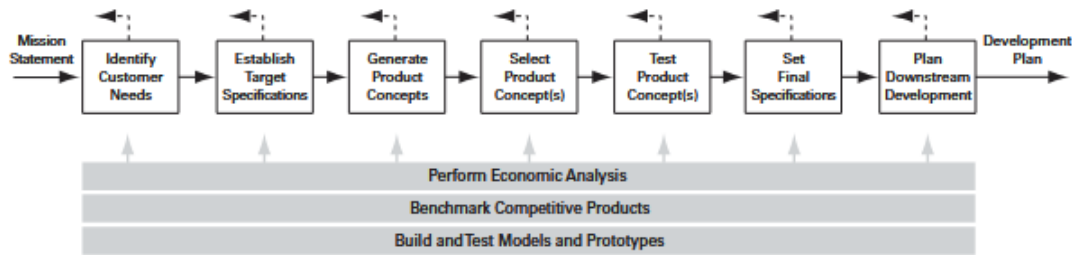


Figure 2: Concept Development Process by Ulrich & Eppinger
[3]

- Identifying customer needs is tied to identifying the explicit and latent needs of the customer. It normally includes gathering the raw data with the help of interviews, focus groups or surveys and then interpreting and organizing these statements into a concrete list.
- Establishing target specifications quantifies the identified customer needs. In this step the needs are represented by a list of metrics. Competitive benchmarking information is collected and the list of metrics are given ideal and accepted target values.
- Concept generation includes several techniques for examining the possible solutions for the given needs and specifications. It is important to generate as many concepts as possible during this step to ensure that the solution space has been properly explored. By the end of this step a project usually has a list of concepts with sketches and short descriptions for each concept.
- Concept selection is where the list of concepts gets analyzed and compared to eliminate the weakest of the contenders. There are several methods available for this, including external decision, product champion, multivoting and prototype and testing. Here the authors of the book flags specifically of the risk for the need to iterate.

- Concept testing is as the name suggests where the final concept/concepts get tested to see if they meet the requirements. The purpose of the tests must be clearly defined and the reactions and acts of the participants should be measured. Depending on the outcome of this stage, iteration or adjustments may be necessary.
- Setting final specifications means going back to the list of specifications from step two in the process and adjusting them as needed based on the final concept design. Tradeoffs are often necessary to make based on what specifications are prioritized in the end.
- Planning downstream development is the last step of the design process and it entails selecting and identifying resources for the project as well as creating a schedule. This step is usually summarized in a contract book which encompasses all information learned from the previous steps as well as the planning from this final step.

2.2.2. IKEA Democratic Design

Democratic Design is IKEA's guiding framework for creating products that are both desirable and accessible. It aims to make good design available to the many, not just the few, by balancing five dimensions: form, function, quality, sustainability, and low price. These dimensions are not treated as separate goals but as interconnected requirements that shape design decisions from concept to production.

Form refers to a product's sensory and aesthetic characteristics. In IKEA's Democratic Design Manifesto, form is presented as one requirement within a combined design mission rather than as an independent styling priority. The manifesto frames the goal as achieving "beautiful form" in parallel with function, quality, sustainability, and affordability. This implies that decisions about appearance and material experience should be assessed in relation to, and sometimes constrained by, the other four dimensions. [4]

Function focuses on what the product does and how well it supports daily life. This dimension is closely aligned with Don Norman's insights on usability. In *The Design of Everyday Things*, Norman writes that poorly functioning products often fail because they do not account for human behavior or expectation. A well-functioning product must not only fulfill its purpose but also communicate how it works without requiring instruction. IKEA designers frequently visit homes around the world to observe how people live. This research informs functional improvements that reflect the real needs of users, such as adjustability, stackability, or ease of assembly.[4, 6]

Quality in product development refers to a product's capacity to retain its performance and reliability throughout its lifecycle. This includes material durability, structural integrity, and the ability to remain useful over time. For example, a modular storage unit that can be expanded, or a chair that continues to provide comfort and stability after years of daily use, illustrates a practical interpretation of quality.

IKEA also articulates an ambition for products where "quality and function exceed people's expectations". The manifesto further links long-term quality to extending product life, including through reuse or adaptation. From this perspective, quality is treated as a long-term requirement that interacts with the other dimensions, not only as performance at the point of sale.[4]

Sustainability concerns responsibility across the full lifecycle, not only material choice or manufacturing method. The manifesto frames sustainability as long-term responsibility that spans sourcing, production conditions, and customer use, and it also emphasizes enabling people to live "more sustainable lives" through what products and solutions make possible. In this sense, sustainability functions as both a design constraint and a use-oriented ambition, affecting material selection, production decisions, durability, and strategies for longer product life.[4]

Low price is treated as a core condition for accessibility. The manifesto explicitly links low price to making products available to more people. Rather than being an afterthought, affordability is positioned as a design requirement that must be achieved simultaneously with form, function, quality, and sustainability, shaping choices about materials, manufacturing processes, and product architecture.[4]

2.2.3. *Circular IKEA*

Circular design can be defined as an approach to product development that aims to keep products, components, and materials in circulation at the highest possible value for as long as possible. In the IKEA Circular Product Design Guide, this intent is grounded in the logic of the circular economy, which is contrasted with linear patterns of production and disposal.[5]

According to the guide, Circular Design is not only an end-of-life concern but a design orientation that must be embedded into product development so that products can practically circulate through multiple lifecycles.

The guide structures circularity around “circular loops” that define **reuse**, **refurbishment**, **remanufacturing**, and **recycling** as mechanisms to retain value and extend life for resources, products, parts and materials. **Reuse** is defined as customer use and care, including maintaining, repairing or upgrading and adapting to evolving needs, as well as enabling secondhand markets. **Refurbishment** is described as restoring used or damaged products to “‘like-new’ condition” outside the customers home. **Remanufacturing** is described as using usable parts from dismantled products in new product production. **Recycling** is described as transforming parts into new raw material for IKEA or external supply chains and is characterized as “the last step for every product part”. Interpreted as a hierarchy, the loops suggest that design should prioritize strategies that keep whole products and high-value parts in use before relying on material recycling.

Circular Design is one of several elements in the sustainability dimension of Democratic Design (see 2.2.2). The Circular Design principles support designing for intended use while planning how lifespan can be extended. The principles function as design heuristics for enabling circulation and should be treated as an integrated set of requirements that should shape product architecture early, rather than a downstream environmental optimization.

- Design for renewable or recycled materials.
- Design for standardization.
- Design for care.
- Design for repair.
- Design for adaptability.
- Design for disassembly and reassembly.
- Design for remanufacturing.
- Design for recyclability.

2.2.4. Design of Everyday Things - Don Norman

To better ensure the quality of the user experience with the product, the book "Design of Everyday Things" by Donald T. Norman has been used. [6]

The first chapter discusses signifiers and affordances and their importance on how people perceive what is possible to do with a product. Affordances can be simplified as roughly what actions are possible with a product and signifiers relate to how these possibilities are communicated. This chapter is important since our product should leave as small an impact on the aesthetics while the functionality should remain as clear and understandable as possible.

The second chapter discusses cognition, the three levels of processing and the seven stages of action. The author of the book discusses how these interact with each other and presents "seven fundamental principles of design" by the end of the chapter. These are as follows:

1. Discoverability: The user is able to determine the possible actions and the current state of the product.
2. Feedback: A continuous stream of information makes it easy to perceive the cause and effect of actions taken and the new state of the product.
3. Conceptual model: All the information necessary to understand the product and create a conceptual model of it is available.
4. Affordances: The affordances needed to successfully operate the product exist and are available.
5. Signifiers: Existing signifiers aid with discoverability and feedback from actions are clear and understandable.
6. Mappings: The controls of the product follow principles for good mapping and their respective actions are easily understood.
7. Constraints: Constraints help guide user action and take the form of physical, logical, semantic or cultural.

All of which have been considered during the execution of the project.

Chapter six discusses design thinking and the concepts human centered design (HCD) and the double-diamond model. For this project, the Ulrich & Eppinger design methodology is the base for the design process. The four steps of HCD outlined by Norman are Observation, Idea generation, Prototyping and Testing. These correspond to stages 1-5 in the U&E concept development process (see Figure 2) and this book will serve as a complementary source for ideas.

The seventh and final chapter of the book is labeled "Design in the World of Business" and addresses the real life limitations set on product development. These have been into account when deciding on the projects delimitations with regards to time, cost and deliverables. While not the primary focus of this project, disregarding these limitations would inadvertently lead to a less viable concept.

Chapters 3-5, while an interesting read, have not been utilized to any notable degree during this project.

2.3. Risk Analysis

The risk analysis done during the project was based on the EU General Product Safety Regulations GPSR, Regulation 2023:988.[7] The GPSR Article 5 states that all Economic operators have the duty to only make safe products available on the European market. Article 6 of the GPSR "Aspects for assessing the safety of products" outlines which specific characteristics of a product which should be taken into account when assessing the safety. For this project, the parts of article 6 that are relevant, given the scope of the project, are 6.1 (a-f). [7]

Article 7 "Presumption of conformity with the general safety requirement" states that the product should primarily conform to existing European standards and where none are applicable, national ones. Due to the nature of our product being a modification of two existing products it was deemed too difficult and time consuming to find exactly which standards the product should comply with. Thus, this will be left to more experienced people at IKEA. Should they choose to further advance with the product beyond the scope of this project. [7]

Still, there are parts of the GPSR which are applicable to the project, mainly parts of Article 9 "Obligations of manufacturers". Specifically Article 9.2 (a) stating manufacturers should carry out internal risk assessments and provide documentation regarding the product and the possible risk areas. The article states; "an analysis of the possible risks related to the product and the solutions adopted to eliminate or mitigate such risks, including the outcome of any reports related to tests conducted by the manufacturer or by another party on their behalf". In this case, this report will act as the documentation, with the internal risk analysis being conducted based on SS-EN ISO 12100:2010 "Safety of machinery – General principles for design – Risk assessment and risk reduction" in combination with insights learned from lectures on risk assessment in the course "engineering design principles" at Lunds Tekniska Högskola.[7–9]

While SS-EN ISO 12100:2010 is aimed at more sophisticated machinery, it still provides a solid structure for risk analysis. To aid in identifying risks, Article 6 of the GPSR was used in combination with the EU Safety Gate Risk Assessment (SAGA). These scenarios were then rated based on their interpreted severity and likelihood. Scenarios in which the product of these two numbers was too high or where the severity was deemed extra important the design team aimed at identifying the root cause and mitigating the risk. Finishing with identifying if any new risks had been created. [8–10]

2.4. Division of Work

The workload was shared evenly between the two authors throughout the project, with both contributing across all phases and making decisions jointly. To maintain steady progress, report writing and CAD development were carried out in parallel. Each author took primary responsibility for different sections of the report and different design tasks, while continuously coordinating, reviewing each other's work, and aligning on conclusions. Ideation, problem framing, and concept selection were conducted collaboratively, and both authors had equal authority in proposing, challenging, refining, and discarding ideas. Where specialized capabilities were required, external support was used only for the specific tasks outside the authors competence or available resources. Aside from these limited expert assisted activities, all project planning, analysis, design iteration, and documentation were performed by the two authors.

Throughout the project, progress and interim results were reviewed in multiple check-in sessions with IKEA representatives. These meetings provided domain constraints and feasibility feedback that informed parts of the analysis, while interpretation, synthesis, and all final decisions remained the responsibility of the authors.

3. Research

The research conducted during this step was split into different categories. The patent search focused on more theoretical possible solutions while the IKEA search and external searches focused more on actual products and the customer responses. The information gathered was then used when creating specifications and concepts.

3.1. *Patent Search*

The patent search was conducted using Espacenet. Since the concept generation part of the project had not yet started, the search terms and classifications were quite broad. Nevertheless, this part provided insight into how manufacturers imagine the availability of charging in sofas as well as possible mechanisms for hiding and revealing sofa attachments and modifications. The classifications are based on the "Cooperative Patent Classification - CPC", which is a joint initiative between the European Patent Office and the US Patent and Trademark Office. Mostly variants of the A47C - CHAIRS;SOFAS;BEDS classification were searched. The first letter "A" is the broadest domain and means "Human Necessities", "47" is the specific class and in this case means "Personal or Domestic Articles", the "C" can be seen as a subclass and narrows it down to "CHAIRS;SOFAS;BEDS". Going further to the A47C 17/00 group narrows it down to "Sofas;Couches;Beds". [11]

Some patents used for further discussion within the design team include:

- US10212519B2 [12]
- US2014148049A1 [13]
- WO2021230527A1 [14]
- CN112869437A [15]

These were chosen as they integrated seating and electrical outlets or chargers, ways to hide these and looked interesting to the design team.

The general consensus within the team was that these current solutions either focused on integrated, often wireless charging that was a poor fit for retro fit solutions or on bulky solutions with quite "invasive" attachment methods to the existing furniture.

3.2. *IKEA Search*

To identify existing solutions and previous development efforts related to accessible power outlets in furniture, IKEA's product range was reviewed. Online forums were searched, and discussions were held with Erik Hult at IKEA. The aim was to determine whether similar solutions had previously been developed and whether lessons could be learned from their implementation or discontinuation.

An IKEA product was found called SIGNUM. A bracket for holding the KOPPLA socket and installing it under a sofa. This product was no longer in production so this led to some further research as to why this product was canceled.

Another product called ÅSKVÄDER that served as a modular socket was nearing discontinuation. The reason for that might lead to further insight into our problems. Sadly, this proved a dead end as no further information was found or provided.

3.3. *External search*

The external search was carried out to identify existing solutions and gather relevant inspiration from the market. This was done to broaden the understanding of how similar needs are currently addressed and to complement the internal insights gathered during the project. The purpose was both to examine competing products and to study related solutions that could contribute with insights regarding function, installation and user interaction.

Search terms included things such as "detachable power socket", "cable management socket", "extension lead management" and "cable organizers" and these were first used on a regular search engine. The searches identified retailers, brands and specific forums which were then browsed for additional information and solutions. The results from the external search were used as input for the continued concept development and the establishment of target specifications.

3.3.1. 3D-Printed alternatives

As a way to explore current solutions and insights made by expert users the team took it upon themselves to search through maker-forums. The findings show that most solutions are aimed at more desktop applications, though they could be adapted to fit a variety of furniture. The majority of the 3D-printed products found were simple brackets that were fixed in place by screws though certain solutions were slightly more advanced, incorporating hinged action or clamps. These findings strengthen the argument that there is an interest for these types of solutions, focusing on simple, easy to install retrofit solutions. [16, 17]

An issue with these maker forums however is the requirement of owning a 3D-printer to be able to make use of these 3D-files.

3.3.2. Online retailers

Current online retailers offer a range of products, partially addressing the problem. These products were studied both in how they solved the issue of power availability but also what the response of customers were. These were used when formulating the list of metrics in part 4.1 of this report. These products and the takeaways from customer comments are visible in Table 1.

Product Name	Source	Takeaways
Väggfäste för grenuttag	[18]	Do not want to drill. Avoid having to hold the socket when plugging or unplugging. No sharp edges.
Brennenstuhl Estilo Charging Station with Textile Surface	[19]	Pleasant design. Can be shown. Blends with sofa. Flat plug is useful if the outlet is behind the sofa. Gets hot, which feels unsafe. Brand recognition. Easy to hide cables between sofa seats.
Brennenstuhl Estilo Sofa Socket with USB Charging Function	[20]	Practical. Used frequently in the sofa.
Table Socket with USB C 20W 4 Way Power Strip Desktop Individually Switchable with 4 USB C and 2 USB A Multi-Socket with Switch Surge Protector with 2M Cable for Home Office	[21]	Attached to a bed table. Can be used in multiple orientations. Protects the table from damage. Buzzing sound creates a feeling of unsafety. Long cord is useful. Weak screw. Glue-down attachment reduces the need to hold the socket. Adapted to IKEA bed. Attachment and maneuvering are somewhat clumsy. No glue or screw is preferred.

Table 1: Selection of existing retail products and takeaways

4. Specifications

The establishment of target specifications is based on the process outline by Ulrich & Eppinger. In this process a list of metrics based on our research into the problem and current solutions is created. This list is then compared to current solutions to better guide and narrow down the concept generation to better fit the actual needs of the market. This is done through a list of specifications which serve as goals for the development team.[3]

4.1. Preparing Metrics

Preparing the list of metrics begun by taking our own experiences with the problem and searching internally and externally for current solutions. This was followed up by consultation with Erik Hult at IKEA. It became clear that certain specifications and requirements would change depending on what type of concept we would arrive at during the concept generation and the exact pieces of furniture the project would focus on. Thus it was decided that this stage was to be revisited during the duration of the project to ensure the best possible outcome. The list of metrics presented in Table 2 is the initial list compiled during this step.

No.	Metric	Importance (1-5)	Units
1	Possible to retrofit (adj)	5	<i>binary</i>
2	Chargers are unaffected (adj)	5	<i>binary</i>
3	ISO compliant	4.67	<i>binary</i>
4	Symmetrically mountable	4.67	<i>binary</i>
5	Accessible while seated (adj)	4.67	<i>binary</i>
6	Compatible with IKEA Koppla power strip	4.58	<i>binary.</i>
7	Furniture comfort is unaffected (adj)	4.5	<i>binary</i>
8	Compatible with popular models (adj)	4.44	<i>binary</i>
9	Volume required for connectors	4.17	<i>mm / mm³</i>
10	Passes IKEA test lab (adj)	4.17	<i>binary</i>
11	No impact on structural integrity (adj)	4.08	<i>binary</i>
12	Headroom left under sofa	4	<i>mm</i>
13	Low design impact	3.83	<i>subjective</i>
14	Successful user test time	3.67	<i>s</i>
15	Successful user test %	3.67	<i>%</i>
16	Smooth operation (adj)	3.5	<i>subjective</i>
17	Supportable weight of connectors	3.33	<i>g</i>
18	Instructions needed for product	2.67	<i>n</i>
19	Time taken to install product	2.17	<i>s</i>
20	Tools needed to install product	2.17	<i>n</i>

Table 2: Metrics for specifications

4.1.1. The Koppla Socket

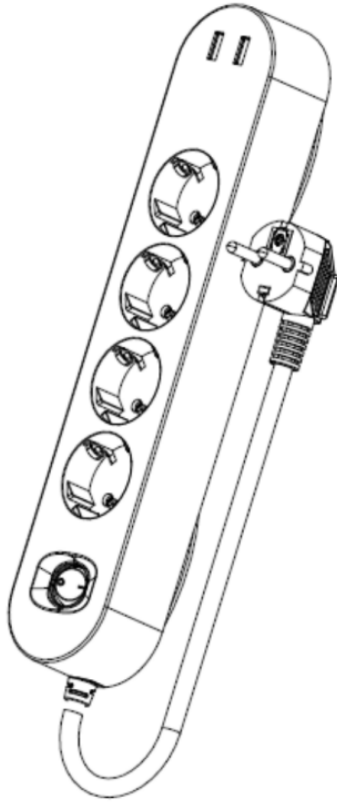


Figure 3: The KOPPLA socket.
Adapted from IKEA internal
product drawing [22]

With compatibility with already established IKEA product in mind, the KOPPLA socket (see Figure 3) was chosen as the electrical connector to use to set the dimensions needed. If a concept that did not use this specific connector would prove better then it would act as a placeholder because most options would use the same amount of space or less.

The Koppla socket already have features that allows it to attach to other products. Those features could be used to fasten the socket to the device in development.

The Koppla socket has 4 Schuko outlets, 2 USB A outlets and a rocker switch. The color of the socket and cable length and material varies but the dimension of the socket is the same between these variant.

4.1.2. Connector Specifications

The space needed for the connectors when they are attached to the socket is estimated by selecting some connectors that represent a broad spectrum of appliances. Measurements taken from generic "off-brand" replacement connectors are used to estimate the space (see Figure 4 and 5). These replacement connectors are slightly larger then the originals which makes them suitable placeholders.

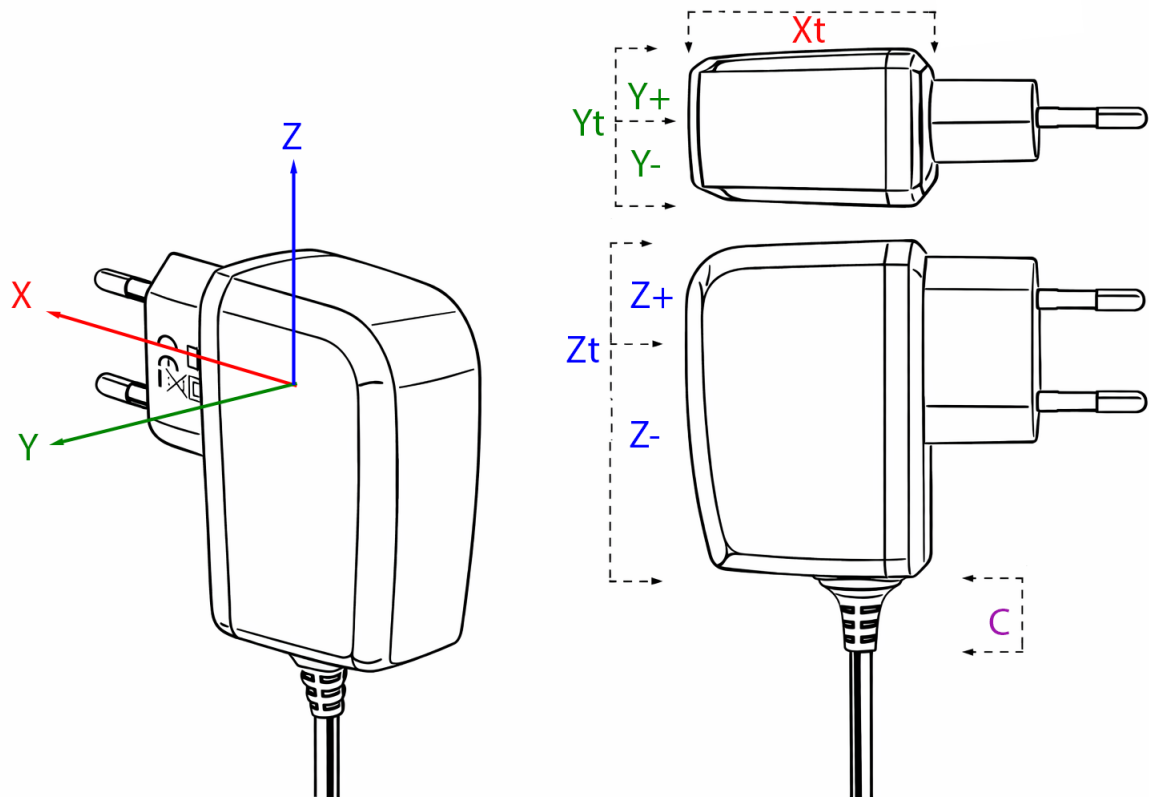


Figure 4: Dimensions of cables

Notes: Coordinate system and names of measurements. The "Cellonic" charger is used to display the dimensions.

The connectors is inserted into the socket at a 45° angle which leads to a different height and width when the sockets outer shell is used as a reference for the coordinate system (see Figure 6). In table 5 each connectors tilted dimensions can be seen together with the formula with which they were obtained.

