An exploratory study of 3D-printed hallway furniture

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Abstract

This Master Thesis project was conducted in partnership with Ekbacken Studios, a company that specialises in the production of home furniture manufactured with 3D-printing of recycled plastics. The request from the company to add hall furniture to their line of products resulted in the project's scope. In order to address this request, a Master Thesis project was undertaken to develop a concept for hall furniture, with a specific emphasis on determining client requirements. Furthermore, the project has been guided by the company's fundamental principles of sustainability, exceptional quality, and captivating design.

In order to develop the hallway furniture concept, Design Thinking process was used. The focus of the development primarily revolved around the conceptual development phase, as the objective of the project was to generate a conceptual design rather than a fully functional and market-ready product. In order to learn more about the hallway storage requirements of the company's customers, observations and user and expert interviews were conducted as part of the research process. Later on, this was regarded as requirements that was utilised as a guiding principle in the process of developing the concept.

The ultimate iteration of the conceptual design — Full Function concept for hallway furniture was designed to meet the storage needs of a diverse range of products, as specified by the target audience. The idea gives the hallway an airy yet organised first impression by using partially open and hidden storage. The curved contour of the concept brought a unique and individualised element to an otherwise mundane living area.

Keywords: hallway furniture, 3D-printinted furniture, storage options, user research

Sammanfattning

Detta examensarbete genomfördes i samarbete med Ekbacken Studios, ett företag som är specialiserat på tillverkning av hemmöbler tillverkade med 3D-printning av återvunnen plast. Begäran från företaget att lägga till hallmöbler till sin produktlinje resulterade i projektets omfattning. För att möta denna begäran genomfördes ett examensarbete för att utveckla ett koncept för hallmöbler, med särskild tonvikt på att fastställa kundens krav. Dessutom har projektet styrts av företagets grundläggande principer om hållbarhet, exceptionell kvalitet och fängslande design.

För att utveckla hallmöbelkonceptet användes Design Thinking-processen. Fokus för utvecklingen kretsade i första hand kring den konceptuella utvecklingsfasen, eftersom målet med projektet var att generera en konceptuell design snarare än en fullt fungerande och marknadsfärdig produkt. För att lära sig mer om kraven på hallförvaring hos företagets kunder genomfördes observationer samt användar- och expertintervjuer som en del av forskningsprocessen. Senare sågs detta som krav som användes som ledstjärna i arbetet med att utveckla konceptet.

Den ultimata versionen av den konceptuella designen — Full Function-konceptet för hallmöbler designades för att möta förvaringsbehoven för ett brett sortiment av produkter, enligt specifikationerna av målgruppen. Idén ger hallen ett luftigt men ändå organiserat första intryck genom att använda delvis öppen och dold förvaring. Konceptets böjda kontur gav ett unikt och individualiserat element till ett annars vardagligt vardagsrum.

Nyckelord: hallmöbler, 3D-printade möbler, förvaringsmöjligheter, användarforskning

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1 Introduction

The Introduction chapter provides an overview of the project's background, including information about the project initiator Ekbacken Studios and other players involved. Research questions, delimitations, and the project's goal and objective are all explained.

1.1 Background

This degree project is being conducted in partnership with Ekbacken Studios, a company that specialises in designing furniture made from recycled plastic derived from discarded fishing nets. Ekbacken studio suses recycled plastic in the process of 3D printing high-end furniture that showcases a timeless design, contributing to a sustainable climate.

The company's motivation for creating a hallway furniture stems from their aspiration to design pieces that are suitable for everyday usage, specifically targeting the concept of furniture for a hall. Hence, this thesis will concentrate on formulating a concept that aims to discern the specific requirements of the company's target demographic for furniture that exudes a sense of timelessness and functionality.

1.2 About Ekbacken Studios

Ekbacken Studios specializes in the production of environmentally sustainable and artistically exceptional furnitures. Their mission is to redefine luxury and the way we consume (Ekbacken Studios, 2023). The aesthetically pleasing design of furniture can be created via consideration for the well-being of our world. By engaging in the practice of upcycling waste materials, their furniture exhibits a remarkable combination of durability and design, thereby making a significant contribution towards mitigating climate change.