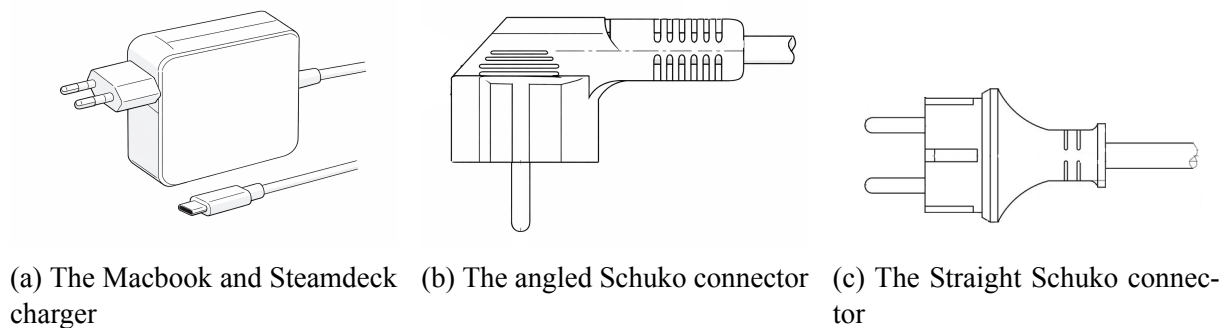


Figure 5: The different types of connectors

Table 3: Dimensions

Name	Weight g	Xt mm	Zt mm	Z+ mm	Z- mm	Yt mm	Y+ mm	Y- mm	Direction of cable	C mm
Macbook	165	74,93	29,97	14,99	14,99	74,93	13	61,93	x-	20
Steamdeck	201,5	56	30	15	15	56	15	41	x-	20
Cellonic	68	37	61	20	41	25	12,5	12,5	z-	35
Schuko Angled	-	17,5	35	17,5	17,5	69,5	18,25	18,25	y-	33
Schuko Straight	-	37,5	42	21	21	42	21	21	x-	0

Notes: Measurements were taken from bigger "off-brand" replacement chargers.

The measurements of the connectors were then adjusted to take into account the directions of the cable and some extra length to allow the cable to bend. This means that the "safe" volume does not need to be entirely hidden as cables that are being used will be seen either way.

Table 4: Adjusted Dimensions

Name	Weight g	Xt mm	Zt mm	Z+ mm	Z- mm	Yt mm	Y+ mm	Y- mm
Macbook	165	<u>125</u>	29,97	14,99	14,99	74,93	13	61,93
Steamdeck	201,5	<u>106</u>	30	15	15	56	15	41
Cellonic	68	37	<u>126</u>	20	<u>106</u>	25	12,5	12,5
Shuko Angled	-	17,5	35	17,5	17,5	<u>79,5</u>	18,25	<u>61,25</u>
Shuko Straight	-	<u>67,5</u>	42	21	21	42	21	21

Notes: Adjusted table with the strain relief (C) and an additional length was added (in most cases 30mm) in the direction of the cable, for bending of the cable. Each cables largest dimension is marked.

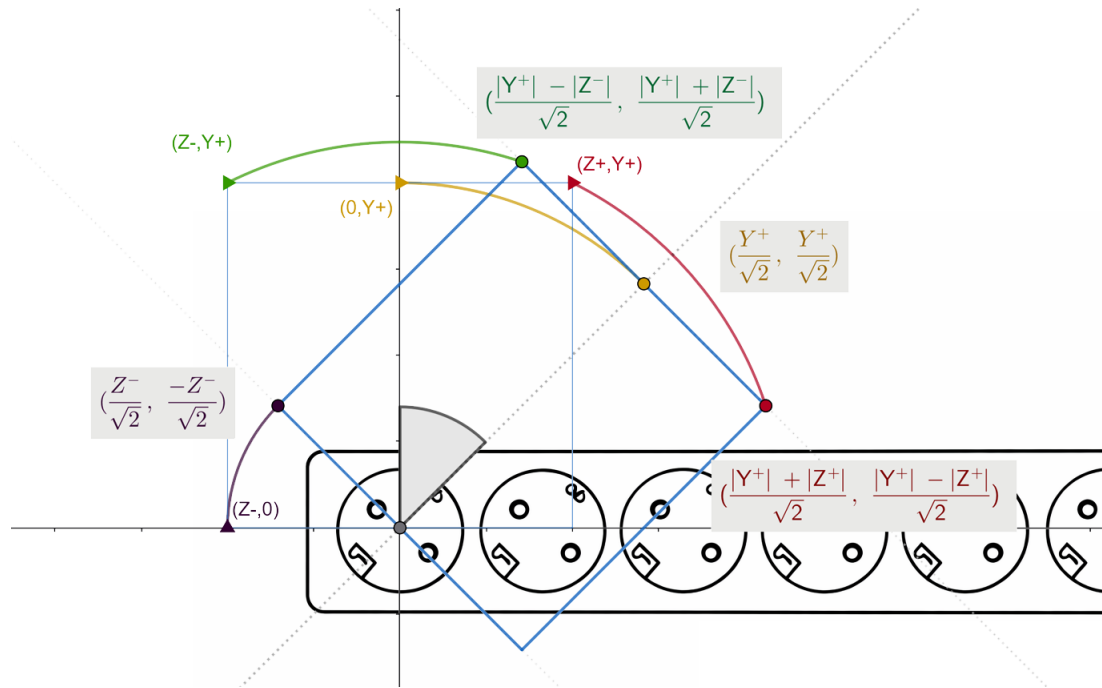


Figure 6: Rotation of connector

Notes: The 45° rotation of the outlet gives the height clearance needed for the connector.

Table 5: Tilted length, width and depth

Name	Upper Width $\frac{Z^+ + Y^+}{\sqrt{2}}$ mm	Lower Width $\frac{Z^- + Y^-}{\sqrt{2}}$ mm	Upper Length $\frac{Z^- + Y^+}{\sqrt{2}}$ mm	Lower Length $\frac{Z^+ + Y^-}{\sqrt{2}}$ mm	Depth mm
Macbook	19,9	54,4	19,8	54,4	<u>124,9</u>
Steamdeck	21,2	39,6	21,2	39,6	106,0
Cellonic	23,0	83,8	23,0	23,0	37,0
Schuko Angled	25,3	55,7	25,3	55,7	17,5
Schuko Straight	29,7	29,7	29,7	29,7	67,5

Notes: The maximum width among both the upper and lower case is used and the same goes for the length. The depth is the same as it is not affected by the 45° rotation. The color corresponds to the dimension in figure 7 and in table 6.

The dimensions in table 6 define the "Safe Volume" illustrated in Figure 7. This volume represents the minimum spatial envelope required to accommodate the connected plugs and cable routing without interference. It was used as a design guideline during concept development to ensure sufficient clearance around the electrical connections.

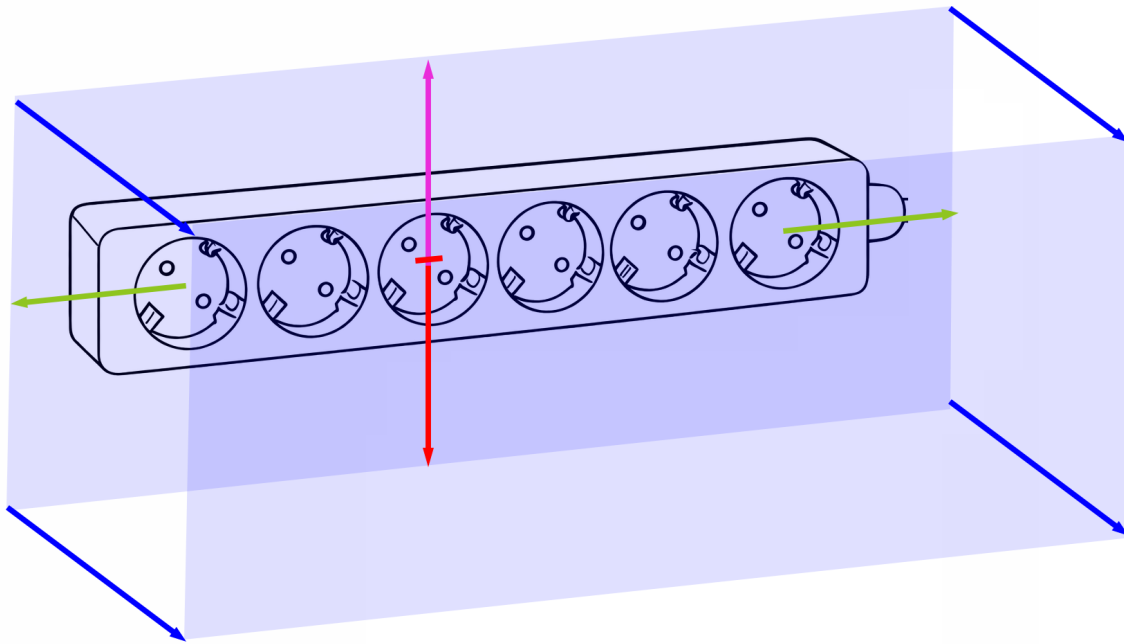


Figure 7: Safe Volume

Notes: The width(green), lower length(red), upper length(pink) and depth(blue) creates a volume that represents the safe-space needed for the connectors.

Table 6: Safe volume

Name	Width mm	Upper Length mm	Lower Length mm	Depth mm
Safe Volume	83,8	29,7	55,7	124,9

Notes: The safe volume is not considered when hiding the contraption. The volume is intended as space claim recommendation.

4.1.3. Furniture Specifications

A list of 10 sofa models has been provided by Joel Eriksson (Product Development Engineer) and Erik Hult (Design Engineer) from Inter IKEA. These 10 models have been chosen as they are popular models that also fit our original application, which is that a robot vacuum can pass beneath it.

- MANNARP
- GULLVALLA
- SALTSJÖBADEN'
- KLIPPAN
- LANDSKRONA
- UPPÅKRA
- VALNÄS
- SALTMYRAN
- SÖDERHAMN
- EKTORP

One model, the UPPÅKRA, has features which are too different from the other models and is therefore not considered in the development process. It has a very shallow hidden area beneath the cushions. Far smaller than any other of the models on the list. So when dimensioning the space claim it would be reasonable to consider this an outlier. The final concept may on a later stage prove to be compatible with this model but adjusting the concept to fit this model would over-complicate the task.

To get a sense of the available space, all of the remaining models were stacked occupying the same space and aligned by lower inner edge of the front and side of the sofa (see Figure 8). This resulted in a "combined sofa" which gave us the volume of the shared unoccupied space (see Figure 9). If a device could fit within that volume it would fit in all of the 9 models. The "combined sofa" also provided the maximum distance from the unoccupied space to the outside. The "combined sofa" did not offer any insight to possible points of attachments because only the negative space was shared among the models and not the positive.

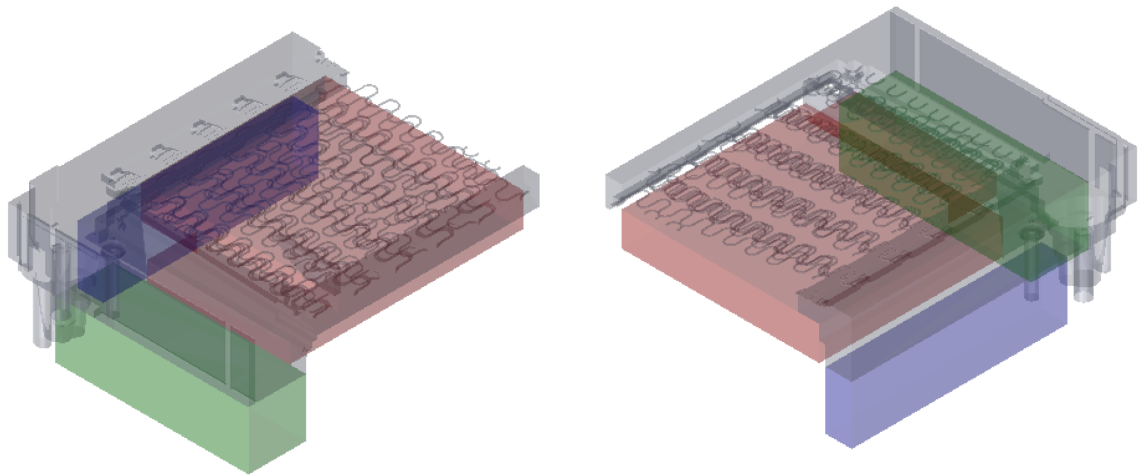


Figure 8: Combined Sofa seen from above

Notes: The hidden volume(red) represents the safe-space needed for hiding the contraption and socket when it's not in use. The front depth(blue) and side depth(green) represents the maximum distance below the edges of the sofa

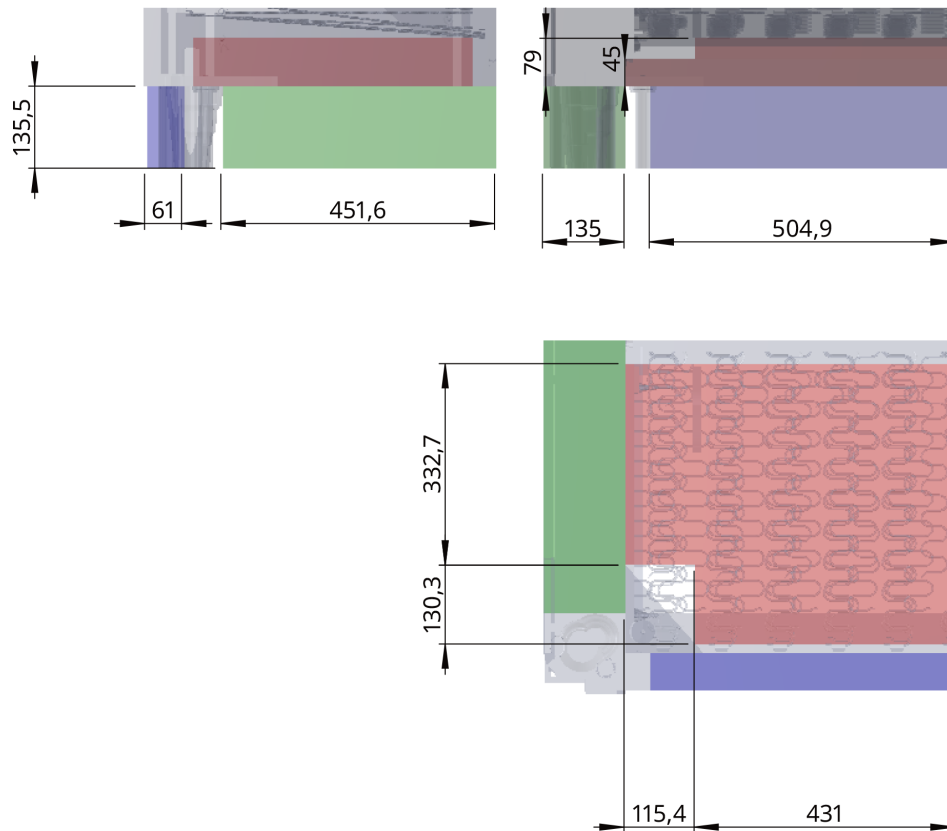


Figure 9: Measurements

Notes: The hidden volume(red) The front depth(blue) and side depth(green)

4.2. Benchmark competitors

Following the second step in the target specification process described by Ulrich and Eppinger, competitive benchmarking was used to understand how existing solutions address the problem and where they fall short. Benchmarking was used to evaluate available solutions and to see what kinds of designs were common in those solutions, especially regarding mounting strategy, accessibility, visual impact, and retrofit potential.[3]

Because the project was carried out under student-level budget and time constraints, the identified products and DIY (Do it yourself) solutions could not be acquired and physically tested. The assessment was therefore based on publicly available product images, descriptions, installation principles, and dimensional reasoning, combined with the project's own customer insights and furniture measurements. This limitation reduces the certainty of some judgments, especially for qualities such as perceived sturdiness, exact ease of installation, and long-term wear. The material was still sufficient to compare solutions against the initial metrics established in section 4.1. These metrics included retrofit feasibility, compatibility with KOPPLA, seated accessibility, comfort impact, design impact, and compatibility with benchmark sofa models.

The benchmarked solutions (see Appendix E) were grouped into three practical categories: DIY solutions, IKEA related solutions, and commercially available third-party products. The categories represent different priorities. The DIY category often focuses on functional problem solving. The IKEA category is relevant because it shows solutions within the company's own ecosystem and what has already been explored. The third-party product category shows how adjacent markets solve similar accessibility problems without being designed around IKEA furniture or the KOPPLA system.

4.2.1. DIY

The DIY solutions were primarily identified through maker platforms and online communities, where users had published 3D-printable brackets and mounts intended to hold power strips such as IKEA KOPPLA (see Appendix E). These solutions were useful because they showed how users had already tried to solve the problem in practice. As noted in the external search, most of these examples were relatively simple brackets, often fixed in place with screws, although some examples introduced angled placement, clamping, or hinged movement.

A main advantage of these DIY solutions is that they can often be added to an existing setup. Because several examples were built for an existing KOPPLA strip, they scored well on reuse, cost, and compatibility. This supports IKEA's circular approach by keeping existing products in use for longer. [5]

At the same time, the DIY solutions also revealed several recurring weaknesses. Many of the solutions seem to assume that the user has tools, freedom to modify the furniture, and sometimes access to a 3D printer. That makes them less suitable as an IKEA solution for a wider user group. Another issue is that several concepts solve the mounting problem without making the power strip easier to reach while seated. Many of them also rely on visible brackets, screws, or exposed geometry, which may affect the appearance of the sofa.

Most of the solutions seem to be made for one specific setup rather than for several sofa types. According to our delimitations (1.3), compatibility had to be considered across a set of benchmark sofa models. In contrast, most DIY concepts appear to be adapted to a specific local setup rather than dimensioned for a family of sofas. They were helpful for inspiration, but less helpful as a basis for a scalable specification.

The DIY category was useful because it showed that there is interest in retrofit cable-access solutions and because it provided several simple attachment ideas. Many of the user-made solutions did not fully solve seated accessibility, visual integration, installation quality, or standardization.

4.2.2. Products

The product category included both IKEA-related references and commercially available third-party solutions, see Appendix E. Unlike the DIY examples, these products were finished market solutions and gave a clearer picture of how similar problems are currently solved. The reviewed examples included clamped desk outlets, adhesive holders, loose sofa-oriented socket solutions, integrated furniture solutions, and the discontinued IKEA SIGNUM holder for KOPPLA. Together, they showed a wider range of approaches than the 3D-printed examples.

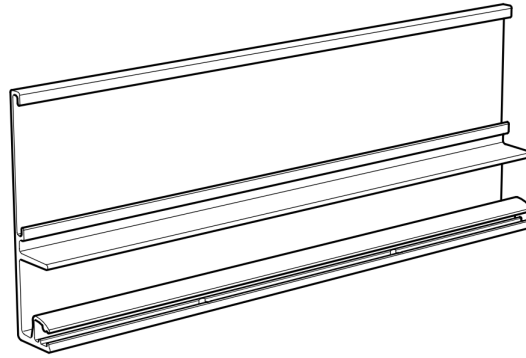


Figure 10: The designated KOPPLA holder SIGNUM by IKEA. (Picture from manual [23])

The SIGNUM holder (see Figure 10) was especially relevant because it shows that IKEA has already explored a holder for KOPPLA. In other words, this is not a new need within the IKEA ecosystem. The product is no longer in production but it still serves as an important benchmark reference, since it confirms that mounting a power strip on furniture has already been considered meaningful. SIGNUM was useful less as a model to follow and more as proof that a KOPPLA-based solution has already been considered.[23]

The product category also showed several limitations when compared with the project brief. Many of the solutions addressed only parts of the problem. Some provided good access to power, but were not compatible with IKEA KOPPLA. Others were easy to install, but relied on adhesive attachment or loose positioning rather than a more integrated and robust mounting principle. Several solutions were also visually prominent, meaning that they remained visible in the room rather than blending into the furniture. Even if these products work in general living room or desk settings, they do not fully match the project's goals regarding low design impact, sofa compatibility, preserved comfort, and retrofit feasibility.

This was especially clear when integrated sofa solutions were compared with retrofit-oriented products. Built-in socket solutions can have low visual impact because they are built into the furniture from the start. However, they are less useful for a retrofit project because they assume a new sofa rather than modification of an existing one. Several add-on products are easier to retrofit, but achieve this at the cost of higher visibility or weaker integration. Many of the existing products solved one part of the problem well, but not the whole problem.

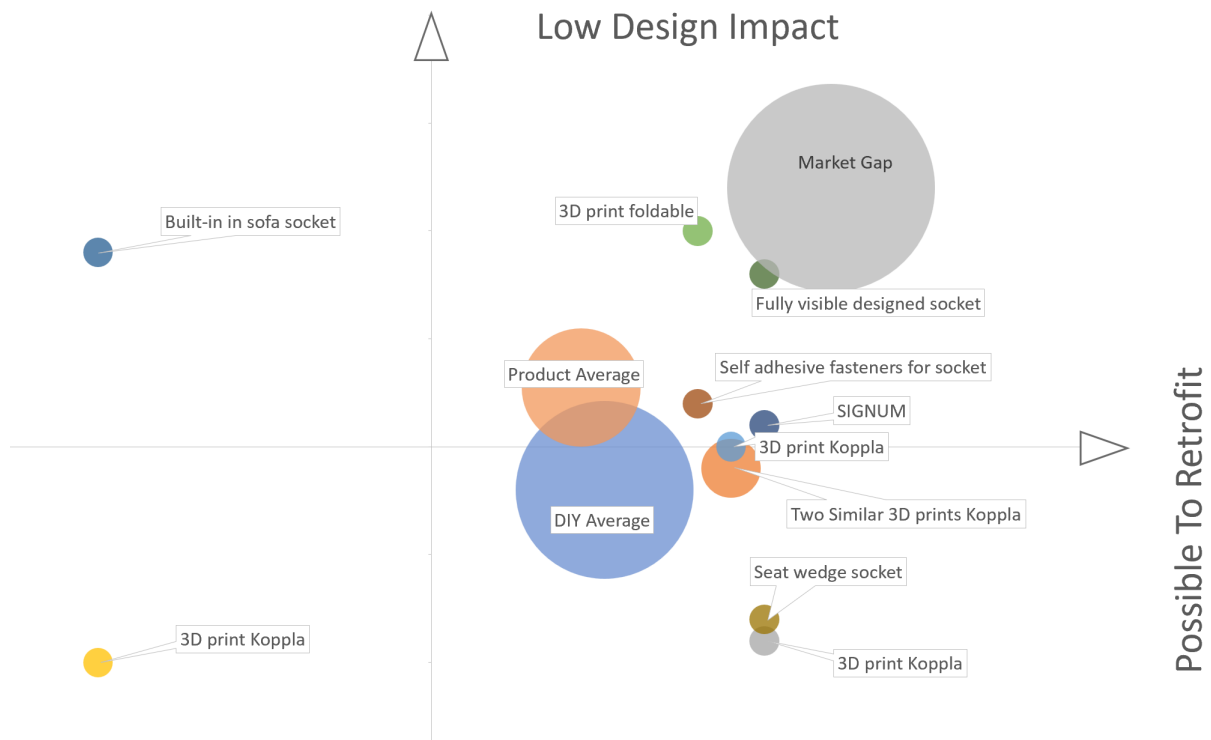


Figure 11: Competitors mapped according to our benchmarks and the market gap

The product references showed that the market has several partial solutions, but few that combine the main requirements of this project. This became clearer when the benchmarked solutions were mapped qualitatively based on retrofitability across sofa types and design impact, as shown in Figure 11. In that comparison, integrated sofa solutions tended to occupy the low-retrofit but relatively low-impact part of the solution space, while several add-on products clustered closer to moderate retrofitability but with more visible design impact. This left a gap where both low design impact and broad retrofit potential would need to be combined.

4.3. Set ideal and marginal values

Based on the metrics defined in Section 4.1, target values were established to guide the continued concept development. These values are divided into ideal targets and marginal limits, following the framework of Ulrich and Eppinger [3, p. 99].

The ideal values are primarily derived from the required space for connectors, represented by the safe volume (Figure 7 and Table 6). This volume provides a guideline for preferred dimensions that allow typical connectors to be used without interference. Since connectors and cables do not need to be fully concealed during operation, these values are treated as targets rather than strict requirements.

The marginal values are defined by the available space beneath the reference sofa models. The “combined sofa” analysis (Figure 8 and Figure 9) provides the maximum allowable dimensions for a solution intended to be compatible across multiple products. Designs exceeding these limits would not fit all models.

The resulting ideal and marginal values for the most relevant metrics are summarized in Table 7. Together, these values define the design space within which the concept development is carried out.

Table 7: Updated target specifications based on initial metrics

Metric	Imp.	Unit	Marginal Value	Ideal Value
Possible to retrofit	5	bin.	Requires minimal adjustment	No modification required
Chargers are unaffected	5	bin.	Minor interference acceptable	No interference
ISO compliant	4.7	bin.	Meets minimum requirements	Fully compliant
Symmetrically mountable	4.7	bin.	Left/right version required	Fully symmetric
Accessible while seated	4.7	bin.	Reachable with effort	Easily reachable
Compatible with IKEA KOPPLA power strip	4.6	bin.	Compatible with adapters	Direct compatibility
Furniture comfort is unaffected	4.5	bin.	Minor impact acceptable	No impact
Compatible with popular models	4.4	bin.	Majority of models	All 9 reference models
Volume required for connectors	4.2	mm	Must fit within available space	Within defined safe volume
Passes IKEA test lab	4.2	bin.	Meets basic criteria	Fully compliant
No impact on structural integrity	4.1	bin.	Comparable to original leg	Exceeds original leg
Headroom under sofa	4.0	mm	$\geq$ minimum from Fig. 9	Maximized
Low design impact	3.8	subj.	Visible but acceptable	Hidden / minimal
Successful user test time	3.7	s	< 180	< 60
Smooth operation	3.5	subj.	Functional	Smooth and intuitive
Supportable weight of connectors	3.3	g	Supports typical connectors	Supports worst-case scenario
Instructions needed for product	2.7	n	Basic instructions required	No instructions needed
Time taken to install product	2.2	s	< 300	< 120
Tools needed to install product	2.2	n	1 tool	No tools

5. Concept Generation

For the concept generation phase, both Norman and Ulrich & Eppinger emphasize the need to generate a large amount of potential concepts. To achieve this a large number of different generation methods have been employed. [3, 6]

According to Ulrich & Eppinger, this process can be subdivided into five steps. Starting with reducing the problem into subproblems and continuing with searching internally and externally for solutions. This is followed up by systematic exploration of the solutions through classifications and combinations ending with a reflection on the process. [3]

In this case, since the problems and mechanisms were largely unknown, the team decided to start with the internal search to better get a grasp of the solution space. For the external search of the concept generation process, the same products and solutions identified in the research chapter were used. This was followed by the problem breakdown and systematic exploration.

5.1. *Internal search*

For the internal search, both authors were initially tasked with individually performing brainstorming sessions. It was important that the individual sessions were completed first as not to pollute each others ideas. These results were then discussed in group and separated into similar solutions. As the next step a group brainstorming session was completed.

To continue with the generation a round of Bodystorming using an IKEA sofa of the Söderhamn series was conducted. Bodystorming can be seen as a sort of roleplay brainstorming and works well as a discovery method when the design problem has physical aspects or as a way to break thinking patterns. The purpose of the session in this case was to explore the design space in the physical context of the sofa. For example; assembly methods, ergonomics and reach.[24]

This identified further concepts and a specification regarding the angle of incidence of an observer of the sofa. A note was made to decide which percentile of people in our market, and at what distance, they would be unable to view the product, since this was to be the base for the "invisible" criterion.

5.2. Subproblem breakdown

After these sessions, the problem was deconstructed into sub problems to further divide the solutions into groups. These sub groups were then kept in mind when performing the rest of the concept generation. These subproblems are visible in Table 8.

Subproblem	Possible Solutions
Fastening - How the device attaches to the sofa	Screw in from side, Screw in from base, Glue, Shower curtain rod, On the Leg, Washer on leg, Angle Bracket, Sofa stretchers
Input (Reveal/Hide) - The input from the operator	Pull with hand, Rotate rod, Wire, Button, Slide action
Mechanism (Reveal/Hide) - Mechanism by which the power strip moves	Rails, Rotating rod, Slide rod, Spin leg, Double pivot rail, Spring bayonet, Horizontal rotation, Curved rail, Double rails, Rail with pivot, Hinges, Roller curtain
Drive - The energy input driving the mechanism	Hand, Foot, Spring, Gravity
Mechanism Lock - Secures device in end positions	Rails that deform, Passive, Magnets, Click-Clack mechanism, Bayonet, Locking-spring, Latch

Table 8: Subproblems and Possible Solutions

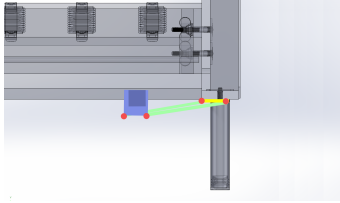
5.3. Concept combination

The purpose of the concept combination was to ensure that the design-space had been thoroughly investigated. Since the group had identified 5 different sub problems, with some overlap between revealing and hiding the product, the decision was made to carry out this step using only the two sub-problems "mount" and "Mechanism". This list was then analyzed to see which combinations had already been covered by the other steps and which combinations led to new feasible ideas.

5.4. List of Concepts

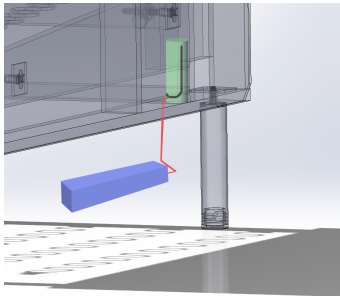
Figures 12-14 show the concepts deemed worthy for consideration. When this initial list of concepts had been set, the group consulted supervisor Erik Hult for guidance on which of the early solutions seemed promising. During this meeting, Erik Hult also emphasized the importance of studying how to reach the device and operate it, which was deemed important for the screening process.

Figure 12: Concept overview of concepts 1-6



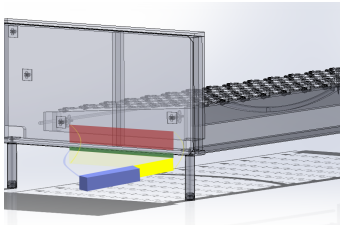
Concept 1: Double Axle Swing

Two sets of arms swing the socket out from underneath the sofa. The height of legs are the same as the furthest distance the socket needs to travel due to the armrest.



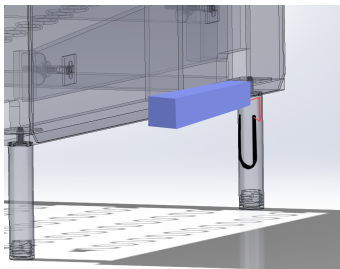
Concept 2: Spring bayonet

A spring-loaded bayonet with a track to guide the power socket between positions.



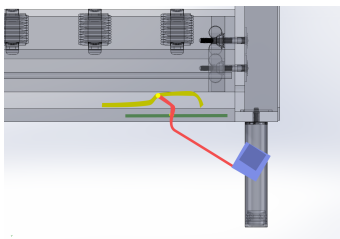
Concept 3: Two directional hinge

The power strip is first lowered from the red position 180° by a hinge and then extended by a second hinge.



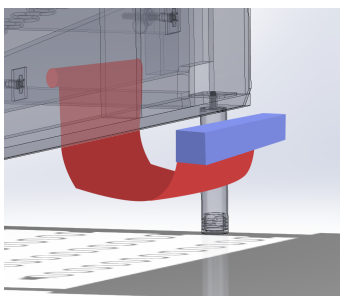
Concept 4: Spring bayonet leg

Similar to concept 2 but one of the legs of the sofa is replaced by the device. Either a new leg design or based on an existing one.



Concept 5: "Flip-Flop" rail guide

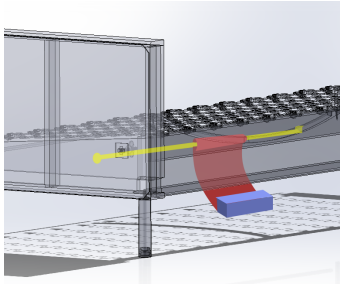
The power strip is mounted on two vertical rails, one of which is shaped to allow the device to change elevation to allow passage under the armrest.



Concept 6: Roller Curtain

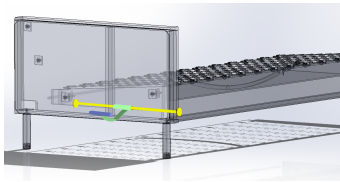
You pull out the power strip as far as needed to connect chargers and then you use the mechanism as you would a curtain to pull the strip and chargers up away from sight.

Figure 13: Concept overview of concepts 7-12



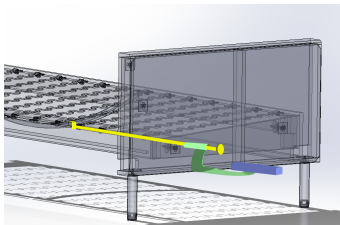
Concept 7: Roller Curtain on telescope

Similar to concept 6 but mounted to be accessible from the front



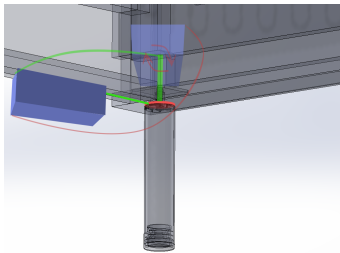
Concept 8: telescope with swing-arm

The telescope rod rotates to take the power socket from the hidden to the revealed position



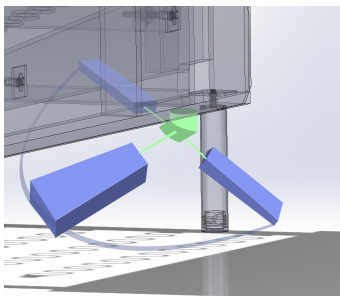
Concept 9: telescope with translating arm

The power socket travels along the arm, which is itself fixed to the side of the sofa and the stretcher.



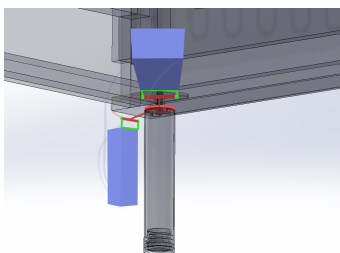
Concept 10: Washer with rotation around arm

A washer with an axial bearing that swings around. The socket swings around the arm which allows the socket to pass under the wall.



Concept 11: Tilted rotor

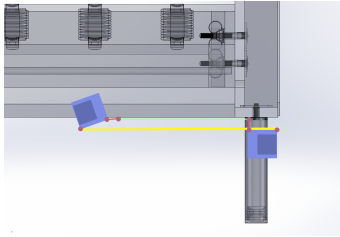
A tilted rotor swings the socket down and out or in and up.



Concept 12: Washer with fold

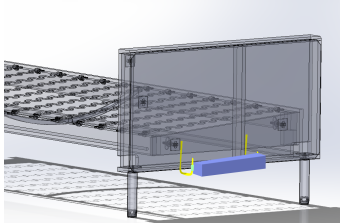
A washer with an axial bearing that swings around. Is installed between the leg and the sofa. An additional axle allows the socket to fold to pass under the wall of the sofa.

Figure 14: Concept overview of concepts 13-18



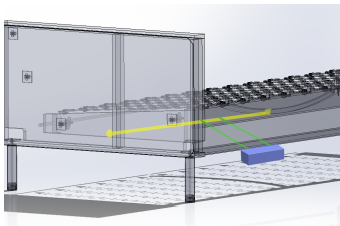
Concept 13: Double rail with pivot

Two sets of parallel rails are positioned atop of each other. A link from the upper rail locks the distance from the rail to the socket but is free to rotate. When pushed all the way back this forces a pivot motion that makes the outlets face inward.



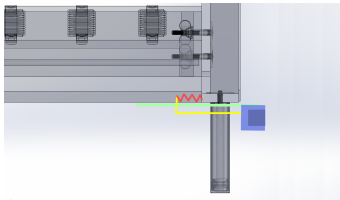
Concept 14: J-rail

The socket is guided along two parallel rails that leads from the outer to the inner position. It is possible to let the rails flex apart from each other and thereby lock the socket in the outward and/or inward position. There are many similar variants to this idea.



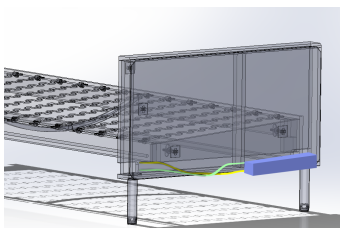
Concept 15: Telescopic pole with slanted rails

Between the stretcher and the inner wall a telescopic pole is attached. A double rail allows the socket to slide from the lower outward position to the higher, hidden inner position.



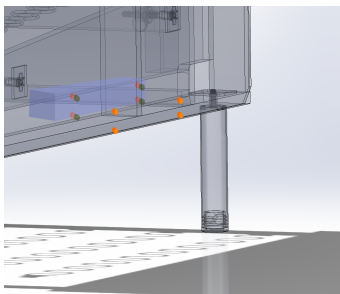
Concept 16: Spring loaded slider

A spring pushes/pulls the socket along a rail. It either helps the socket move inward or helps release the socket so it is easier to reach.



Concept 17: Spinning rails

Two parallel rails goes from the outside to the inside while performing a 180° spin. This makes the outlets face outward when out and inward in the inner position.



Concept 18: Magnets

On the socket, magnets are attached so that the socket can be placed both inside and outside of the sofa. The user manually moves the socket between the positions.

6. Concept Selection

The concept selection was done in multiple stages to take the generated concepts down to a single direction for continued development. The first screening reduced the number, this was followed by low-fi prototyping and evaluation. After these steps, the selection decision was made.

6.1. First Screening

The first screening of the generated concepts was made using methods taken from Ulrich & Eppinger. The screening was made to efficiently reduce the number of prototypes the group needed to create. This was achieved through the methods "Product champion" during which the concepts were turned over to an influential member of the design team, in this case supervisor Erik Hult at IKEA for his insights and preferences. This method was combined with a concept scoring matrix to select a total of five concepts to further explore.[3]

The evaluation categories used during concept screening were derived from the target specifications presented in Table 7. While the target specifications provided a comprehensive set of requirements for the final product, many of them could not be meaningfully assessed at the concept stage. Requirements such as ISO compliance, structural integrity, and installation time depend on implementation details that were not yet defined. Related specifications were grouped into broader concept-level evaluation categories that could be assessed based on the available concept descriptions. These categories were accessibility, simplicity, design impact, modularity, robustness, and pluggability.

The relative importance of each evaluation category was determined through discussion within the project team. Rather than assigning absolute weights, the categories were compared against one another and assigned importance values that reflected their relative significance. These values were only intended to establish the relative importance between categories and were therefore assigned on an arbitrary scale. The weighting factors shown in Table 9 were subsequently calculated by normalizing the importance values according to

$$M_n = \frac{I_n}{\sum_{i=1}^N I_i} \quad (1)$$

where I_n is the importance assigned to category n , M_n is the resulting weighting factor, and N is the total number of evaluation categories. This normalization ensures that the weighting factors sum to one while preserving the relative importance assigned to each category.

Accessibility was assigned the highest weight, followed by simplicity and modularity, since these criteria were considered most important for the intended solution. Robustness and pluginability were also taken into account, while design impact was given a lower weight in the overall assessment. This was due to that all of the concepts were mostly hidden and the difference between each concepts were not that great. By applying these weights as multipliers in the scoring matrix, concepts that performed well in the most important categories were given greater influence on the final result. This allowed the total score to better reflect the priorities and requirements of the project.

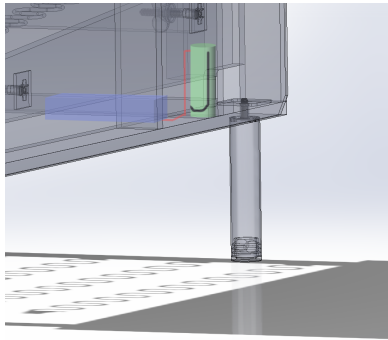
Table 9: Evaluation Points and Weights

	Accessibility	Simplicity	Design Impact	Modularity	Robustness	Pluggability
Multiplier	0.29	0.24	0.05	0.19	0.10	0.14
Importance	3	2.5	0.5	2	1	1.5

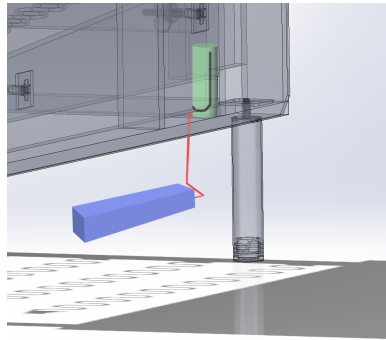
The concepts were evaluated using a weighted scoring matrix, shown in Table 2, in order to compare the generated ideas in a structured manner. Each concept was assessed against the categories accessibility, simplicity, design impact, modularity, robustness and pluginability. The score shown for each category is the weighted score, meaning that the original assessment in each category was multiplied by the corresponding weighting factor. These weighted category scores were then added together to obtain the total score for each concept.

In addition to the numerical scoring, each concept was also accompanied by a short comment from IKEA, shown beneath the concept name in the table. These comments were taken into consideration together with the total score when deciding which concepts to proceed with. The concepts marked in green were selected for continued development and further prototyping, as they were considered the strongest alternatives based on the combined assessment. The concepts marked in yellow were identified as runner ups, meaning that they showed potential but were not prioritized for continued prototyping at this stage. The concepts marked in red were scrapped, as they were deemed less suitable in relation to the project requirements. The yellow highlighted values within the table indicate the highest score achieved in each individual category and were used to show which concepts performed best in specific areas, even if they were not among the highest scoring concepts overall.

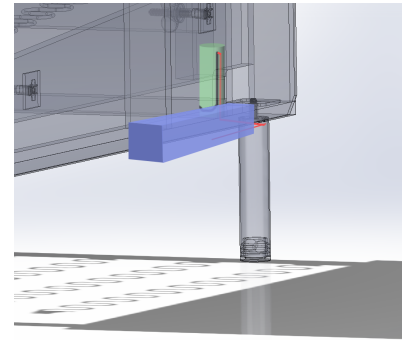
6.1.1. Remaining concepts



(a) The socket is in its hidden position beneath the sofa, concealed behind the vertical panel forming part of the armrest.

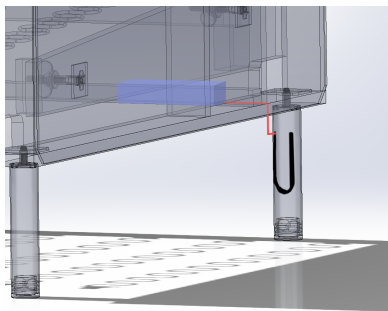


(b) A handle actuates the mechanism, pushing the socket along an arm through a guide slot, causing it to rotate outward beneath the edge.

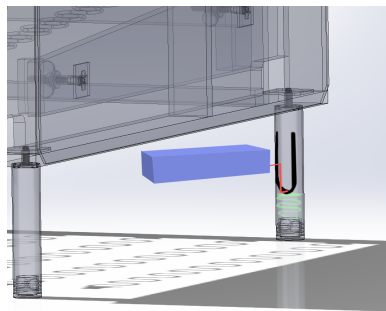


(c) In the revealed position, the socket is accessible to the user; reversing the motion returns it to the hidden position.

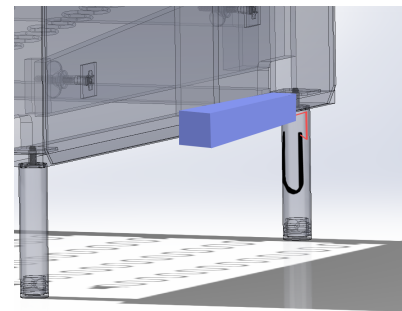
Figure 15: Spring-loaded cylinder



(a) The socket is in its hidden position beneath the sofa, behind the vertical side panel.

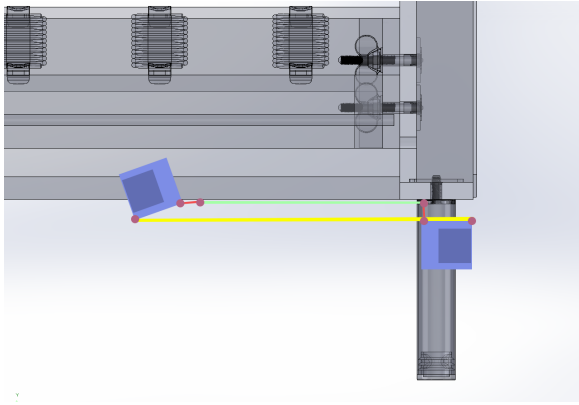


(b) A handle actuates a spring-loaded mechanism located within the leg, guiding the socket outward along an arm and through a controlled path.

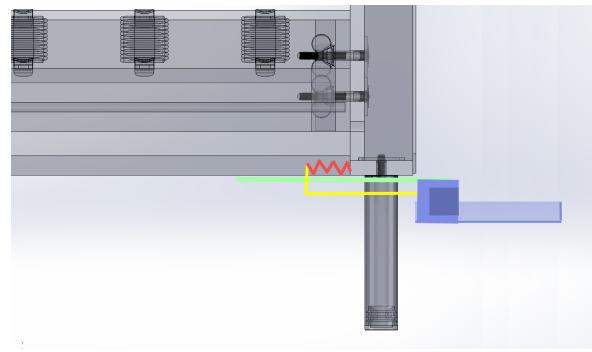


(c) In the revealed position, the socket is accessible on the side of the sofa. Reversing the motion returns it to its hidden position.

Figure 16: Spring-loaded leg

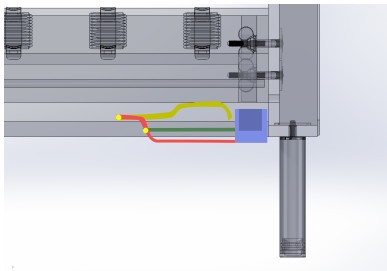


(a) Two sets of parallel rails are positioned above each other. A link connected to the upper rail constrains the distance between the rail and the socket while allowing rotational freedom. As the mechanism moves between the outer (accessible) and inner (hidden) positions, this constraint induces a pivoting motion, rotating the socket to face outward when extended and inward when retracted.

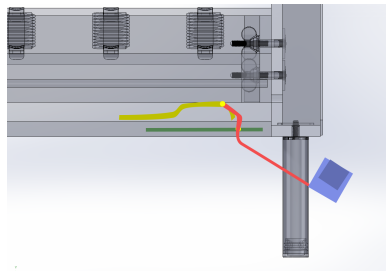


(b) A spring assists the socket as it moves along a horizontal linear rail, reducing the effort required to both extend and retract the mechanism. Due to the purely linear motion, a tray can be integrated beneath the socket without interfering with the movement.

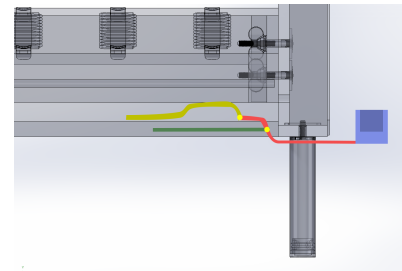
Figure 17: "Double rail with pivot" and "Spring loaded linear rail"



(a) The power strip is in its hidden position beneath the sofa, guided by two vertical rails.



(b) As the mechanism extends, one of the rails, with a profiled geometry, guides the socket along a combined vertical and horizontal path, allowing it to pass beneath the armrest.



(c) In the revealed position, the socket is accessible outside the sofa. Reversing the motion returns it to its hidden position.