Ekbacken Studios was founded in the year 2022 by a group of five individuals who shared a common interest in design and sustainability. This group consisted of a professor specializing in digitalization, three engineers, and a fashion designer. Ekbacken Studios is a subsidiary of the Ocean Tech Hub's Peniche Ocean Watch program, which is a blue circular economy endeavor established by two of the founders of Ekbacken Studios. The primary objective of this initiative is to repurpose discarded fishing nets in Portugal through the process of upcycling (Penich Ocean Watch, 2023).

The fishing industry is responsible for around 50% of ocean litter, which has significant consequences for marine ecosystems and biomass. Ghost nets, which are abandoned fishing nets, ensnare marine organisms on the exposed bottom, while the presence of ocean debris hinders fish from successfully reproducing, leading to a decline in fish populations (Penich Ocean Watch, 2023).

Ekbacken Studios employs a process wherein discarded materials are transformed into design and esteemed products to minimize environmental impact. The use of life cycle assessment is employed to ensure the security of our entire operational processes. Not only do we only do we utilise trash from external sources, but from external sources, but they also ensure that the items they manufacture are designed for circulation during the user phase. Additionally, we assume the obligation of repurchasing each item once it reaches the end of its lifespan, enabling us to recycle and repurpose the materials to create new products.

The companys ambition is to design and manufacture furniture with a long lifespan, capable of enduring for numerous years and multiple generations. A percentage of the earnings generated by Ekbacken Studios is allocated to Peniche Ocean Watch, which in turn invests these funds in local organisations that actively promote social and environmental sustainability. The furnitures incorporates PENYLON®, a recently developed material created through a collaborative effort between Ocean Tech Hub and Ekbacken Studios (Penich Ocean Watch, 2023).

Ocean Tech Hub is now engaged in the investigation and advancement of techniques pertaining to the sustainable recycling and upcycling of outdated fishing nets that are gathered from various Portuguese ports. This endeavour is being undertaken in close partnership with the local fishermen residing in the region. Fishing nets composed of premium polyamide

material possess considerable potential as a valuable resource for novel production techniques such as LSAM 3D printing. The polyamide is combined with additives in order to enhance the generation of value. The utilisation of 3D-printing as their chosen mode of production enables them to effectively reduce production waste by ensuring that manufacturing occurs solely upon receipt of an order. After a product has completed its life-cycle, its material can be subjected to grinding processes to facilitate its reuse in the production of a new product, thereby establishing a sustainable circular system (Penich Ocean Watch, 2023).

The present production hub is situated in Sweden. The objective of Ekbacken Studios is to establish production hubs worldwide, employing a production technique that enables proximity to customers achieving global presence through local operations.

1.3 Problem description

Multiple challenges may impact the progress and result of this project. One problem is that the 3D printer has limitations on the proportions it can produce, which will impact the dimensions of the hallway concept. An additional obstacle arises from the inability of the 3D-printed layers to overlap one another due to the limitations imposed by the extruder. This will have an impact on the potential approaches to designing different concepts and should be considered during the period of developing the concept. Furthermore, the 3D-printed material is not suitable to drilling or sawing due to the potential for delamination between its layers. Hence, it is necessary to take into account the process of assembling various components.

1.4 Objective

The objective was to design a furniture concept for a hallway. The aim was to include the perspective user-centered design approach and investigate possibilities for hallway furniture adaptable for homes. The following brief was given as a starting point for the project: A unique furniture design for a

hallway that can be produced using the process of 3D printing and is intended to be included in Ekbaken Studios' product range.

1.5 Research questions

- How does modern hall furniture look?
- What strategies may be implemented to enhance the overall experience for consumers purchasing sustainable furniture?
    - What strategies may be employed to attract customers to select environmentally-friendly high-end furniture?
- What strategies may be implemented to enhance the manufacturing process for hall furniture?