Figure 18: "Flip flop"

6.2. *Low-Fi Prototyping*

Lo-fi prototypes were made to test the initial concepts early in the development process. These were done to evaluate the basic functions, mechanisms and feasibility of the concepts before further development. By using simple materials and methods, the team was able to quickly explore the concepts in physical form and identify advantages, limitations and areas in need of improvement. The results from this stage were then used as support in the continued concept evaluation and development.

6.2.1. *Prototype Creation*

To test the initial five concepts, four prototypes were created. This was done due to the fact that concepts "The Flip Flop" and "Double Rail with Pivot" were deemed similar enough when it comes to function that one prototype would suffice. These prototypes were created using different techniques, chosen after which technique the authors deemed would yield the best result, prioritizing speed and accuracy.

The first prototype created of the "Spring loaded linear rail with tray" concept was made using cardboard and was measured and cut by hand. The advantage of this technique was that the measurements and mechanisms could be adjusted as the prototype was created. The main drawback that became apparent quickly was the strength of the material when trying to evaluate the prototype, as well as the fact that creating the prototype took longer than anticipated.

The rail based concepts were combined and their prototype created by laser cutting MDF - Medium Density Fiberboard into guides and using spare metal rods as axles. The pivot from cardboard was made after realizing the time it had taken to create the first prototype did not reflect the quality or functionality of the prototype.

The prototypes for the cylinder based concepts were created using additive manufacturing since the small tolerances for the mechanism would take more time to get right using cardboard or similar materials rather than simply using CAD and sending it to print.

6.2.2. *Prototype Evaluation*

The prototypes were evaluated by being mounted to a generic foot stool. The choice of using the stool instead of a sofa was made since the length of the legs and frame structure bore similarities to IKEA sofas while the stool offered simple access and movability. The compromise was deemed acceptable as we had kept in mind the calculated volumes when designing the prototypes and the functionality was the main thing being evaluated.

The evaluation criteria used during prototype testing were based on the concept screening categories presented in Table 9 rather than the detailed target specifications in Table 7. Many of the target specifications, such as ISO compliance, installation time, structural integrity, and compatibility across multiple sofa models, could not yet be meaningfully verified using the early prototypes. The prototypes were evaluated on whether they demonstrated the potential to satisfy these

requirements in a future implementation. The selected criteria therefore focused on concept level qualities that could be assessed through physical prototyping and observation. Still maintaining the priorities established during concept selection.

The prototype functionality was evaluated based on several criterion, these were;

- The accessibility of the prototype, both in the "in" and "out" position and the means of manipulating the prototype to move.
- The simplicity of the solution when it comes to amount of parts, size and attachment.
- If any of the concepts meant a higher design impact than initially conceived during the generation phase.
- The modularity of the prototypes when it came to the requirement of having it both be mounted on either side of the sofa and the requirement of multiple platforms.
- Lastly the robustness of the solutions were evaluated. This criterion was slightly subjective however since detail design and materials were not part of the prototyping at this stage.



(a) Extended.



(b) Retracted.

Figure 19: A spring loaded linear rail with an added tray.

The spring-loaded linear rail with tray (Figure 19) is a relatively simple concept that offers built-in storage space. It may also be possible to implement it using existing drawer-slide mechanisms, which could make development easier. At the same time, it takes up space under the sofa, especially because it lacks vertical movement. Which would interfere with the vacuum robot. It may also be difficult to extend it fully without exposing the rails or creating other visually undesirable details. The mounting solution is somewhat more complicated and would be hard to standardize.



(a) Extended.



(b) Retracted.

Figure 20: Spring loaded leg concept



Figure 21: Spring loaded leg with placeholder foam

Notes: The blue foam is a placeholder for the IKEA KOPPLA and has roughly the same size as the socket.

The spring-loaded leg (Figure 20) works in theory well across all models and provides a solid attachment point that does not need to be modified. This makes it broadly compatible and structurally reliable. However, the concept creates a lever effect, which could introduce mechanical challenges.

In addition, different models have different leg designs, and these variations are often more aesthetic as well as structural, which makes it harder to create a solution that feels consistent across the range. Another limitation of the current prototype was that it was not symmetrical, meaning it could not be mounted on both sides of a sofa with the same result.



Figure 22: Spring loaded cylinder

Notes: A suitable combination of attachment surfaces could not be identified for the Spring loaded Cylinder.

The spring-loaded cylinder (Figure 22) has the advantage of being discreet, which makes it appealing from a visual standpoint. On the other hand, it is difficult to mount properly and may also be awkward for the user to reach and operate. It must also deal with height limitations that are shared across all models, which makes integration more difficult.



(a) picture 1

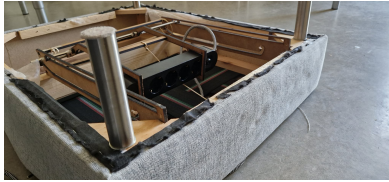


(b) picture 2



(c) picture 3

Figure 23: "Flip flop"



(a) picture 1



(b) picture 2



(c) picture 3

Figure 24: "Flip flop" seen from below

The Flip Flop (Figure 23) and Double Rail with pivot (Figure 17a) concepts performed well in terms of function and stability. However, they became large because the cable had to be placed inside the rail. Since each model has different attachment points, it was difficult to make the solution broadly compatible. The concept worked well in two dimensions, but it became significantly more complicated in three dimensions. In practice, it ended up being wider than it was deep, which made it feel bulky. It was also rather awkward to mount into the product.

6.3. Selection Decision

The rail concepts (“Flip flop”, “Double rail with pivot”, and “Spring-loaded linear rail with tray”), together with the “Spring-loaded cylinder”, showed that solutions requiring attachment points inside the sofa are difficult to generalize across different models. Internal structures, dimensions, and attachment possibilities vary significantly between products, these concepts would require model-specific adaptations, limiting their potential as a universal solution.

In contrast, the “Spring-loaded leg” concept makes use of an already existing and relatively standardized interface. IKEA uses an M8 screw to attach legs in most products where the leg is mounted to a flat surface. While this is not a strict universal standard across all furniture, it is widely used and provides a consistent and accessible attachment point.

Another important factor was ease of installation. Concepts that required access inside the sofa or more complex mounting steps were found to be less suitable, both in terms of user experience and practical implementation. The spring-loaded leg could be installed using the same approach as replacing a standard furniture leg, which reduces the risk of incorrect assembly and makes the solution more accessible to a wider range of users.

The physical size and integration of the concepts also influenced the decision. Rail-based solutions and the flip flop concept tended to become bulky, partly due to the need to accommodate the cable within the mechanism. This not only affected the aesthetic impression but also limited their compatibility with different furniture geometries. The spring-loaded leg, although not without its challenges, allowed for a more compact and discreet solution.

Some mechanical limitations were identified in the spring-loaded leg concept, such as the lever effect and variations in leg design across different furniture. However, these were considered more manageable within the scope of further development than the fundamental limitations of the other concepts.

Based on these considerations, the spring-loaded leg was selected as the primary concept. The combination of a standardized attachment interface, relatively simple installation, and broader compatibility made it the most promising direction for continued development.

7. Concept Validation

The concept validation started with a risk analysis and mitigation to identify and adjust the concept before mid-fi prototyping began, though the mid-fi prototyping still became a highly iterative process before leading to the final concept. This concept was then expanded upon with material suggestions and manufacturing methods to move the concept into the system level design stage. This was then followed by evaluating the feasibility and usability. The final step of this chapter updates the specifications.

7.1. Risk Analysis

This chapter presents the risk analysis conducted for the selected concept. The purpose was to identify potential risks early in the development process and use the results to guide design decisions and prototype development.

7.1.1. Concept Risk Analysis

To evaluate the concept the methodology discussed in Section 2.3 was utilized. The risks that scored high enough on the combined severity and likelihood as well as high severity cases are shown in Table 10 for the spring loaded leg. The scale 1-5 has been used to quantify the perceived severity and likelihood. With 1 representing a low severity/likelihood and 5 a high severity/likelihood.

All of the risks that made the list were kept in mind during the further development of the design. Certain risks, those who got a score above 10 and cases where the severity was deemed of extra importance were more thoroughly assessed and an effort was made to address them early on in the prototyping process. Any risks identified beyond number 18 were identified during the prototyping or testing process but have been inserted into the table for clarity and to collect all information in one place, as part of the risk analysis documentation.

Nr.	Interpeted Risk	Sev.	Lik.	=	Assumed Root Cause
1	Person puts a limb or body in opening and is trapped with finger or clothing	3	4	12	Slot opening and moving part makes for possible pinch
2	Person puts a body part between the moving parts while they move together; the body part gets trapped and put under pressure (crushed)	3	3	9	Travel slot too big and uncovered
3	Person puts a body part between the moving parts while they move close by (scissor movement); the body part gets trapped between the moving parts and put under pressure (shearing)	4	3	12	Travel Slots too big and too uncovered, leading to sharp edges being available to cut if post processing insufficient
4	A body part, hair or clothing of a person is entangled by the rotating part; this causes a pulling force	2	4	8	Clothing is trapped by the arm of the product while in movement.

Nr.	Interpeted Risk	Sev.	Lik.	=	Assumed Root Cause
5	Person hits sharp corner or is hit by moving sharp object; this causes a puncture or penetration injury	2	4	8	Sharp edges on handle, screws sticking out from manufacture
6	Person touches sharp edge; this lacerates skin or cuts through tissues	4	3	12	The surface between the slots get bent outwards due to high stresses and tilts a sharp edge outwards
7	Product collapses by overloading	3	4	12	Person interprets the "KOPPLA" as a solid place to stand and the product collapses
8	Product collapses by overloading	4	3	12	Insufficient strength of the leg, use of sofa or use of product
9	Person (child) swallows small part; the part gets stuck in larynx and blocks airways	4	2	8	improper mounting or similar leads to small part getting loose
10	Person tries to fit a part, needs too much force to fit, product breaks; or part is too loosely fitted and gets loose during use	3	3	9	Wrong tolerances, complex assembly
11	Design requires use of considerable force when operating the product	5	3	15	The koppla or the chucko are misaligned and the force required to insert/take out the chucko damages the product

Nr.	Interpeted Risk	Sev.	Lik.	=	Assumed Root Cause
12	Elastic element or spring under tension is suddenly released; person in the line of movement is hit by the product	2	4	8	Product unexpectedly leaves a locked position and during its spring loaded motion it hits the operator
13	Person trips over product, falls and hits the floor; or person bumps into product	4	3	12	Product is left in "open" position and person not used to the hazard trips
14	Operating the product by foot causes the user to loose balance	4	2	8	Handle is slippery or otherwise not suited for socks
15	Design causes unhealthy posture of person when operating the product	3	3	9	Unergonomic handling makes repeated use of the product painful for the user (bad mechanisms for extending/retracting product)
16	Person on the accelerating product loses balance, has no support to hold on to and falls with some speed	4	2	8	handle slot moves in more than one direction
17	Product overheats; fire	5	1	5	Product in the inner position has no airflow to cool the product and temperature increases over the safety limit.
18	Person can touch part of the product that is at high voltage; the person receives an electric shock and may be electrocuted	4	1	4	Cable bends improperly and causes exposed wiring

Nr.	Interpeted Risk	Sev.	Lik.	=	Assumed Root Cause
19	Dust or debris ruin mechanism	3	4	12	Open slot leads to intake point for dust

Table 10: Risk Analysis Results - Spring Loaded Leg [10]

7.1.2. Initial Risk Mitigation

For the Bayonet Leg concept, **risks 1-3** were all suspected to have to do with the travel slot being too wide and exposed in our initial concept. As a suggested solution, a "guard" was to be added above and below the handle to reduce the risk of fingers getting trapped in the slot while operating the product. **Risks 4,5** were both directly tied to the handle and to reduce the chance of clothing getting caught, the geometry of the handle was adjusted, both size and shape. In Figure 25 the original handle can be seen that tries to adress these risks.

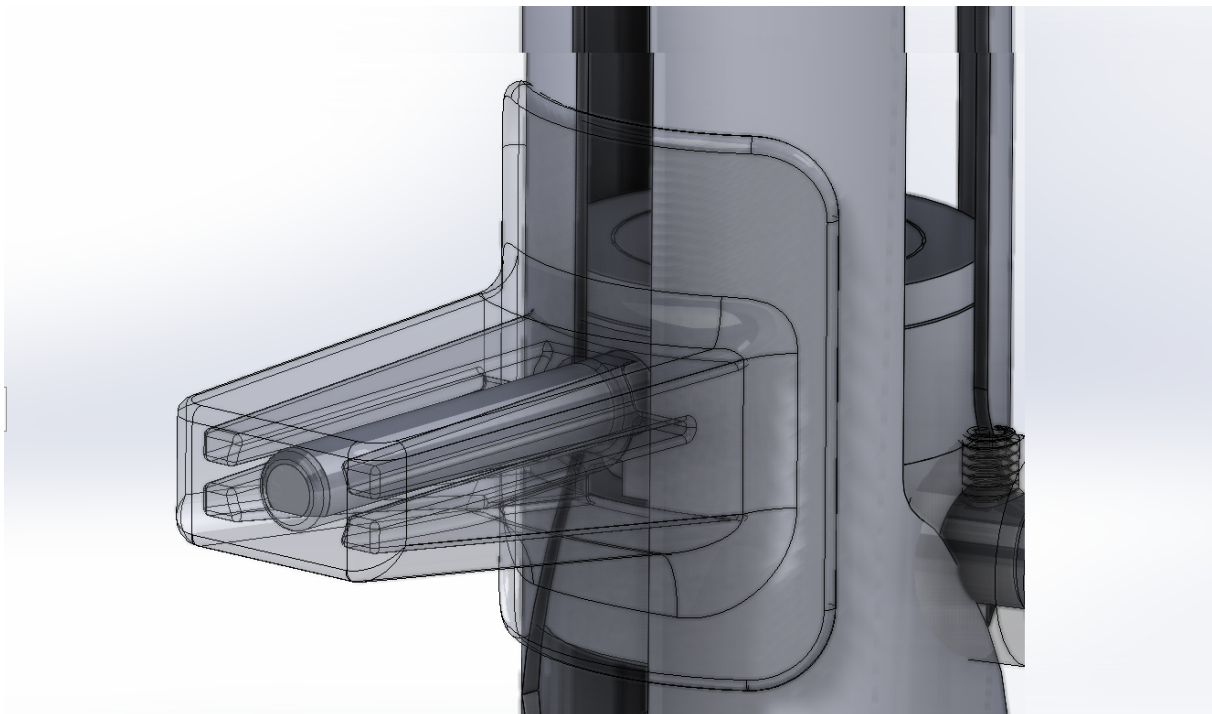


Figure 25: Early version of the handle

Risk 6 The "free" surface that was created by the travel slots on the cylinder, Figure 31, was deemed of extra importance. This was because it constitutes both a risk for the operator and for the product. The risk of the lip of this surface bending outwards with use was deemed quite probable with repeated use and multiple initial suggestions were made to address this. These included;

- Locally fortifying the outer surface of this part of the leg - sacrificing homogeneity and increasing production costs.

Increasing the thickness of the outer wall - increasing material cost.

Cut the guide on the inner pillar thus shifting the forces and strains from guiding the arm from the outer shell to the inner pillar - forcing a more robust inner pillar to ensure proper mechanical properties.

Risk 7 has several ways to be mitigated, warnings of different kinds, but that would affect the aesthetics, and children, while not the intended audience, might not care. The top of the product could be slanted, serving as more of an anti-affordance to stepping. Another solution could be that the product might stay under the sofa in the extended position as well.

Risk 8, the leg collapsing, could not be fully ensured to be mitigated due to the scope of the project but simple strength calculations were made to check if any designs were deal breakers. Initially the bending moment caused by unplugging chargers exceeded the yield strength of simple steels with the given arm geometry and a way to mitigate this had to be found. The calculations were based on the requirement that the maximum force for plugging and un-plugging this type of socket is 54N according to IEC60884-1. [25]

The arm was modeled as a cantilever beam with the diameter ($d = 0.008m$), fixed where it attached to the leg. Two loads were applied to the arm, the weight of the KOPPLA when fully loaded with cables ($2.5kg$), which added a bending moment and slight torsion. Then the bending moment from unplugging the Schucko ($54N$). The distances for which these loads were applied were varied when testing for solutions. The bending stress was calculated as $\sigma_b = M_b/W_b$, with the two bending loads as a resultant as they apply in perpendicular planes. The shear stress was calculated as $\tau = M_t/W_t$ and the Von Mises effective stress then became $\sigma_e = \sqrt{\sigma^2 + 3\tau^2}$. This number was then compared to the assumed yield strength of $300MPa$ but despite varying the lengths a satisfactory safety factor could not be reached.

The solution was to add a separate plate on the bottom of the sofa-frame which the product docked into in the open position. This plate then absorbs the forces, alleviating the lever effect on the arm. Figure 48n shows how this dock could look.

Another way for the leg to collapse is simply by buckling under load when the sofa is in use. Since this concept inherently cuts at least one groove into the main cylinder of the leg the rigidity and strength of this component will always be less than that of the standard leg. It is also hard to calculate by hand the exact differences due to geometry variations and thus the design team recommends a computational analysis such as the finite element method be conducted on the final concept. This is further expanded upon in section 9.2.3.

Risk 11 was also tied to the strength of the construction regarding unplugging the chargers. Though the root cause was argued more to be tied to ease of access rather than inherent instability.

Risk 12 requires clear endpoints and the device to be locked or held firmly at them even when not in use.

Risk 13-14 relate to tripping hazards which means a high severity. 13 carries similar mitigations as the climbing hazard 7. 14 is harder to mitigate but choosing the right spring for the product and adding an anti slip surface on the top of the handle were both ways identified.

Risk 15 by offering several ways to operate the product, for example by foot or by hand. The user can then adapt their use to what is most suitable to them.

Risk 16 once again relates to falling, initially the proposed solution was to add a separate slot for the handle and the arm, though further testing proved this to be an inefficient design for the product.

Risk 17 is tied to operating temperature of the cables with 70 degrees being the maximum several producers list. Sadly this project did not have the time or resources to fully test this. One suggested solution however is to make it impossible to retract the product with chargers still attached. Though the exact use requires further discussion. [26, 27]

Risk 18 is tied to the minimum bending radius required for power cables. For this project, the monetary means to acquire the relevant standards were not there. Instead the team looked at different producers of H05VV-F power cables for guidance and came up with between 6-8D for occasional flexing application, with D being the outer diameter of the cable. One outlier with 10D requirement was also found but this was for handheld equipment. [26, 27]

7.2. *Mid-Fi Prototyping*

The mid-fi prototyping phase focused on translating the selected concept into a more mechanically defined solution. The aim was to explore how the mechanism could be integrated into an existing sofa leg, how the KOPPLA socket could be attached and moved, and how the design could remain compatible with retrofitting. Several iterations were developed during this phase, moving from early slot-based mechanisms toward a simplified configuration with fewer moving parts and a more practical installation process.

7.2.1. *BANKABY as a Starting Point*

The criteria that the device replaces an existing leg of the sofa led to a design based on the leg it replaces. The BANKABY leg had a clean design that made it compatible with most couches and is thick enough to house the internal mechanism. All of IKEA's sofa legs use an M8 screw to fasten it so the device would potentially be very suitable for retrofitting if the device maintains the original characteristics of the leg. Maintaining the same height, diameter, fastening screw, and at least the same structural integrity as the original leg was a primary goal.

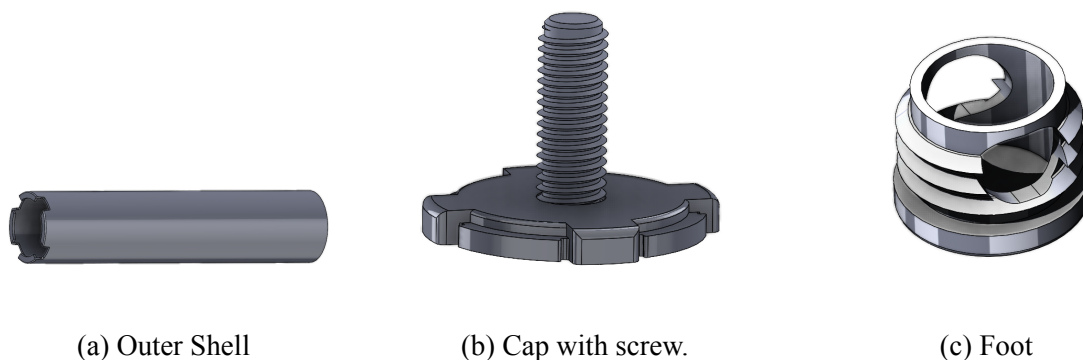


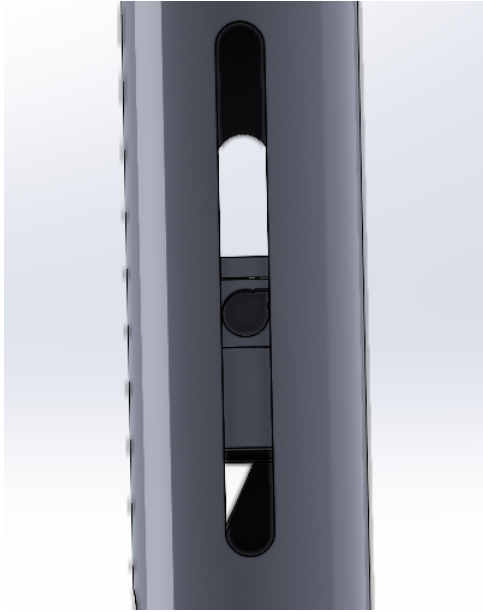
Figure 26: Parts of the original BANKABY

The BANKABY leg is originally made up of three parts. The outer shell (Figure 26a) and the cap with an integrated screw (Figure 26b) are both made out of steel and the foot (Figure 26c) is made out of plastic.

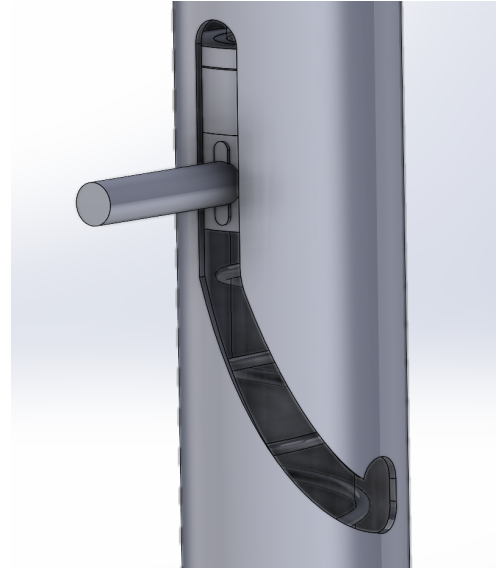
7.2.2. Initial Slot-Based Mechanism

Our first version used the same parts but with two slots cut in the outer shell, one running vertically (Figure 27a) and the other in a mirrored J-shape (Figure 27b). The intention was to allow the user to only perform vertical motion using the control handle while the KOPPLA socket moved vertically and rotated simultaneously.

An arm (Figure 30) made from an 8 mm steel rod, bent to the required dimensions positions the KOPPLA socket in the desired location. Initially, the arm was secured with a pin directly into the runner but later a spigot was added to the runner to allow the end user to easier attach the arm themselves. The arm's dimensions was depended on design changes to both the leg and the KOPPLA clamps.



(a) Vertical slot for the handle



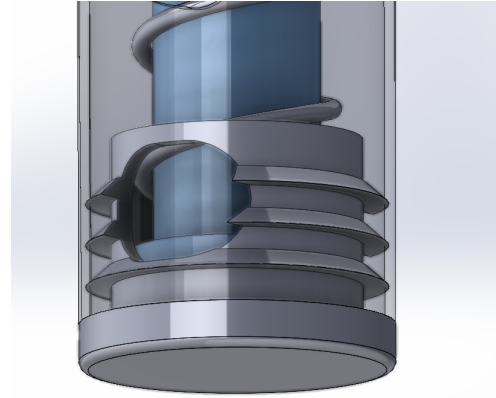
(b) J-shaped slot for the arm holding the KOPPLA socket

Figure 27: Slots cut in the shell

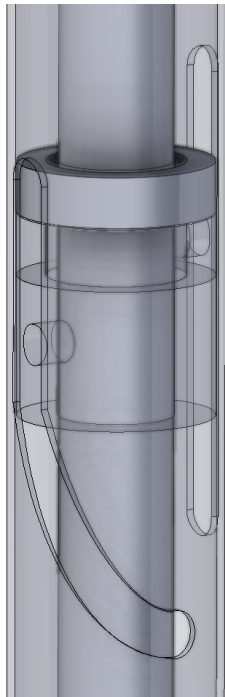
Inside the shell, a pillar (Figure 28a) was added, to maintain structural stability and to guide a sliding configuration of runners (Figure 28c) vertically along it. The spring, which pushes the runners upward, is seated on a protruding edge at the base of the pillar and threaded around the outside of the pillar (Figure 28b). The protruding edge of the pillar enables a snug fit into the original BANKABY foot. The top the pillar supports the cap and absorbs forces resulting from the reduced structural integrity of the shell due to the slots cut out of it (Figure 28d).



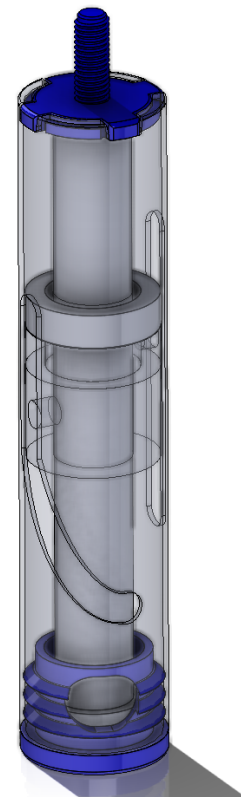
(a) Pillar



(b) Spring mounted around the pillar fitted inside of the shoe



(c) Configuration of runners



(d) The pillar holds up the cap while resting inside the foot.

Figure 28: Slots cut in the shell

7.2.3. *Arm and Socket Attachment*

IKEA has a socket holder for the KOPPLA system (Figure 29a) and this was used to attach the KOPPLA socket to the arm. The KOPPLA socket itself does not have an obvious docking interface and it was useful to build on an existing

IKEA product that was already made to hold this specific socket. This made it possible to attach the KOPPLA socket to the arm without modifying the socket itself. For this, a clamp component that slides into an angled gap of the socket holder was developed (Figure 29b) and when a second clamp is used on the other side, the arm locks them in place (Figure 30b).

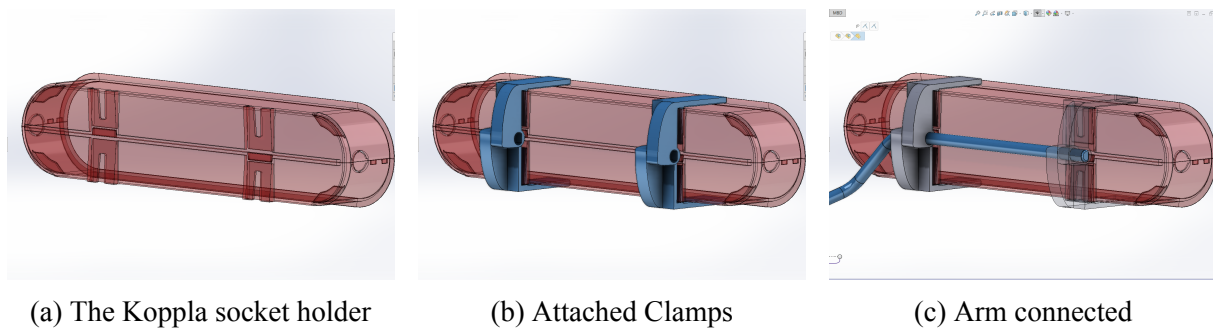
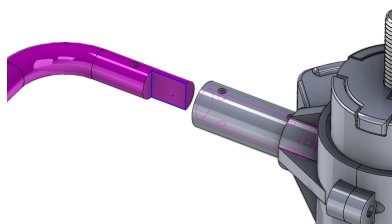
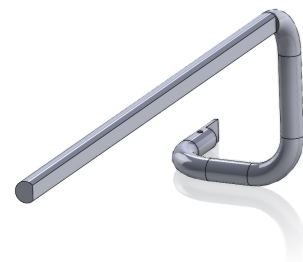


Figure 29: Attaching the Koppla to the arm



(a) The final design of the arm being inserted into the sleeve



(b) The final arm design.

Figure 30: Details of arm

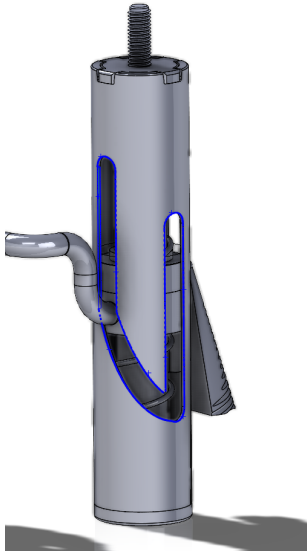
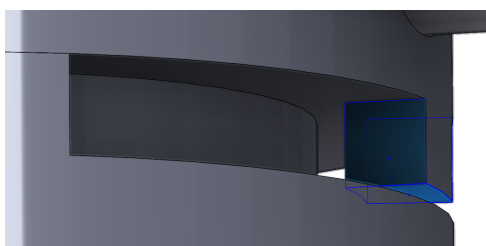


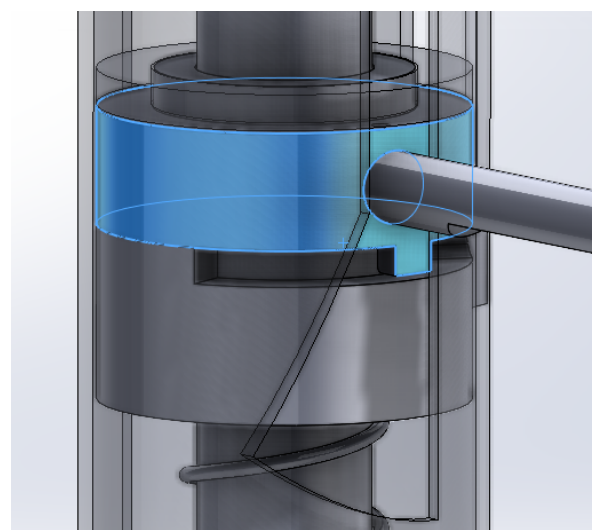
Figure 31: The U-slot

While the prototype was not yet fully functional, the development continued on features improving the user experience. Modifying the J-slot into a U-slot (Figure 31) would make the socket rise from its lowest position while the back of the socket slides along the sofa's side. This would allow the user to insert a connector with one hand without putting too much force on the mechanism in the leg as the side of the sofa acts as support for the horizontal force applied during connection.

At the lowest point of the U-slot path (Figure 33c), the arm would move straight toward the revealed position if not otherwise guided. This led to a runner configuration (Figure 32b) that allows the handle to push the arm-runner to the left while rotating freely in the opposite direction.



(a) The Tooth and guide ledge

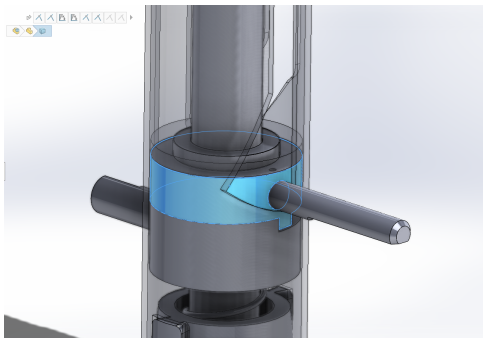


(b) the handle's runner (blue) and the arm's runner

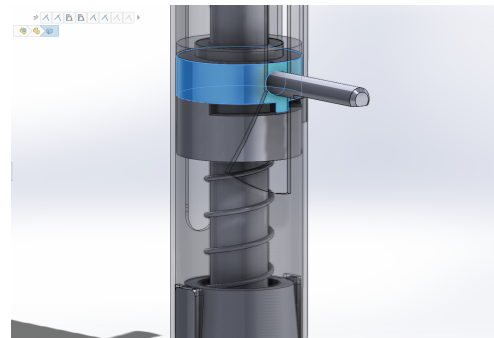
Figure 32: The steering of the runners

A protruding "tooth" (Figure 32a) on the handle's runner engages with a guide ledge on top of the arm's runner, allowing the steering to be controlled by the relative start and end positions of the ledge. To the right of the tooth, the length of the ledge ensures that the tooth cannot push the arm's runner to the right (Figure 33b). But in its lowest position the arm's runner has moved sufficiently to the left to be close enough to make contact with the tooth.

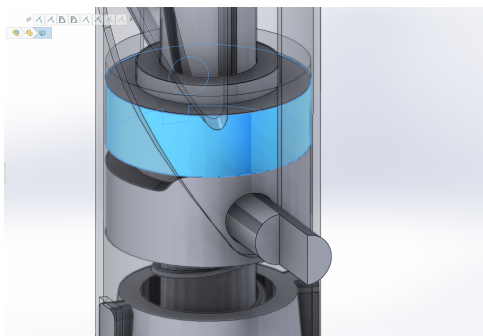
A widening at the bottom of the handle's slot allows the user to steer slightly to the left in the lowest position (Figure 33a), thereby guiding the arm to retract toward its hidden position (Figure 33d).



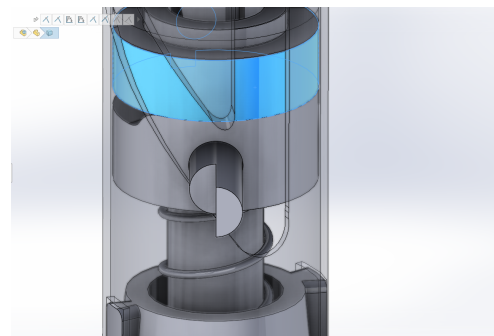
(a) At the lowest position the handle can push the arm clockwise to steer it in the desired path



(b) The handle follows the arm's movement upwards and can freely rotate anti-clockwise without affecting the arm



(c) At its lowest position the arm wants to move straight upwards but the clockwise push from the handle forces the arm up in the slot that leads to the retracted position



(d) When the arm is steered in the desired position the handle does no longer affect the rotation of the arm

Figure 33: Runner configuration

To attach both the arm and the handle to the runner, a locking pin (Figure 34) proved to be the most convenient solution during the prototyping phase. This method could later be replaced with another attachment method, if deemed unsuitable for mass production. Examples of other potential methods include shrink/press fits or a keyway and key.

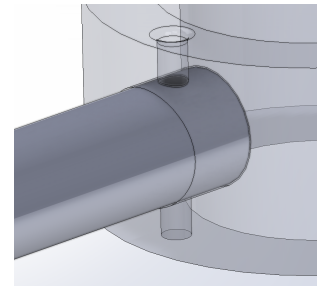
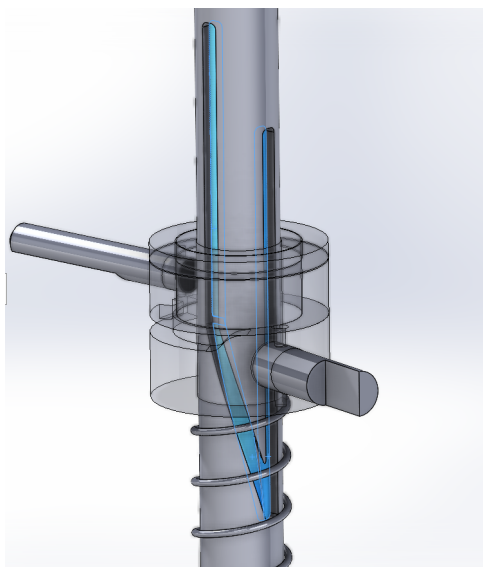
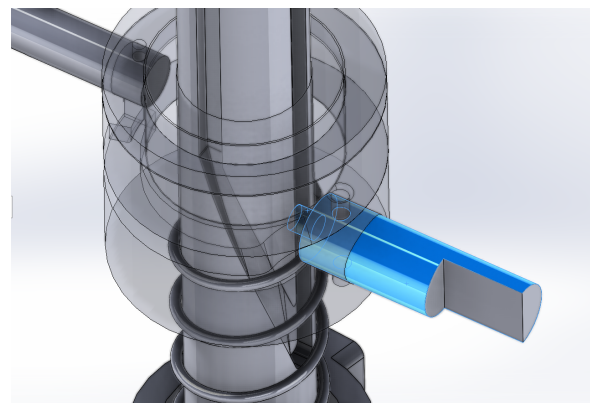


Figure 34: Locking pin



(a) Guide path on pillar



(b) Guide pin on the arm-spigot

Figure 35: The guiding groove on the pillar

7.2.4. *Guide Path and Structural Issues*

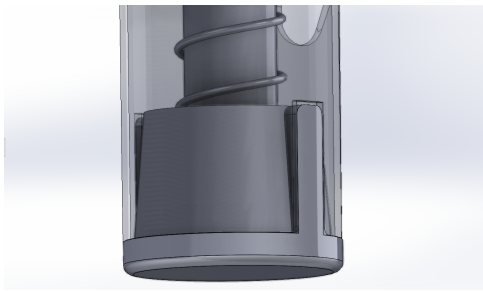
Using the shell as the sole guidance for the arm caused too much stress on the shell. During prototyping, the parts cracked in a way that indicated a high concentration of load in the shell wall. No detailed calculations were performed at this stage, the observed failure suggested that the same principle would be unsuitable even if the shell were manufactured from thin steel. To guide the arm without contacting the shell, an inner guide path (Figure 35) was added to the pillar.

A guiding pin (Figure 35b) was added to the inner end of the arm (later developed into an "arm spigot" to facilitate installation). This guiding pin runs along a groove that follows the same path as the slot in the shell. The pin determines the rotation and absorbs the loads that would otherwise be applied to the "peninsula" in the U-shaped slot.

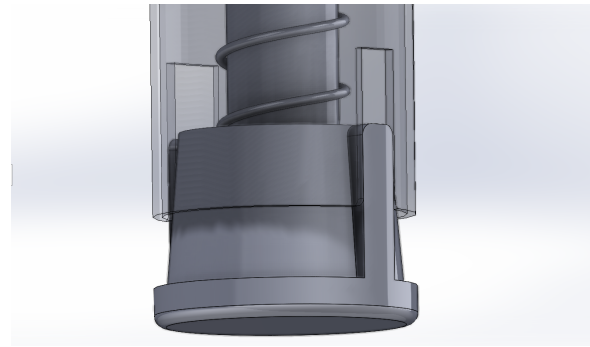
7.2.5. Installation and Orientation Challenges

Both the slots in the shell and in the pillar had to be aligned with each other, which created an alignment issue during installation. When only the outer shell needed to be oriented relative to the sofa, the user could simply adjust how tightly the leg was screwed into the sofa. A flexible washer and the slight compliance of the wood would allow some adjustment while tightening the leg. This means that the user could stop tightening when the shell was facing the correct direction, rather than depending on the thread ending in the exact right orientation.

This issue led to a series of over engineered solutions. The need to adjust the orientation of both the pillar and the shell simultaneously, while still maintaining ease of assembly, proved difficult to resolve efficiently. The pillar was made thinner to better accommodate a weaker spring, as initial tests showed that the original spring was too powerful. The foot and pillar were combined into a single component, and two rotational locking keys (Figure 36) of different sizes were introduced on either side of the foot. The slots in the shell were given corresponding sizes, ensuring that the pillar could only be inserted in the correct orientation.



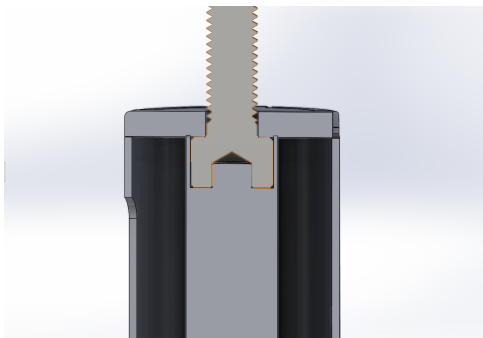
(a) A slot in the combined pillar and foot fitted in gaps in the shell but only in a specific orientation



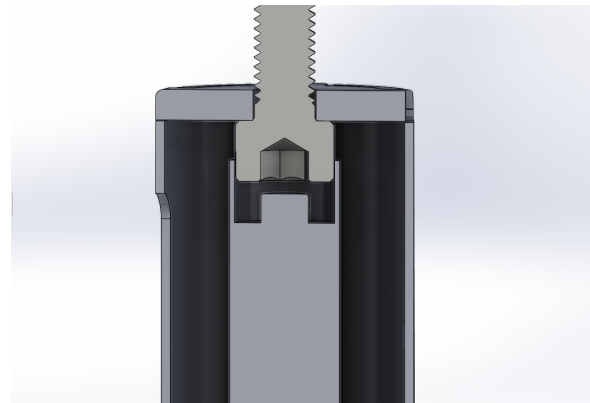
(b) The pillar could be detach slightly which lowered the top of the pillar away from the top cap

Figure 36: Orientation locked pillar

When the pillar was in its lowered position, it detached from the hex socket screw that runs through the top cap. The top of the pillar was shaped to match the corresponding hex key (Figure 37).



(a) The upper position locks the pillar to the screw



(b) In the lower position, the screw remained fixed in relation to the sofa thread, while the leg could rotate freely around it. This made it possible to adjust the orientation of the device after the screw had been tightened

Figure 37: Locking the screw

The solution worked, but not very well. User testing with a manual (Figure 38) describing the installation procedure showed that the installation was too complicated, and even with clear instructions, the results varied.

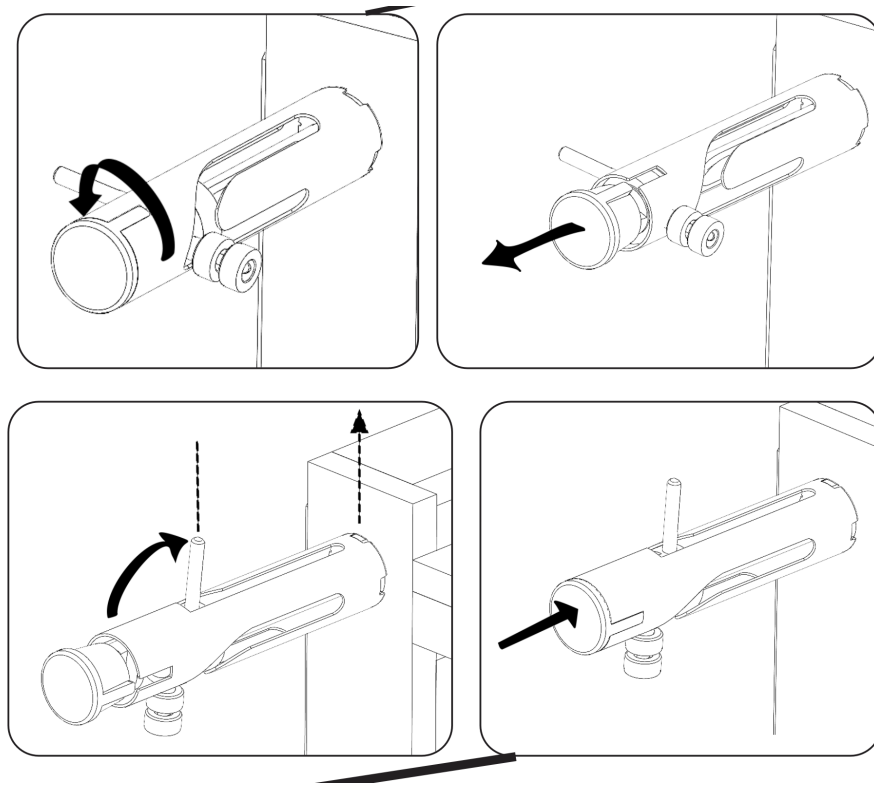


Figure 38: Parts of the user manual

7.2.6. *Simplified Hollow Pillar Design*

Moving forward, we decided to simplify the design by making the pillar hollow and allowing a longer screw to run through its entire length (Figure 39). The relatively long screw was needed because the screw head was too wide to fit within the thinner section of the pillar. The screw had to reach the wider base section, where there was sufficient space for the head and hex socket. An opening at the bottom of the pillar allows access to the hex socket and facilitates attachment while maintaining the correct orientation relative to the sofa. The opening is covered with an end cap made from a softer material, which also prevents the steel from scratching the floor (see Figure 41).

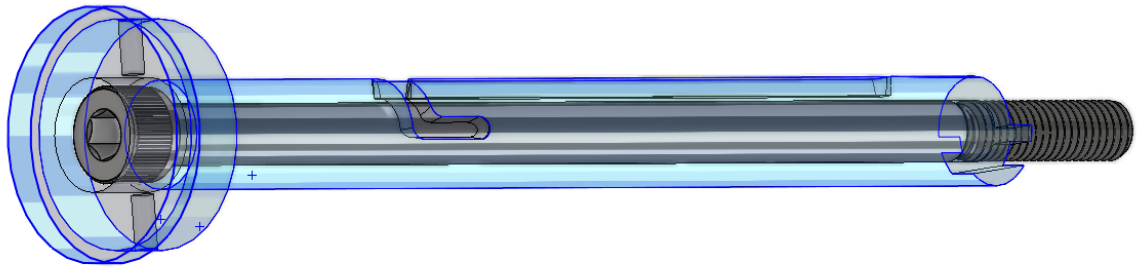


Figure 39: The hollow pillar with a long screw running through it

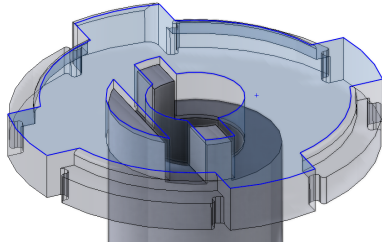


(a) The device can be oriented in the right position with the screw retracted

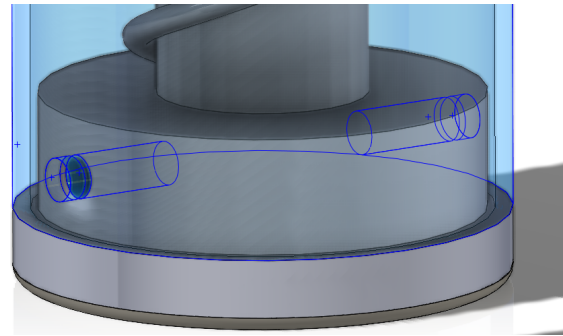
(b) When the screw is completely fastened and in its upper position the end cap can be attached

Figure 40: The hollow pillar allows the screw to be controlled from the opening under the lower end cap

At the top of the pillar, a pattern has been machined (Figure 41a) that only allows the correct orientation due to corresponding features in the top cap. During assembly, screws (Figure 41b) are used to lock the pillar to the shell, making installation straightforward for the end user. During mass production, the screws could alternatively be spot welded. While this would result in a smoother surface (provided some post processing such as grinding), it would prevent replacement of the spring or other repairs, thereby reducing the product's service life.