1.6 Delimitations

- Since the project is based on 3D printing, there will be no conclusion regarding analyses of mechanical properties. The mechanical properties of 3D-printed plastics can be complicated to predict, and there is a lack of data on the topic.
- The budget for the end product will not be set. Therefore, there will not be a inclusion of a budget analysis.
- A finalized product on a scale of 1:1 will only be created if Ekbacken Studios has the time and resources to create it.
- The 3D-printed products, with the use of the filament PENYLON, are prone to crack upon drilling, Therefore, attachments are avoided to be attached to the material through drilling of holes or sawing.
- The 3D printer has limitations of the size it can print in.

1.7 Thesis Outline

The report is structured into nine primary sections, each containing sub-components. The first section of the paper provides an overview of the current situation, known as the context section. Subsequently, a theoretical framework is presented that clarifies the design approach. The subsequent

four sections define the design process, empathize, define, ideate, prototype, test, and final concept. The subsequent section introduces the ultimate concept, which is subsequently followed by a section dedicated to discussion and conclusion.

2 Theoretical framework

This chapter provides an overview of the theoretical study conducted on the design techniques employed in the project, along with an explanation of the design thinking process that served as the framework. The subjects discussed in this chapter will establish the fundamental basis for the ultimate concept.

2.1 3D-printing

Additive manufacturing, or 3D printing, is a technique that constructs a tangible thing by sequentially depositing materials layer by layer according to a digital model. Additive manufacturing, in contrast to subtractive manufacturing, builds its ultimate product by adding parts rather than removing away from a block of material (Autodesk, 2023).

The term 'rapid prototyping' is occasionally employed to describe 3D printing technologies. This traces its origins to the early era of 3D printing when the technology initially surfaced. During the 1980s, the initial development of 3D printing techniques led to their classification as rapid prototyping technologies. This categorization was due to the limited capability of the technology at that time, which was primarily useful for creating prototypes rather than actual production parts (Hubs, 2023).

Over the past few years, 3D printing has evolved into a very effective option for producing various types of parts, while other manufacturing technologies such as CNC machining have become more affordable and easier to use for prototyping purposes. While there are still some who use the term 'rapid prototyping' to specifically mean 3D printing, the definition

of the phrase is expanding to encompass all methods of extremely quick prototype (Hubs, 2023).

Additive manufacturing is a process that constructs three-dimensional objects by sequentially adding and fusing layers of material. This approach has little initial time and expenses, making it very suitable for prototyping. Components can be manufactured quickly and disposed of after being utilised. 3D printing excels in its ability to generate parts in a wide range of geometries, which is a key advantage of this technology (UltiMaker, 2023).

A major drawback of 3D printing is that the majority of things produced are naturally asymmetrical or not entirely dense, resulting in a lack of material and mechanical qualities compared to parts generated using subtractive or formative techniques. Fluctuations in cooling or curing conditions can cause tiny changes in different prints of the same part, which limits their consistency and repeatability (UltiMaker, 2023).

2.2 Furniture Industry

Retailers, manufacturers, suppliers, designers, and manufacturers make up the intricate value chain of the furniture sector. Over 30,000 individuals in Sweden were employed by 2319 Swedish businesses operating in the business sector in 2020, including business to business (B2B) transactions. 26 billion SEK worth of items were bought by Swedish citizens in the same year. 75% of the furniture imported from the EU and the remaining 25% created in Asia make up the Swedish furniture sector, which deals with both produced and imported items (TMF, 2020a). Imported furniture is in higher demand annually, according to the Swedish Federation of Wood & Furniture Industry. This growth may be attributable to lower production costs in other nations (TMF, 2020b).

Elfa, a Swedish corporation, manufactures storage solutions and annually releases reports that address the storage requirements of the Swedish population. A total of 1011 interviews with Swedish residents who were 18 years of age or older were compiled into the 2020 report, Förvaringsrapporten 2020. The median living area for Swedish inhabitants was 95 square metres, per the research. On the other hand, the average storage size for residents of Stockholm was 8 square metres, while the

average for the rest of Sweden was 9 square metres, excluding attic and basement storage. With an average of 9–10 square metres, households with children in particular had the most storage.