(a) The top cap locks the pillars orientation



(b) Screws hold the pillar in place after assembly

Figure 41: The hollow pillar allows the screw to be controlled from the opening under the lower end cap

7.2.7. *Final Mid-Fi Prototype Configuration*

The structural integrity of the shell was compromised due to the two slots cut into it. Additionally, two separate runners introduced too much friction, so a single runner operating through a simpler L-shaped slot was adopted that can be seen in Figure 42. The shell would still deform slightly in the lower position on the prototype, when under the load from the arm. To combat this, the guiding slot in the pillar was retained to allow the arm to move smoothly without interfering with the shell.

The KOPPLA socket with four outlets, a switch, and USB connectors applied significant torque to the mechanism due to its length and weight. Within the KOPPLA socket family, this was the largest and heaviest unit considered during the prototyping phase. If the mechanism could support this socket, it was assumed that it would also be suitable for smaller variants.



Figure 42: The L-slot with the solo-runner inside

The initial plan was to add a guide slot to the original BANKABY leg. However, this was not feasible within the project budget due to the cost estimate provided by the workshop. To simplify prototyping, a smaller KOPPLA socket with three outlets was used instead. This reduced the mechanical load on the prototype and made testing more appropriate for the 3D printed plastic components, which served as temporary substitutes for parts intended to be manufactured in steel. This limited the extent to which the prototype could verify performance under the highest expected loading condition. New clamps were developed to fit the new socket, and they are attached to the arm in a similar way to the previous design as seen in Figure 43.

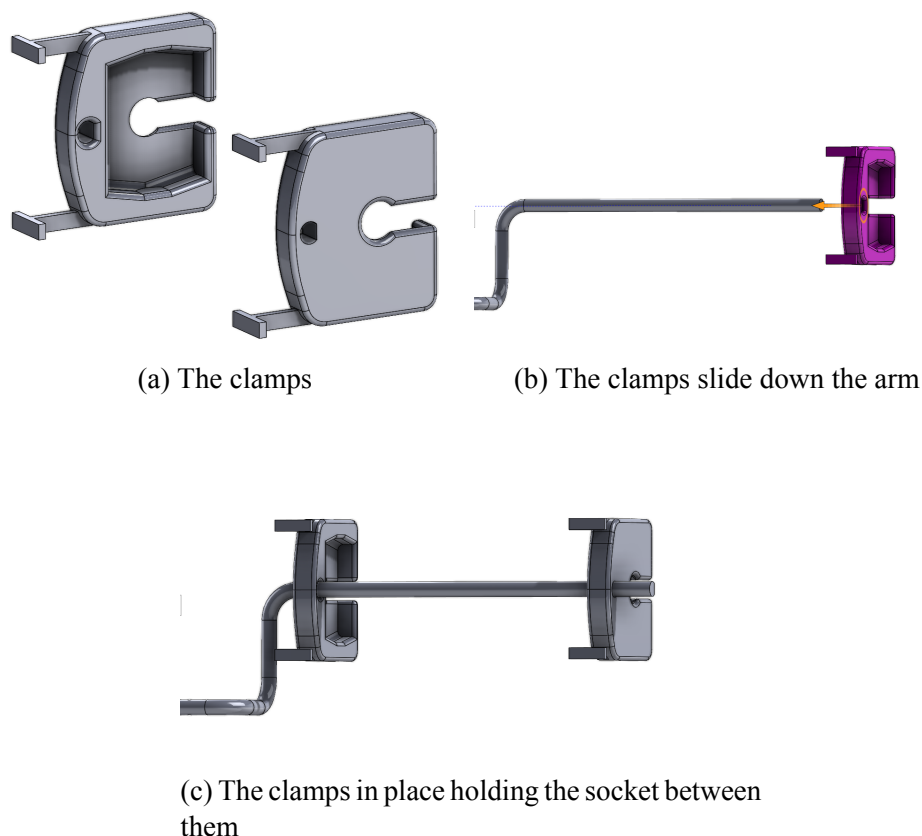


Figure 43: The Clamps for the smaller KOPPLA socket

The idea that the handle and arm could share the same slot led to the development of a combined handle collar. From the single slot in the shell, a spigot attaches to the now simplified runner. One half of the collar is positioned so that the spigot passes through it, after which the second half is attached and fastened with screws, enclosing the shell (Figure 44). A sleeve is then fitted over the spigot and secured with a locking pin. A second locking pin is added by the user after the leg has been attached to the sofa to secure the arm.

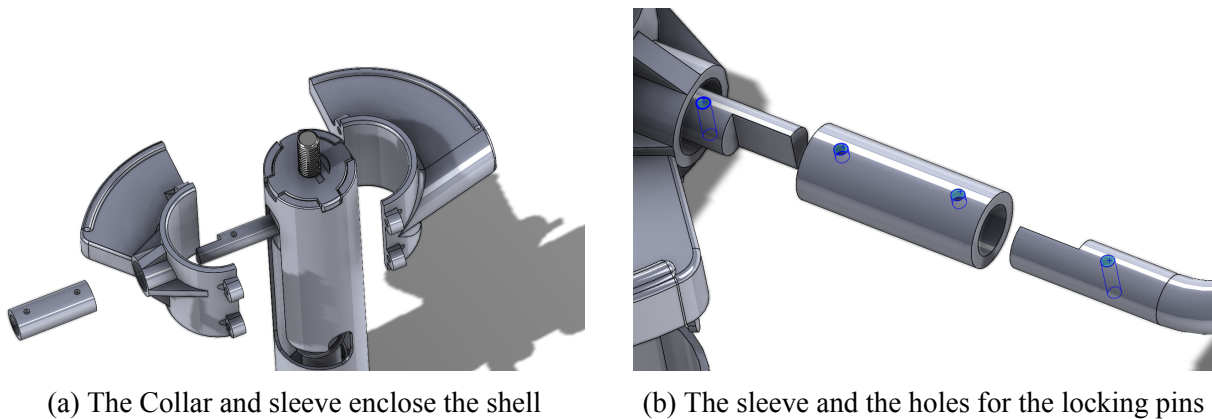


Figure 44: Installing the collar

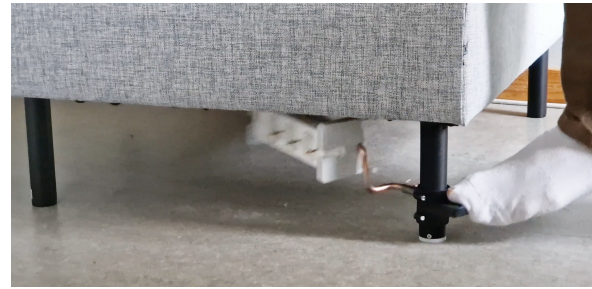


Figure 45: Collection of prototype iterations

7.2.8. *Final Prototype*



(a) Hidden position



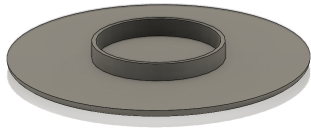
(b) Operating the device

Figure 46: Final prototype on sofa

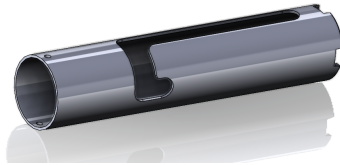


Figure 47: Revealed position

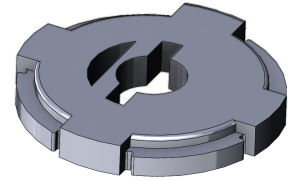
The iterative development carried out during the prototyping phase leads to the final prototype (see Figure 47). The prototype represents the outcome of the most successful design decisions throughout the process. It can also be regarded as a snapshot of the development at the point where the project timeline forced a transition from iteration to completion.



(a) End cap



(b) Shell



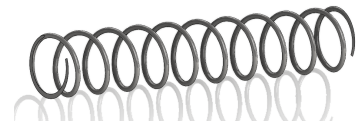
(c) Top cap



(d) Screw



(e) Pillar



(f) Spring



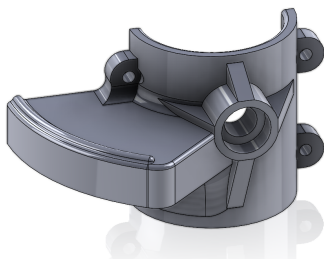
(g) Runner



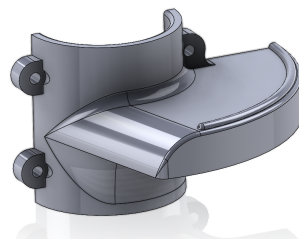
(h) Spigot



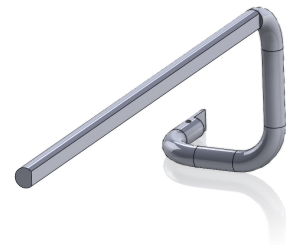
(i) Sleeve



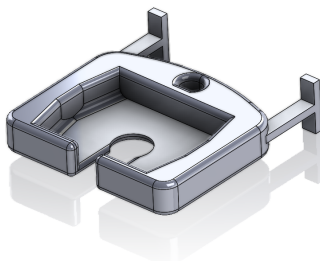
(j) Collar (arm side)



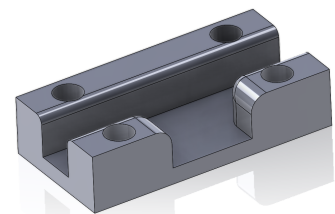
(k) Collar (handle side)



(l) Arm



(m) KOPPLA clamp



(n) Dock

Figure 48: Parts

7.3. System Level Design

System-level design is according to Ulrich and Eppinger the next step following the concept development phase. For the project brief and with the given design philosophy from IKEA, this part was introduced earlier. System level design starts defining the components and architecture of the product, as well as geometry and assembly plans. [3]

The Different parts of the final prototype as well as the assembled state are visible in Figure 49, with the different individual components and their reference name visible in Figure 48.



Figure 49: The parts

7.3.1. Material & Manufacturing Suggestions

The objective was to use as readily available production methods and materials as possible for the different components of the concept. These were derived from the teams own experience producing parts by for example milling and turning and should only be taken as suggestions for the current concept architecture. Following is a breakdown of the different components seen in Figure 48.

- The End cap is planned to be plastic, for example polypropylene (PP) or polyethylene (PE). The team suggests the part to be injection molded, the geometry lends itself well to the production method and with a simple mold, the potentially larger volumes would make up for the higher tooling cost. For smaller test runs it can be kept 3D printed.
- The Shell is thought to be largely the same shell as in the BANKABY leg from IKEA and the team suggests it stay that way apart from the slot being machined through 4-Axis milling. Laser cutting could be explored as a method, provided that the circular geometry of the shell would not pose a problem.
- The Top cap follows the same thinking as the previously mentioned shell. The method is kept the same apart from the orientation-slit. The team acknowledges that the current slit visible is not very manufacturable at scale but could easily be replaced by for example a third slit instead, making more of a plus-shape.
- The Screw is a standardized M8 partially threaded socket head screw with a 170mm length in the 3D model and a 180mm length in the prototype as that is what we had available. The CAD file in this case was retrieved from the McMaster-Carr product catalog and the team suggests this part to be ordered from an existing manufacturer.

- The Pillar is to be constructed of steel. The dimensional accuracy, surface finish, and possible hardening treatments are all things to be considered and an expert should be consulted to finalize the most suitable material and treatment for the pillar. The slot is once again thought to be created through milling. And the threaded holes in the bottom by drilling.

Worth noting is that this part could quite possibly be manufactured cheaper if it was split at the bottom and the wider part attached through a shrink fit. The longer part created through cold-drawing steel and later milled to final dimensions. The wider part either turned on a lathe from a massive cylinder or from a drawn one.

- The spring is another standard part, provided by Lesjöfors. For the prototype the "Tryckfjäder CSS 1.25X17.25X140" was used though further testing is needed to see exactly which is best suited. The design team made a diagram to aid in the selection process, visible in Figure 50.
- The Runner could be turned from a solid steel rod or from a cold-drawn hollow cylinder, followed by drilling for the holes.
- The Spigot was turned from a steel rod and later milled and drilled in the prototype stage. Since the diameter is standard, this should work for production as well.
- The Sleeve, created by drilling a roll formed metal tube and finishing the surface internally by hand, could be replaced by a standard sleeve coupling, given that the inner diameter is a standard measurement.

- The Collar, split between Figures 48j,48k and the handle were initially designed to be manufactured by injection molding, preferably with a two shot technique to add a higher friction layer to the top of the handle. The current iteration of the handle was 3D printed and admittedly is not that easily manufactured by injection molding. Some of the guidelines for injection molding include reducing undercuts and having one specified wall thickness. Which the current model has not been adapted to, due to time constraints from simply getting a working handle. A solution could be to use a core to support the handle shape of the collar and using the interfacing surface between the halves as the split line.
- The Arm was bent, in this case manually, from a steel rod and later milled and drilled. This we believe is one way to produce the final part.
- The KOPPLA clamp ideally would be injection molded as well, though it might have to be hollowed out from one end to avoid sink marks or similar defects.
- The Dock is the final piece of our ptototype and once again one that with some adjustments could be injection moulded in PP or PE.

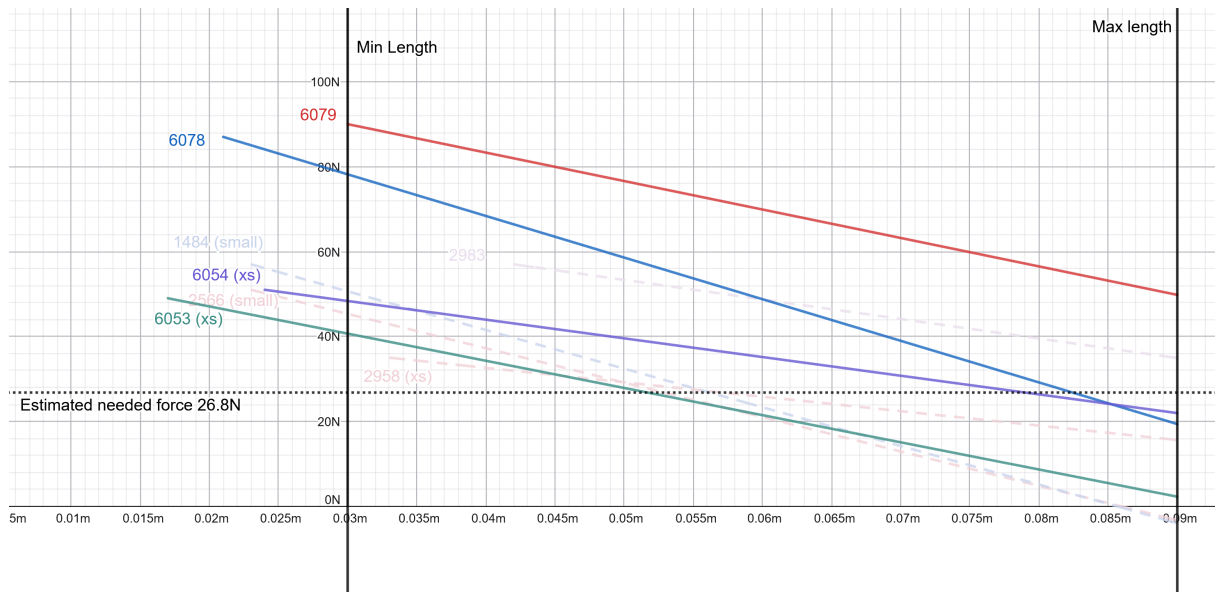


Figure 50: Diagram of springs

In addition to these parts, fasteners such as screws are readily available M2 and M3 variants and to fasten the outer KOPPLA clamp a shaft collar, o-ring or similar can be used.

7.3.2. Assembly

As with most IKEA products the assembly of the device can be divided into two phases, one that takes place at the manufacturer (see Figure 51) and one that takes place during installation by the end user (see Figure 52). During the design process a lot of effort was made to ensure that the device would be easy to install while also compact during transport. The arm and the KOPPLA clamps would increase the package dimensions during transport if they were attached when purchased. Another aspect is modularity. While the arm in the final prototype will be compatible with most relevant furniture, it would be possible to make other versions of the arm that would suit specific furniture better. Along with the KOPPLA clamps the arm could be replaced to accommodate another version of the KOPPLA socket. With that in mind, the design prioritizes a simpler way of attaching the arm and KOPPLA clamps while a more secure and somewhat more complex method of assembling the rest of the device was chosen.

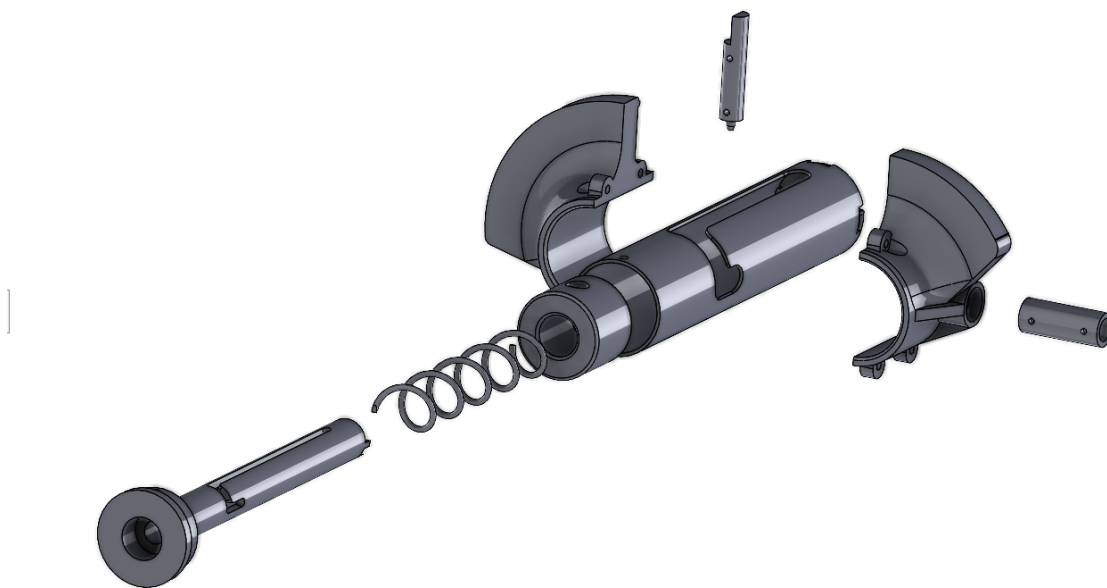


Figure 51: Parts assembled in factory

7.3.2.1. Factory assembly

First the top cap (Figure 48c) would be inserted and fastened into the shell (Figure 48b). During the prototyping phase, a different material and therefore a different attachment method was used for the top cap. The original BANKABY in metal, has the end corners folded around the top cap while that was not possible with the 3D printed PLA (Polylactic Acid) part, as bending would cause it to crack. A modified end cap that could be slid in from the top to simulate the part placement was used while prototyping. The orientation of the cap has to correspond to the slots in the shell but otherwise the assembly is similar to IKEA's original assembly process of the BANKABY leg.

The spring (Figure 48f) would first be threaded on the pillar (Figure 48e) first then the runner (Figure 48g) would be threaded on top of the spring. The pillar along with the spring and the runner would then be inserted into the shell. The orientation of the pillar has to align to the top cap, to fit in to the opening that corresponds to the top of the pillar. The top cap is in turn is aligned with the shell, ensuring that the pillar's guide groove and the shell's slot for the arm are aligned. The alignment makes sure that the holes for the screws in both the shell and pillar correspond, and screws are inserted through the shell and into the threaded holes of the pillar.

After inserting the spigot (Figure 48h) into the runner, the most demanding part of the assembly begins. Inserting a locking pin that locks the spigot in place through the slot in the shell requires precision during assembly. The tolerance must be tight as an overly wide slot for the locking pin would lead to too much play in the joint, causing the arm to wobble.

Meanwhile the force of the spring tends to push the runner to a position where the locking pin can't be inserted. During mass production this would be solved by either shrink fitting, welding or automating the insertion of a locking key.

With the spigot in place, the two collar parts (Figures 48k 48j) would be put around the shell so that the spigot goes through the hole in the half of the collar that's intended for the arm. These would be joined by 4 screws with nuts. Using a permanent attachment method, such as welding or blind riveting, would make it difficult or impossible to replace individual parts during repair. When the collar is in place the sleeve (Figure 48i) is inserted into the collar with the orientation of the holes for locking pins in mind.



Figure 52: Parts assembled at home by end user

During the prototyping phase a low tolerance and friction kept the sleeve securely in place. During mass production a similar method or a shrink fit would be suitable. Although not strictly part of the assembly, packaging considerations dictate that the screw is inserted into the pillar and the end cap is attached to the bottom. This is the most space efficient way for packaging it and if the product is close to its final configuration it provides the user with a clear reference for how it should look after installation.

7.3.2.2. Home assembly and installation

To make the device as versatile as possible, a right- and left-oriented versions of the leg could be sold. The parts dependent on the orientation are the pillar, the shell and the two collar pieces. In addition, the arm and clamps should be packaged separately so that the user can choose clamps according to the KOPPLA model and arm according to the sofa and the length of the KOPPLA.

The installation procedure would start by first removing the leg that the device intends to replace. Turning the furniture on its side, with the leg positioned horizontally and off the floor, is recommended. Unscrewing the leg by hand, revealing the threaded hole that will be used to attach the device is the next step.

After removing the end cap, a hex key (also known as an Allen key) is used to thread the screw inside the pillar into the hole where the original leg was attached. With one hand holding the device in the correct orientation so that the slot aligns with the corresponding features of the furniture, the other hand would use the hex key to tighten the screw. When the whole device has been attached so tightly that the device does not rotate the end cap can be re-attached.

Next, the user inserts the arm into the sleeve, it only fits in the correct orientation. When inserted a locking pin is inserted to secure the arm in the sleeve. A single KOPPLA clamp is then threaded onto the arm. The KOPPLA socket (sold separately) is then be fitted inside the clamp while the other clamp secures it in place. The cable is pointing away from the device to prevent the cable from bending to much. A rubber O-ring would then be threaded on the end of the arm preventing the clamps from sliding off.

The cable could be hung with small hooks along the horizontal springs under the furniture. Or cable clamps could be attached with small nails inside the sides of the furniture. The cable is routed to a part of the sofa where it can be connected to an outlet out of sight. The cable would need enough slack between the moving socket and the first attachment point to reach its lowest and highest positions.

7.4. Feasibility

The feasibility of the selected concept was assessed from economic, ethical, and environmental perspectives. As the project was limited to concept development and prototyping, several factors affecting feasibility could not be fully evaluated. Instead, the analysis focuses on whether any major obstacles were identified that would prevent further development of the concept.

7.4.1. Economic Feasibility

It is difficult to accurately assess production costs without insight into IKEA's internal material selection, manufacturing processes, and pricing strategies. The intention has therefore been to create a concept that is feasible to manufacture without excessive material waste, rather than to optimize cost in detail. The final economic viability would depend on factors outside the scope of this work, including exact material choices, production methods, and volume considerations. What can be said however is that the current solution would constitute a significantly more expensive leg than the current legs, driven by the increase in complexity, number of parts and material.

7.4.2. Ethical Feasibility

Similar to the economic feasibility analysis, many of the key factors of analyzing the ethical feasibility of this concept, such as material sourcing, supply chains, and production conditions, depend on decisions made later in the product development process and are outside the scope of this work. However, no aspects of the current concept indicate any inherent ethical concerns.

7.4.2.1. Democratic Design Alignment

The development of the device was guided by principles aligned with IKEA's Democratic Design, with particular emphasis on function, sustainability, quality, and low prices. A primary design objective was to simplify installation for the end user, reducing the number of assembly steps and minimizing the need for precise alignment.

The design is based on the standard M8 fastening interface used across IKEA furniture, allowing the device to replace a sofa leg while also enabling compatibility with a wider range of products such as beds, stools, and other furniture. By building on an existing and widely used interface, the solution supports both accessibility and low price, as it avoids the need for proprietary components while increasing the potential applicability of the product.