In terms of storage requirements, 10% of respondents expressed extreme dissatisfaction with their present storage alternatives, especially those who were families with children, irrespective of the age of the children. When it came to their storage, families with children expressed greater dissatisfaction than single households did, and women were generally less satisfied than males. With an 18% response rate, the hallway was the place where the majority of respondents were dissatisfied with their current storage alternatives. Since the hallway is the first room you enter and the last room you see before leaving a house, professional stylist and Feng Shui consultant Jannice Wistrand underlines the importance of keeping it neat and tidy.

The benefit of a clean home was also discussed in the report, with 52% of the respondents citing a favourable effect from having a well-organized home. Furthermore, 28% of respondents stated that having a disorganised home had a negative effect on them. According to the respondents, the most demand for extra storage was for clothes and shoes, with a response rate of 39%. When asked afterward what they did with garments they didn't have enough room for, 45% of the respondents said they attempted to fit their belongings into the storage they currently had without taking use of any empty space, 22% said they stored their belongings more effectively, and 11% said they purchased more storage. The source of this information is Elfa, and the year is 2021.

2.3 Sustainability

The Swedish Trade Sustainability Survey 2021 (Svensk Handel, 2021) examined the growing trend of sustainable consumption. The majority of businesses who took part in the study said that the current corona pandemic has not had an adverse effect on their sustainability operations. It has also just become worse to the point that one in five businesses claimed the pandemic has improved their sustainability. 65% of businesses answered that building their brand was their main motivation for working sustainably, which suggested that consumers were becoming more conscious of the issue. This demonstrated that the market demands a greater attention on

sustainability. High quality had a high response rate of 95% when it came to the category that had the greatest factors influencing consumer trade, such as materials, pricing, and hazardous compounds.

The furniture industry received a high response of 80% when asked about the importance of developing goods and services with a strong focus on sustainability (considering animals, people, and the environment). This represents a 20% increase compared to the previous four years. The circular business model emerged as the dominant social trend at last. According to the poll, furniture was the most commonly purchased used item among customers, accounting for 29% of all purchases, regardless of age and gender.

The sustainability analysis of circular furniture flows conducted by RISE (Research Institutes of Sweden) was utilised to enhance comprehension of circular business models in the furniture industry (Bolin, et al., 2017). Selecting furniture with a long lifespan to promote circular consumption was one of the largest new trends in furniture purchasing. In 2012, the total quantity of waste in Sweden categorised as "mixed and non-differentiated material" amounted to 825,000 tonnes. Independent studies conducted as per the report revealed that approximately 40-50% of this waste consisted solely of furniture. This finding has contributed to an increased recognition of the necessity for a more circular market.

The Swedish government has introduced a measure to revise the Consumer Purchase Act, which will take effect in May 2022. This is in addition to the ongoing trends in sustainable consumption (Finansdepartementet, 2022). By passing this law, the six-month window for complaining about a defective good or service will be extended to two years. The idea was driven by the desire to encourage enterprises to produce more durable goods for a more sustainable society, in addition to the legal requirement that the law be updated in light of the evolving ways in which people purchase in the digital world (Justitiedepartementet, 2021).

3 Design approach

The process chosen for this project was Design Thinking with a User-Centered approach. The following sections will go through the design thinking process and how it's applied to this thesis work with a User-centered approach.

Figure 1: Design thinking process overview

3.1 Design Thinking Process

Design Thinking is a versatile method employed in various contexts to uncover innovative thinking and expedite the design process. Designers engage in a systematic process to create goods, which may also be applied in a professional setting to generate innovative ideas and determine their practical implementation.

Design Thinking is a systematic approach that can be employed to create a user-centered solution for a problem. The approach begins by considering the requirements of the end user and, in contrast to other methodologies, emphasises the real user interaction and experience with the product (Tuttle 2021). The defined process offers a systematic approach to attain an optimal design solution for the target audience, ensuring it caters to their needs effectively.