Sustainability considerations influenced concept selection early in the development process. The design prioritizes mechanically simple and material efficient solutions that align with IKEA's ambition toward more sustainable products.

The collar was designed to support multiple modes of interaction, allowing operation using either hands or feet. This contributes to functional accessibility and reflects an inclusive approach to user interaction. At the same time, safety considerations were integrated into the design to reduce risks such as pinching or unintended movements.

In line with circular design principles, the product was developed with modularity and repairability in mind. Components can be reconfigured for different orientations and replaced individually in case of failure or wear. This approach extends the product's service life and enables adaptation to different use contexts, supporting IKEA's ambition to design for longevity, reuse, and resource efficiency.

7.4.2.2. *Environmental Assessment*

The environmental aspects of the design were considered on a general level throughout the project, although no detailed life cycle assessment was carried out. The focus was instead on making design choices that allow for more sustainable solutions rather than defining them in detail.

One of the main considerations was to keep material use as low as possible. Simplifications of the mechanism, such as reducing the number of components and avoiding unnecessary complexity, were partly driven by cost but also contribute to reducing overall material consumption.

Material choices were not defined in detail, as these are typically determined later in the product development process. Certain concepts were deliberately avoided. Early ideas involving magnetic components were discarded due to concerns related to material sourcing and environmental impact. The design relies on conventional mechanical solutions that are more compatible with established manufacturing and recycling processes.

Focus was placed on product lifetime. The design allows for disassembly in several steps, making it possible to replace individual components such as springs or external parts without discarding the entire product. Some parts are also designed to be reconfigurable, for example to allow different arm suited for different furniture, which may extend the useful life of the product.

It should be noted that the final environmental performance of the product would depend heavily on material selection, manufacturing methods, and supply chain considerations, which were outside the scope of this project. The intention has therefore been to develop a concept that is compatible with more sustainable

7.5. Usability Tests

The usability tests were split into assembly and attaching of the product and then later the use of the product. The structure of these tests were based on the thinking aloud method, during which the participant narrates every action and thought they get. This was followed by some short questions about how they perceived the test process.[28]

7.5.1. Product Installation Tests

The installation tests were carried out on the smaller stool and not the full sized sofa. The test subjects were given a set of written instructions for each step with the labeled parts that were required for said step. The main takeaways from the tests conducted were;

- Understanding the correct orientation when screwing the prototype was not always clear.
- Attaching the arm was difficult, when done after screwing the leg.
- Having to operate the mechanism whilst assembling was scary.
- The arm and KOPPLA attachments were intuitive.
- A lot of thread and a long screw meant screwing for a long time where the test subject might drop the hex key or get worried they had the incorrect orientation.

7.5.2. Product Operation Tests

Due to the time for the project running out there were no structured product use tests done on the final prototype. They were planned to be carried out in the same manner as the installation tests with written instructions on how to operate the mechanism, user narrated and with short test specific questions at the end.

7.6. Updated Specifications

Based on the selected spring-loaded leg concept, several specifications were refined. The updated specifications, including compatibility and key design constraints, are summarized in Table 11.

Table 11: Updated specifications based on selected concept

Metric	Unit	Marginal Value	Ideal Value	Final Concept
Possible to retrofit	bin.	Pass	-	Replaces existing leg using M8 interface
Chargers are unaffected	bin.	Pass	-	Minor interference may occur
ISO compliant	bin.	Pass	-	Risk analysis done, rest unable to verify
Symmetrically mountable	bin.	Pass	-	Implemented as left/right variants
Accessible while seated	bin.	Pass	-	Easily reachable after deployment
Compatible with IKEA KOPPLA power strip	bin.	Pass	-	Uses interchangeable clamps
Furniture comfort is unaffected	bin.	Pass	-	No major impact observed
Compatible with popular models	bin.	Pass	-	6 models supported, 2 with limitations, 1 not compatible
Volume required for connectors - per socket	mm	85x 85x 125mm	-	Smaller koppla used compared to initial concept
Passes IKEA test lab	bin.	Pass	-	Outside project scope
No impact on structural integrity	bin.	Pass	-	Possible weakness, not verified
Headroom under sofa	mm	100mm	160mm	Fits within reference geometry
Low design impact	subj.	Pass	-	Mostly hidden beneath sofa
Successful user test time	s	30s	10s	No formal user tests conducted
Smooth operation	subj.	Pass	-	Guided motion with locking
Supportable weight of connectors	g	300g/socket	500g/socket	Depends on spring
Instructions needed for product	pages	15	10	Basic instructions needed
Time taken to install product	min	10 min	5 min	Needs more user testing
Tools needed to install product	n	3	1	Hex key, screwdriver required
Supported Force - remove connector	N	54	110	Docking not tested to these levels

8. Results

The outcome of this project is a developed concept supported by a functional prototype (seen in 7.2.8), a complete 3D-CAD model (described in 7.3 and seen in Figure 53). The results are based on the concept development, prototyping, and validation activities presented in Chapter 7. The following section presents the final concept.

8.1. Final Concept

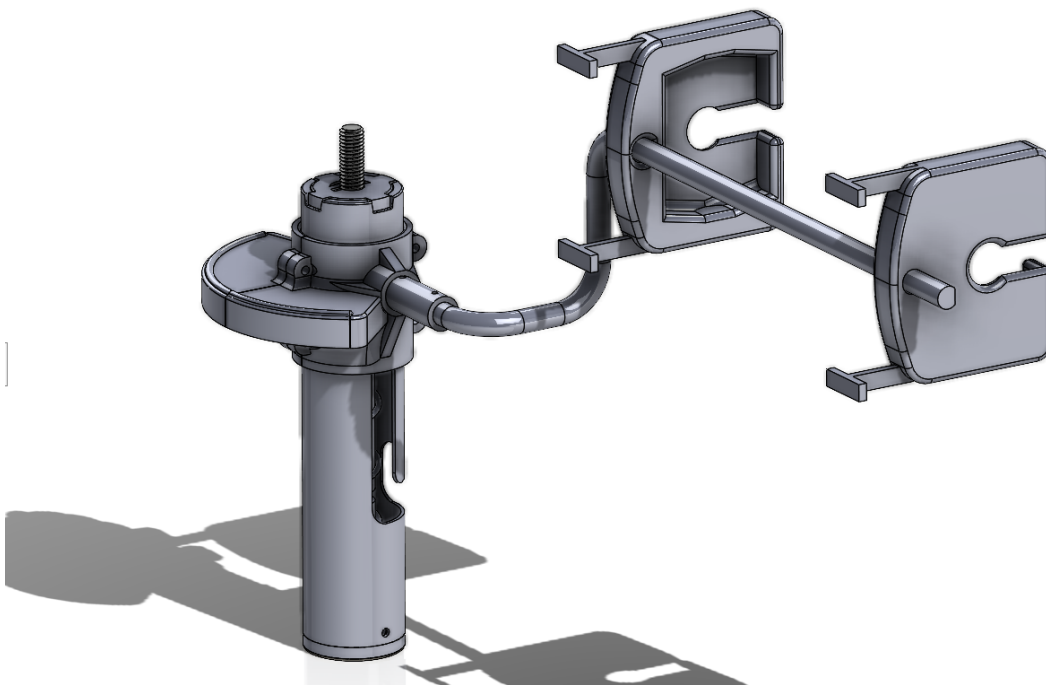


Figure 53: CAD model of the final Concept

The final concept is a spring-loaded leg mechanism that replaces an existing sofa leg and integrates a concealed power distribution solution. By utilizing the standard M8 interface, the device can be mounted directly without requiring internal modification of the furniture.

The concept enables a power outlet to transition between a hidden and an accessible position beneath the sofa. In the hidden position, the socket is concealed behind the vertical structure of the sofa, minimizing visual impact and avoiding interference with robotic vacuum cleaners. When activated, the mechanism moves the socket outward and rotates it into an accessible position, allowing the user to connect devices while seated.

The motion is achieved through a combination of vertical translation and rotation, actuated by a combined handle/pedal. The mechanism locks in the accessible position and returns to the hidden state through a spring-assisted reverse motion. This provides a controlled and intuitive interaction without requiring continuous user input.

To accommodate variations in furniture geometry, the concept is implemented in left- and right-oriented variants. The arm connecting the socket to the mechanism is designed to be replaceable, enabling adaptation to different distances between the leg mounting point and the outer edge of the sofa. The socket itself is attached using interchangeable clamps, allowing compatibility with different KOPPLA configurations.

The design maintains the primary structural function of the original leg while integrating the additional functionality. At the same time, components can be disassembled and replaced, supporting maintenance and potential extension of product lifetime.

9. Discussion

The final prototype should be understood as a proof of concept rather than a production-ready solution. The purpose of the project was to explore how power access could be integrated into a sofa in a way that is discreet, retro-fittable, compatible with robotic vacuum cleaners, and accessible to the user when seated. In relation to this purpose, the prototype demonstrates a promising direction. It shows that there is an unused and visually hidden area underneath the sofa that can be utilized without significantly affecting the overall appearance of the furniture. It also shows that the existing M8 leg interface offers a highly useful and almost standardized attachment point for further functions beyond the basic purpose of supporting the sofa.

By replacing an existing leg rather than adding an external product to the sofa, the concept is able to use an already accepted interface while preserving the visual expression of the furniture. This supports the idea that the solution is a reasonable product direction.

Several important compromises were made during the development of the final concept. One of the most important was the decision to only have one open slot in the outer shell. This made it possible for the guide pin to move through the required path. The collar became another important compromise, as it distributes forces, functions as both handle and pedal, and helps protect the user from getting caught in the open slots. However, this also made the collar a complex component with several simultaneous roles, which later sections discuss in relation to ergonomics and manufacturability.

At the current stage of the project, formal functional tests have not yet been completed. This limits the extent to which the prototype can be evaluated against all final specifications. The prototype has demonstrated the basic movement principle, the spatial fit underneath the sofa, and the potential of using the M8 interface, but it has not yet verified long-term durability, repeated use, strength under realistic loads, wear in the guide groove, spring performance, or the forces involved when plugging cables in and out.

Aspects such as ISO compliance, structural integrity, long-term smooth operation, supported plug-in forces, installation time, and formal user testing could not be fully verified within the project scope and time. This means that the results should be interpreted as evidence of concept feasibility rather than complete product validation.

The limitations of the method, prototype, and testing process also affect the reliability of the results. Several components were developed quickly in order to create a functional prototype, which means that some design decisions were based on approximate dimensions, 3D printed parts, and practical adjustments rather than final material properties or optimized manufacturing methods. As a result, conclusions regarding friction, wear, strength, and usability should be treated with caution. The prototype is valuable because it reveals important design opportunities and problems, but it cannot fully predict how the solution would perform as a finished product.

9.1. Planning and Theory

A concept can be refined indefinitely and to meet all deliverables, certain deadlines had to be imposed. This results in that we have a functioning prototype but there are many details that have potential for improvement. The road from a concept to a manufactured product is long and there are many steps towards a finished product that were never feasible to include. As mentioned in the methods sections, the Ulrich and Eppinger concept development process was used as a base. The actual process taken in the project did differ and it is illustrated in Figure 54. Since the problem had been established beforehand, identifying customer needs became less defined and the team used external research to complement their knowledge. Planning the downstream development was not part of the project and instead it ended with the updated specifications and a final concept suggestion.

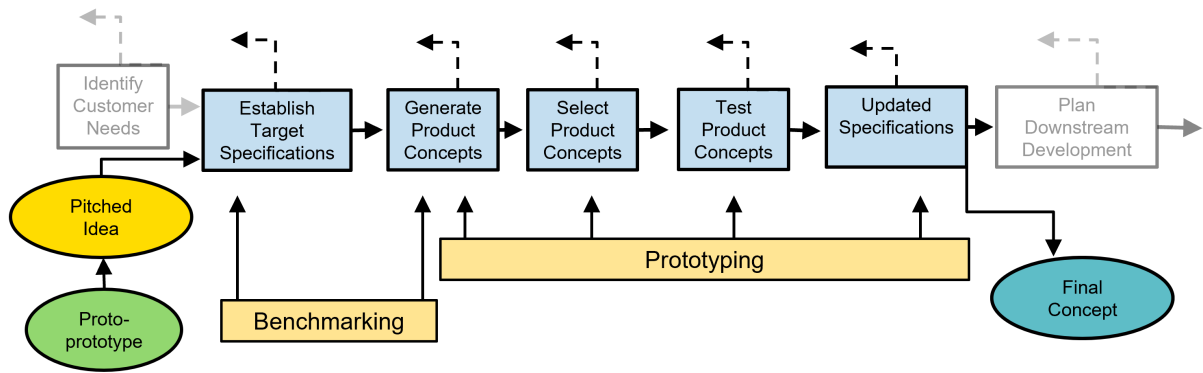


Figure 54: Adapted process

More time was spent exploring the solution space since we felt that there were no existing solutions that properly addressed the goals laid out for the project. What really took longer than anticipated was the mid-fi prototype stage. The number of iterations and changes made to get to a functional prototype were many and thus the original time plan for the project had to be revised. The updated GANTT of the actual time taken for each step is shown in Appendix C.

9.2. Further Development Suggestions

While the developed concept and prototype demonstrated the feasibility of the proposed solution, several areas were identified that would benefit from further development. The following sections summarize recommendations related to user research, functional and ergonomic refinement, manufacturability, simulation, and modularity. These suggestions are based on observations made during concept development, prototyping, and testing.

9.2.1. User Research

Due to time constraints, the user testing of the final prototype was quite limited as well. Installation tests were conducted but We suggest further evaluation of the ergonomics of how people will operate the product. Will people lie down in a sofa looking at their phone? How well does it adapt to different living room situations? Do people prefer operating it with their foot or with their hand? Do people stand up and use it? Will people prefer it to extend to the front of the sofa instead of the side? Are the current affordances enough for basic users or do you have to know about it?

9.2.2. Parts refining

The following sections focus on individual components of the prototype that were identified as candidates for further refinement. These parts fulfilled their intended function in the prototype but were not fully optimized due to project scope and time constraints. The refinements discussed concern component level improvements related to functionality, ergonomics, and manufacturability.

9.2.2.1. *Functional refinements*

Several functional refinements could be explored in future development of the prototype. One important area concerns the support and locking mechanism when plugging cables in and out of the power outlet. In the current prototype, the mechanism can be moved into its outer, revealed position, but the support in this position has not been fully developed. Further work is needed to determine whether the mechanism should lock rigidly in the revealed position, or whether it should instead remain movable to avoid giving the user a false impression of structural support. If a locking function is included, it should be dimensioned and designed to withstand the forces created when users insert or remove plugs from the outlet.

Another functional refinement concerns cable handling between the power outlet and the portable device being charged. While the current prototype focuses on managing the main power supply cable, thin charging cables, such as USB cables, may still create visual clutter or interfere with cleaning if left hanging or lying on the floor. A future solution could therefore include a USB cable holder or guiding feature that keeps these smaller cables organized when in use. A self-retracting cable solution could also be explored, allowing the cable to disappear when not needed. This would further support the goal of keeping the area around and underneath the sofa free from loose cables.

The clamps designed for the KOPPLA power outlet also require further refinement. Due to time limitations, the clamps for the newer and smaller KOPPLA unit were not designed from an accurate CAD model, but were instead based on approximate measurements. As a result, the current fit is not fully optimized. Future development should use exact product geometry to improve the fit, stability, and repeatability of the clamp design. The clamps also lack an integrated feature that prevents them from sliding off the pin. During the prototype phase, a small rubber piece was used as a temporary solution, functioning similarly to an O-ring. A standard O-ring could be the simplest solution, but this should be evaluated further together with other alternatives. The final solution should prevent unwanted movement while still allowing easy assembly and disassembly.

The strength of the spring should also be further evaluated. The spring needs to be strong enough to support the intended movement and return behavior, while not making the mechanism difficult or uncomfortable to operate. Testing different spring strengths could help identify a better balance between mechanical performance and ease of use.

The docking mechanism, currently based on a thin bent metal pin, should also be evaluated further. In the present prototype, the docking points are drilled in place and their placement needs to be relatively exact. The need for a docking function remains, but the exact shape, tolerance, and installation method could be refined. A more robust and repeatable docking solution could improve both assembly and long-term reliability.

Additional small components could also improve the mechanical function of the prototype. A washer should be added between the screw and the bottom of the pillar to distribute load and reduce wear. Furthermore, a plastic sleeve bearing made from POM(polyoxymethylene) or a similar engineering plastic could be added between the runner and the pillar. This could reduce friction and remove the current metal-on-metal contact. Due to the time required to produce a functional prototype, this solution was not tested, but it should be included in future prototypes to evaluate whether it improves overall mechanical performance.

9.2.2.2. Existing Ergonomical refinements

Several ergonomic refinements could be explored in future development of the prototype. The combined handle and pedal was developed late in the prototyping phase and was primarily designed to guide the user's foot so that the mechanism reaches its outer, revealed position. Less attention was given to supporting the reverse movement, where the mechanism is returned to its hidden position underneath the sofa. Future iterations should therefore investigate how the handle and pedal can better guide both directions of use, making the interaction more intuitive and physically effortless. The current position of the handle and pedal is also very close to the underside of the sofa. This was a deliberate trade-off between visibility and ergonomics. Placing the interaction point higher and further out of sight helps preserve the visual impression of the sofa, but it may also make the mechanism harder to access and operate. Further refinement might be needed to find a better balance between keeping the solution discreet and ensuring that the user can comfortably reach and activate the mechanism.

During the early prototyping phase, the ambition was for the handle to move only vertically, while the arm of the mechanism would perform a combined vertical movement and horizontal rotation. This approach was later abandoned because it created too much friction between the moving parts. The principle could be worth revisiting in future development, especially if the moving interfaces, tolerances, materials, or guiding surfaces are improved. A more controlled movement path could potentially make the interaction clearer and more ergonomic for the user.

Another area for improvement concerns the ergonomics of the installation process. The docking mechanism is functionally necessary but the current solution requires relatively precise handling during assembly. Future development should therefore consider how the installer can be better guided when positioning and securing the arm. This could reduce the need for finger dexterity and make the installation process more intuitive and forgiving.

As mentioned in 9.2.2.1, the locking behavior of the mechanism in the revealed position requires further evaluation. Not only from a functional or mechanical viewpoint but also from a cognitive ergonomic perspective. If the mechanism locks in the outer position, users may incorrectly assume that it can withstand the force of pushing plugs into the power outlet without additional support. This might be able to solve not only with a pure technical solution but with clearer signifiers and physical constraints that keeps the user from applying too much force.

As a result, the lock may create a false sense of stability if installed incorrectly. From a cognitive ergonomics perspective, this is important because the product's behavior may suggest a capability that the mechanism does not yet provide. Future development should therefore either improve the locking and support function so that it can safely handle the expected user forces, or remove the locking function to avoid misleading the user.

9.2.2.3. *Manufacturability refinements*

Several manufacturability refinements could be explored in future development of the prototype. One important area concerns the pillar. In the current design, the pillar has a relatively thin cross-section along most of its height, while the base is significantly thicker. If the part were to be manufactured by turning, this geometry would require a large amount of material to be removed from the original workpiece. More than half of the stock material would likely need to be machined away to achieve the final shape, making the part inefficient to manufacture in its current form.

A possible improvement would be to divide the pillar into two separate components. One part for the thinner upper section and one part for the thicker base. This could reduce material waste and simplify manufacturing. If the pillar is divided into multiple parts, their rotational orientation in relation to each other becomes important. The design would need a reliable way to control this orientation during assembly.

The top of the pillar also includes a geometric pattern intended to lock the rotational orientation between the pillar and the top cap. This feature was designed to be milled from the hollow circular cross-section of the pillar. The corresponding pattern in the top cap could be difficult to manufacture depending on the chosen production method for the cap. This interface should therefore be reviewed and simplified. A more manufacturing-friendly solution could reduce complexity.

The combined handle and pedal, also referred to as the collar, should also be refined from a manufacturability perspective. Earlier in the project, the collar was primarily designed as a functional component intended to be cast and welded. Later in the development process, it also became the main interaction point for the user, functioning as both a handle and a pedal. As a result, an ergonomic shape was added on top of an existing functional geometry rather than being developed together with the manufacturing method from the beginning. This led to a design that is neither fully optimized for ergonomics nor for manufacturability.

Future development should therefore reconsider the collar as an integrated component where function, ergonomics, and manufacturing are developed together. The shape should be simplified to better suit the intended production method, while still supporting comfortable use by both hand and foot.

9.2.3. Simulations and Lab Testing

The spring force should be tested over repeated use to evaluate whether it loses strength over time. If the spring weakens, the mechanism may no longer return or move as intended, which could affect both usability and reliability. Different spring strengths should also be compared to find a balance between smooth operation, sufficient return force, and comfortable user interaction.

In the 3D printed prototypes, the areas of the guide groove where the direction changes showed signs of wear relatively quickly. This raises questions about whether the contact between the guide groove and the pin could deteriorate over time, especially when produced in the intended final materials. The friction that helps maintain the orientation of the mechanism during use should also be evaluated, as well as how tightly the leg can be fastened without negatively affecting movement.

The strength and stiffness of the handle should also be investigated. Since the handle also functions as a pedal, it may be exposed to forces from both hands and feet. Testing is therefore needed to determine how sturdy the handle needs to be, both to withstand expected use and to communicate a sense of reliability to the user. If the handle feels weak or flexible, it may reduce the perceived quality of the product even if the part is structurally safe.

Since the pillar replaces one of the sofa legs, it should have at least the same structural strength and stability as the original leg. Looking at the cross-section of the concept, vertical forces are unlikely to be problematic from an area perspective. However, stress concentrations may occur in the radii and transition areas, especially where the geometry changes. These areas should be evaluated using simulation software and finite element analysis.

Uneven loading conditions should also be tested. A sofa leg is not only exposed to vertical loads, but may also experience rocking, side loads, and uneven forces when users sit down, move, or shift weight on the sofa. These conditions should preferably be evaluated physically using a prototype made from the recommended materials, alternatively using simulation software. If the solid mechanics prove insufficient, parts of the design may need to be resized or reinforced. If testing shows that the pillar is stronger than necessary, material could potentially be saved by reducing dimensions or simplifying the geometry.

Further simulations could also be used to evaluate whether the outer shell could function as the guiding element instead of relying on the current internal guide structure. If possible, this could simplify the inner pillar and reduce the complexity of the mechanism. Such a change could improve manufacturability, reduce the number of critical internal features, and potentially lower friction between moving parts.

The reason as to why these simulations have not been conducted during this project were firstly that the project scope was defined as a concept development that ends with touching on system level design. Detailed structural validation falls under the subsequent "Detail Design" part of Ulrich & Eppingers product development process. Secondly, conducting FEM analysis on geometry that is still subject to change runs the risk of optimizing for a solution that might change in the future. With such short time on our hands, the given starting point, scope and how close to the deadline the final prototype / concept was completed, the team instead prioritized functional validation of the mechanism above starting simulations.[3]

9.2.4. Modularity

The core mechanism that the design team landed on is modular so far as it can be adapted to different legs. When it comes to the left-right orientation. Two different orientations of the product would have to be offered. With this change, the increase of modularity becomes both front-side for left and right orientations.

When it comes do different sofas, the modularity becomes more of a question of the sofa frames and construction. We the team suggest that either one arm be created for each of the sofas of interest. Alternatively, that the product be designed so that it rotates to the front, were the armrests could be disregarded. It could also be explored if the solution is compatible with bed frames

As seen in the report, different KOPPLA power strips were tested during different phases and both could be adapted to fit the design.

10. Conclusion

The development of the cable management solution for seating resulted in a product concept which meets most of the given goals of the project. Since the conception of the project was a pitch for a novel product imagined by the design team this can be seen as a success. The device clears up the space underneath the sofa, provides electricity and does not meaningfully impact the aesthetics (see Figure 55). It is retro-fit friendly though the modularity can be explored further. The deliverables were met, with a functional prototype and suggestions for materials and further development. More user testing would have been preferable with the final prototype but there simply was not enough time left after the build stage. As time was the greatest limiting factor, meaning every detail could not be fully explored, this project should be seen more as a source of inspiration and food for thought for the further development of quality of life add-ons for sofas and beds. The contribution to the design space has thus been the exploration of the possibilities and limitations that arise when attempting to integrate a charging solution onto an existing piece of furniture and how the concept development framework from Ulrich & Eppinger can be applied to such a project.

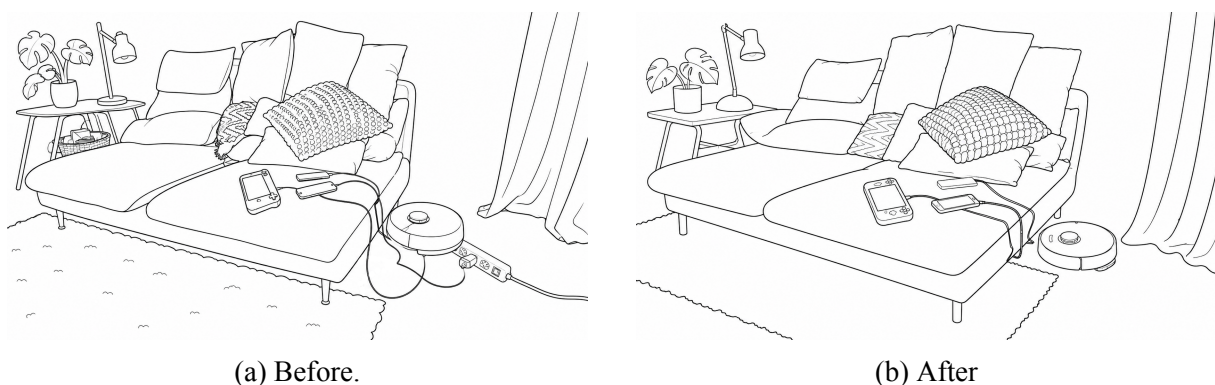


Figure 55: A scenario before and after the concept has been applied

References

- [1] Inter IKEA Systems B V . The birth of IKEA - Filling a gap.; 2026. Accessed: 2026-02-12. Available from: <https://ikeamuseum.com/en/explore/the-story-of-ikea/the-birth-of-ikea/>.
- [2] Ingvar Kamprad. The testament of a furniture dealer; 1976. 1976-2022.
- [3] Ulrich KT, Eppinger SD. Product Design and Development. Sixth ed. Penn Plaza, New York, NY 10121: McGraw-Hill Education; 2016.
- [4] Inter IKEA Systems B V . Democratic Design; 2020. Second edition produced for the IKEA Museum. Includes the Democratic Design Manifesto on page 13.
- [5] Inter IKEA Systems B V . IKEA Circular Product Design Guide; 2024. Version 2024. Internal document.
- [6] Norman D. The Design of Everyday Things. Revised and expanded ed. 250 West 57th Street, 15th Floor, New York, New York 10107.: Basic Books; 2013.
- [7] European Union. Regulation (EU) 2023/988 of the European Parliament and of the Council of 10 May 2023 on general product safety; 2023. OJ L 135, 23.5.2023, pp. 1–51. Official Journal of the European Union, L 135. Available from: <https://eur-lex.europa.eu/eli/reg/2023/988/oj/eng>.

- [8] International Organization for Standardization. SS-EN ISO 12100:2010 Safety of machinery – General principles for design – Risk assessment and risk reduction; 2010. Swedish adoption of EN ISO 12100:2010. Swedish Institute for Standards (SIS). Available from: <https://www.sis.se/en/produkter/standardization/vocabularies/environment-health-protection-safety-/sseniso1210020102/>.
- [9] Tavcar J. Eng Design 1.1: Risk Assessment v4.0 B. Lund, Sweden; 2024. [PowerPoint presentation].
- [10] European Commission. Risk assessment for Safety Gate;. Accessed: 2026-05-19. Available from: <https://ec.europa.eu/saga/#/screen/home>.
- [11] European Patent Office. Cooperative Patent Classification (CPC);. Accessed: 2026-06-04. Available from: <https://www.epo.org/en/searching-for-patents/helpful-resources/first-time-here/classification/cpc>.
- [12] ; Electronic furniture systems with integrated internal speakers. US10212519B2; 2019.
- [13] ; POWER OUTLET EXTENSION SYSTEMS AND METHODS. US2014148049A1; 2014.
- [14] ; VERTICAL FOLDING ELECTRIC OUTLET SYSTEM BURIED IN FURNITURE. WO2021230527A1; 2021.
- [15] ; Furniture with hidden charging function. CN112869437A; 2021.

- [16] felixna. IKEA KOPPLA Power Strip clamping bracket with screws to the top; 2023. Accessed: 2026-02-05. Available from: <https://cults3d.com/en/3d-model/tool/ikea-koppla-power-strip-clamping-bracket-with-screws-to-the-top>.
- [17] @De_Raffi_244955. IKEA KOPPLA Power strip holder (Switzerland and Lichtenstein) (Schweiz und Lichtenstein); 2023. Accessed: 2026-02-05. Available from: <https://www.printables.com/model/663902-ikea-koppla-power-strip-holder-switzerland-and-lic>.
- [18] Clas Ohlson. Väggfäste för grenuttag;. Accessed: 2026-02-05. Available from: <https://www.clasohlson.com/se/Vaggfaste-for-grenutt-ag/p/36-3293?msocid=08834574161262c215df539c174563a2>.
- [19] Brennenstuhl. Brennenstuhl Estilo laddningsstation med textilyta (möbeluttag med 1x eurouttag och 2x USB-laddare) svart/antracit;. Accessed: 2026-02-05. Available from: <https://amzn.eu/d/0588Vicv>.
- [20] Brennenstuhl. Brennenstuhl Estilo soffuttag med USB-laddningsfunktion (grenuttag med 1x eurouttag och 2x USB-laddare, uttagslist med hållskenor) antracitgrått/grått;. Accessed: 2026-02-05. Available from: <https://amzn.eu/d/08D5ozgB>.
- [21] Sixol. Bordsuttag med USB C 20W, 4-vägs grenuttag skrivbord individuellt omkopplingsbart med 4 USB C och 2 USB A, multipeluttag med strömbrytare, överspänningsskydd med 2M kabel för hemmakontor (svart);. Accessed: 2026-02-05. Available from: <https://amzn.eu/d/08JE5P56>.
- [22] IKEA of Sweden AB. KOPPLA Socket Product Drawing;. Internal product drawing provided within the thesis project.

- [23] SIGNUM: Holder for KOPPLA socket w USB port; 2013. Assembly instruction, Design and Quality IKEA of Sweden.
- [24] This Is Service Design Doing. Bodystorming A physical ideation method, sometimes called “brainstorming for the body.”;. Accessed: 2026-05-12. Available from: <https://www.thisisservicedesigndoing.com/methods/bodystorming>.
- [25] Sinuotek. IEC 60884-1 Clause 22.1 Switch Life Test Apparatus For Verification Of Maximum And Minimum Withdrawal Force;. Accessed: 2026-04-09. Available from: <https://www.sinuotek.com/sale-13035228-iec-60884-1-clause-22-1-switch-life-test-apparatus-for-verification-of-maximum-and-minimum-withdrawa.html>.
- [26] HELU. H05VV-F / 05VV-F;. Accessed: 2026-05-13. Available from: <https://shop.helu.com/se-en/h05vv-f-05vv-f-m29450>.
- [27] General Cavi. H05VV-F / 05VV-F;. Accessed: 2026-05-13. Available from: https://www.generalcavi.com/redigo/cache/custom/r2generalcavi/pdf2024/EN/H05VV_F.EN.pdf.
- [28] Jakob Nielsen. Thinking Aloud: The 1 Usability Tool;. Accessed: 2026-05-20. Available from: <https://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/>.
- [29] Cults3D. 3D Print Koppla #1;. Accessed: 2026-04-09. Available from: <https://cults3d.com/en/3d-model/tool/ikea-koppla-power-strip-clamping-bracket-with-screws-to-the-top>.

- [30] Printables. 3D Print Koppla #2;. Accessed: 2026-04-09c. Available from: <https://www.printables.com/model/663902-ikea-koppla-power-strip-holder-switzerland-and-lic>.
- [31] MakerWorld. 3D Print Koppla #3;. Accessed: 2026-04-09. Available from: <https://makerworld.com/en/models/1397957-power-strip-holder-ikea-koppla#profileId-1449254>.
- [32] Printables. 3D Print Koppla Skådis;. Accessed: 2026-04-09. Available from: <https://www.printables.com/model/454638-ikea-koppla-skadis-uk-power-strip-mount>.
- [33] MakerWorld. 3D Print Koppla #4;. Accessed: 2026-04-09. Available from: <https://makerworld.com/sv/models/1442854-ikea-koppla-power-strip-holder#profileId-2258924>.
- [34] IKEAddict. SIGNUM;. Accessed: 2026-04-09. Available from: <https://www.ikeaddict.com/ikeapedia/en/Product/40287905/fr-fr/signum-holder-for-koppla-socket-w-usb-port/Entry/>.
- [35] Reddit. 3D Print IKEA Skotat;. Accessed: 2026-04-09. Available from: https://www.reddit.com/r/functionalprint/comments/1iq4x38/sofa_mounted_power_strip/?tl=sv.
- [36] Megabilligt. Self-Adhesive Power Strip Holder;. Accessed: 2026-04-09. Available from: <https://megabilligt.se/hemmet/organisering/forvaring/sjalvhaftande-hallare-for-grenuttag/>.
- [37] Amazon. Desk Clamp Socket;. Accessed: 2026-04-09. Available from: <https://amzn.eu/d/08JE5P56>.

- [38] Amazon. Sofa Cushion Socket;. Accessed: 2026-04-09. Available from: <https://amzn.eu/d/08D5ozgB>.
- [39] Amazon. Sofa;. Accessed: 2026-04-09. Available from: <https://amzn.eu/d/0iDN5DEt>.
- [40] Amazon. “Aesthetic” Power Splitter;. Accessed: 2026-04-09. Available from: <https://amzn.eu/d/0588Vicv>.
- [41] European Commission. Critical raw materials; 2026. Accessed: 2026-03-25. Available from: https://single-market-economy.ec.europa.eu/sectors/raw-materials/areas-specific-interest/critical-raw-materials_en.
- [42] International Energy Agency. Executive summary - Recycling of Critical Minerals; 2024. Accessed: 2026-03-25. Available from: <https://www.iea.org/reports/recycling-of-critical-minerals/executive-summary>.

A. WBS

WBS - Cable Management for seating concepts.

- 1. Research
 - 1.1 Literature study/Patent search (continuous for entire project)
 - 1.2 Internal research
- 2. Specifications
 - 2.1 Identify specifications/needs/Delimitations (with IKEA)
 - 2.2 Evaluate specifications
 - 2.2.1 Circularity and Democratic Design alignment check (with IKEA)
 - 2.3 Set target specifications/needs/Delimitations
- 3 Concept development
 - 3.1 Generate concepts
 - 3.2 First screening (within our small group, results in 5-10 concepts)
 - 3.3 Low-Fi prototyping
- 4 Concept selection
 - 4.1 Pugh screening
 - 4.2 Concept combination
 - 4.3 Concept scoring (with IKEA)
 - 4.4 Selection decision (results in 2-4 Concepts)

Theo Übelacker & Oskar Troell

- 5. Concept validation
 - 5.1 Feasibility checks with IKEA
 - 5.1.1 System-Level design discussion with IKEA (utilizing existing products)
 - 5.1.2 Rough Economic/Democratic/Environmental assessment (with IKEA)
 - 5.1.3 Detailed patent search (with IKEA?)
 - 5.2 Mid-Fi prototyping (continuous)
 - 5.3 Usability tests (cognitive/ergonomics) (continuous)
 - 5.4 Update/Verify target specifications
 - 5.5 final concept selection (with IKEA) (results in only 1 concept)
- 6. Testing and refinement
 - 6.1 Hi-Fi prototype (continuous for 6.x)
 - 6.2 User testing and reiteration
 - 6.3 Lab testing (if applicable)
 - 6.4 Finalize design
- 7. Further development
 - 7.1 discussion with IKEA about further development
- 8.Documentation
 - 8.1 Goal Document
 - 8.2.1 Thesis Writing
 - 8.2.2 thesis presentation
 - 8.3.1 IKEA documentation (with IKEA)
 - 8.3.2 IKEA presentation (with IKEA)
 - 8.4 Popular science Article.

Figure A1: Work breakdown structure

B. GANTT

Cable Management for seating concepts.

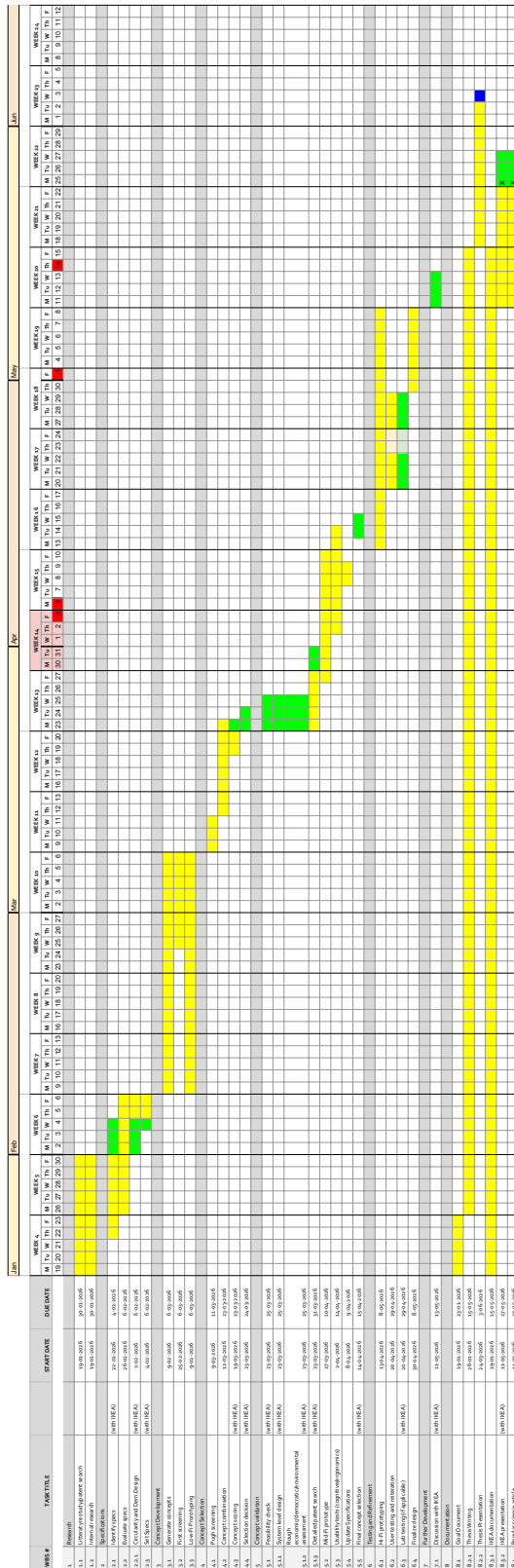


Figure B2: Gantt chart

C. Updated Gantt

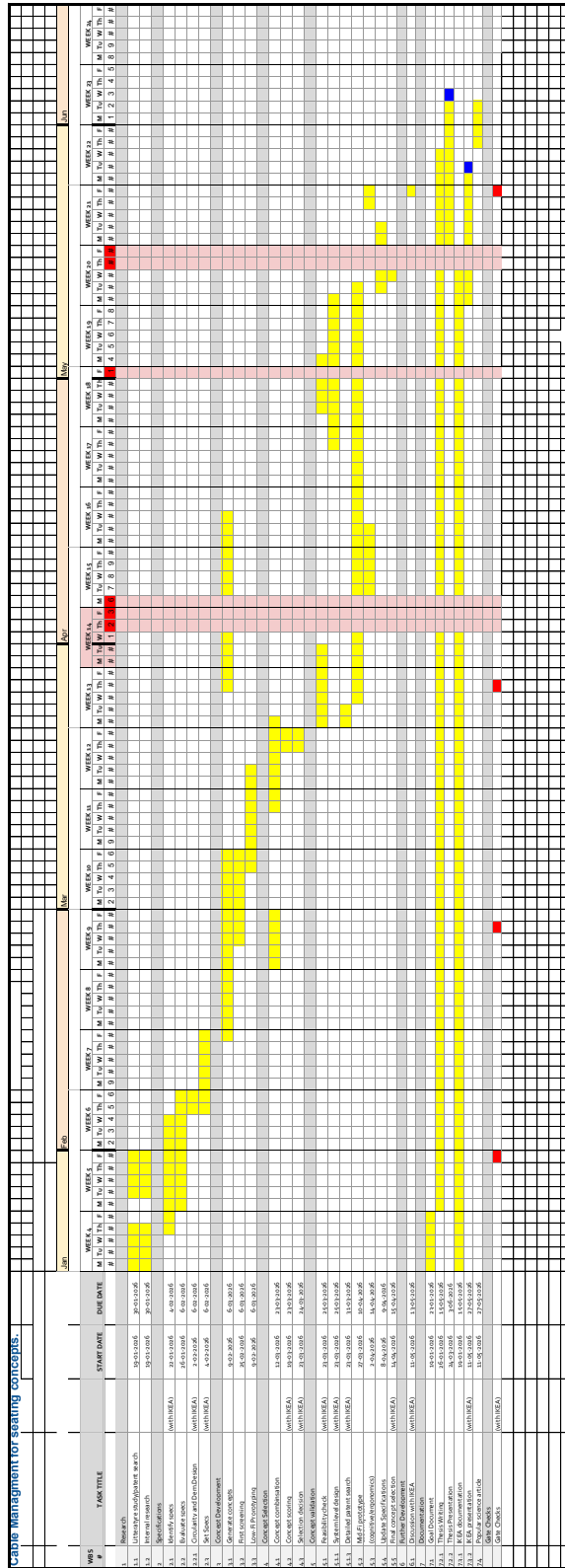


Figure C3: Updated Gantt Chart

D. Core Statements of the Democratic Design Manifesto

We want to change the world! And we want to do so based on our idealistic dream of creating a better everyday life for the many people. But if we're going to change the world, we must also have the courage to change ourselves a bit. To think differently, boldly, crazily, innovatively.

We want to make the world a better place. And we thought we'd start by making everyday life better. More humane, more fun, more simple, more smart, and more attractive. And we want to do it in as sustainable and responsible a way as possible.

We want as many people as possible to have the opportunity to experience an everyday like that. It's a big, fun, amazing challenge, and we seem to be the only ones doing it.

Our mission is the pretty impossible task of combining beautiful form with good function, lasting quality and sustainable production with a low price. And we want to do it in as responsible, playful, inquisitive a way as we possibly can.

We want to demonstrate that it is possible to create products where both the quality and function exceed people's expectations.

We want to show that it is possible to create products where sustainability is not only about taking responsibility for the entire production chain, but also about helping people to live more sustainable lives.

We want to demonstrate that it is possible to create Democratic Design with good form, function, quality and sustainability, at a really low price.

E. Benchmarking of existing power strip mounting solutions

Table E1: Benchmarking of existing power strip mounting solutions

Name	3D Print Koppla #1	3D Print Koppla #2	3D Print Koppla #3	3D Print Koppla Skådis	3D Print Koppla #4	SIGNUM	3D Print IKEA Skotat	Self-Adhesive Power Strip Holder	Desk Clamp Socket	Sofa Cushion Socket	Sofa	“Aesthetic” Power Splitter
Patent no./Product no.						AA-1084545-1						
Link	[29]	[30]	[31]	[32]	[33]	[34]	[35]	[36]	[37]	[38]	[39]	[40]
Description	Static, screwed in, 3D printed, 52.3 mm x 85 mm per rail. Uses an IKEA KOPPLA power strip.	Static, screwed in, 3D printed, uses an IKEA KOPPLA.	45 degrees, static, clamped in place, uses the newer IKEA KOPPLA as a base.	For IKEA SKÅDIS, hanging hook, static and less relevant.	Static, screwed in, 3D printed, uses an IKEA KOPPLA.	Holder for KOPPLA socket with USB port.	Folds in and out, can be held in the inner position with a magnet.	Self-adhesive power strip holder.	Desk socket, clamped in place, 45 degrees.	Clamped between the sofa cushions.	Complete sofa with integrated outlet.	Designed to be visible.
Solution category	Underneath, KOPPLA	Wall-mounted, KOPPLA	Above/underneath, angled, clamp-mounted, KOPPLA	hanging wall mount	Wall-mounted, KOPPLA	Above/underneath, KOPPLA	sofa-mounted, SKOTAT	Adhesive, KOPPLA	Above/underneath, clamp, socket included	sofa-mounted, cushion-clamped	Sofa	Loose socket unit
Static/Movement	Static	Static	Static, 45 degrees	Static	Static	Static	Dynamic, hinge	Static, click-in	Static	Loose	Static, sofa	Loose
Patent/Product/DIY	DIY	DIY	DIY	DIY	DIY	IKEA	DIY	Product	Product	Product	Product	Product

F. Weighted Scores

Table 2: Weighted Scores

	Score	Accessibility	Simplicity	Design Impact	Modularity	Robustness	Plugin ability
1 Double Axle Swing Stable simple solution	3.71	0.86	0.95	0.38	0.57	0.38	0.57
2 Spring Bayonet Stable simple solution	6.62	1.71	1.67	0.43	1.14	0.67	1.00
3 Two Directional Hinge Works but complicated and expensive	5.67	1.14	1.67	0.38	0.95	0.67	0.86
4 Spring Bayonet Leg Has potential	8.90	2.86	2.14	0.33	1.71	0.86	1.00
5 "Flip-Flop" roll guide Simple, has potential.	6.71	2.86	1.19	0.38	0.95	0.48	0.86
6 Roller Curtain Hard to imagine how it would work well	7.29	2.57	1.67	0.38	1.33	0.48	0.86
7 Roller Curtain on telescope A lot of material and unpractical.	4.33	0.86	0.95	0.33	0.95	0.38	0.86
8 Telescope with swing-arm Interesting.	4.90	1.14	0.95	0.38	0.95	0.76	0.71
9 Telescope with translating arm Not viable	5.29	1.14	1.19	0.33	0.95	0.67	1.00
10 Washer with rotation around arm Technically difficult, complicated.	6.38	1.71	1.43	0.33	1.52	0.67	0.71
11 Tilted Rotor Simple solution but not very attractive	7.14	2.29	1.90	0.33	1.33	0.57	0.71
12 Washer with fold Should work but needs more refinement	6.71	1.43	1.90	0.33	1.52	0.67	0.86
13 Double rail with pivot Simple and interesting	6.76	2.86	1.19	0.38	1.14	0.48	0.71
14 J-rail It would always be visible.	7.62	2.00	2.38	0.29	1.14	0.67	1.14
15 Telescope with slanted rails Not practical	5.14	2.00	0.48	0.33	0.76	0.57	1.00
16 Spring Loaded glider (with tray) Good solution.	6.95	2.29	1.43	0.38	1.33	0.67	0.86
17 Spinning rails Over complicated	5.38	1.43	1.19	0.24	0.95	0.57	1.00
18 Magnets Magnets not sustainable*	7.48	0.86	2.38	0.43	1.90	0.76	1.14
19 "Original" The first prototype (as seen in figure 1)	5.95	1.43	1.90	0.38	0.76	0.76	0.71

Notes: Magnets were not considered a sustainable alternative, since permanent magnets often rely on critical raw materials [41] while current recycling and recovery remain limited [42].