The concept of this process is not limited to a single interpretation, since it may also be viewed as a strategy or attitude, in addition to being a development process (IDEO 2018). Hence, it is crucial to establish the specific methodology to be employed. The five steps of Plattner's design thinking process—empathize, define, innovate, prototype, and test—were the inspiration for this project (Plattner 2010). According to Tuttle (2021), these processes don't have to be carried out in order; they can be carried out

concurrently or iteratively. The process's various phases are briefly discussed below under headings, and later in this report, under the corresponding sections, you can find a more thorough explanation of how the methods used in this study were carried out.

3.1.1 **Empathise**

Empathy and comprehension are crucial when developing a product using a user-centered approach, particularly when the designer lacks a personal connection to the situation at hand. The initial phase of the design thinking process involves impartially examining the user's requirements and comprehending the issue at hand, while disregarding any preconceived notions or biases.

In order to gain a comprehensive understanding and avoid just reinforcing preconceived notions, it is advisable to employ several methods such as observations, active participation, and open-ended interviews and discussions (Plattner 2010). The empathise step in this thesis will involve conducting interviews, conducting observations, organising a workshop, and doing several user tests.

3.1.2 **Define**

In the Design Thinking process, the second phase involves identifying and articulating the needs and primary issues faced by the users in the target group. This is done by establishing a problem statement or a needs description. An essential first step in the process, defining the problem statement will assist the in subsequent stages by giving direction and a clear objective to work towards. Finding patterns and intriguing information by synthesising and evaluating the data acquired in the preceding phase

The findings will be uncovered (Plattner 2010). based on the information gathered in the previous phase, to create an appropriate problem statement description.

In order to code the raw data obtained by Empathise, a Bottom-Up methodology will be employed in conjunction with How Might We questions to analyse the data first. Subsequently, a comprehensive examination of the results will be conducted, serving as a precise set of criteria for the entire procedure. Personas will be developed based on test

participant data to provide a clear picture of the subjects of this study. For more comprehensive information, please refer to section 5.

3.1.3 **Ideate**

The ideation stage of Design Thinking is when concepts are created by fusing the knowledge of the subject with the comprehension of the Individuals. Finding inspiration from a wide range of sources is crucial; one should not limit oneself to simple fixes or judge early ideas too harshly. During subsequent stages, the optimal solution will be determined. However, at this particular level, the primary emphasis is on the generation of conceptual ideas (Plattner 2010). The thesis employs two ideation methodologies, namely brainstorming and sketching. For a more comprehensive understanding of the implementation process, please refer to section 6. Ideating does not have to be the entire process when using the Design Thinking iterative approach, but it can be. As a result, there are different ways to generate concepts: using the define problem formulation approach or the analysis of user testing conducted after the prototype is developed.

3.1.4 **Prototype**

Following the creation of concepts, the next step is to commence the process of materialising the ideas through development.

Models or initial versions of a product or design. This stage is carried out so that the concepts can subsequently be tested on users of the target group. The prototype might only have the essential features if it's early in the process; it might even start out as sketches.

Section 6 provides further information on the first iteration of prototyping in this thesis.

3.1.5 **Test**

Following the creation of prototypes, it is necessary to evaluate the outcome by conducting tests with the target audience. Without providing thorough explanations, allowing members of the target group to engage with the model allows for the complementing of user data and the building of more empathy in addition to providing suggestions into ways to improve future development. Multiple prototypes are an excellent technique to conduct the test so that they may be compared (Plattner 2010). For the purpose of comparing various design suggestions.

3.1.6 **User-Centered Design**

Design choices that are based on the requirements and behaviours of people are known as human-centered design, or UCD. Tim Brown discusses the design thinking process (Brown, 2019) addresses the use of the UCD approach. The previously described design thinking has a problem and solutions space, with an emphasis on correctly describing the problem and subsequently meeting the demands of the user. As illustrated in figure –, the UCD is the focus that occur inside each of the design thinking phases: empathize, ideate, define, prototyping, and testing. Throughout the process, the five activities are iterated, or repeated, to obtain further insights and refine the final solution. In the sections that follow, each activity is covered in further detail.

3.1.7 **Design process outline**

The design process outline is showed in figure 2. The phases Idate, prototype and test will be decribed in the section of Concept Development.

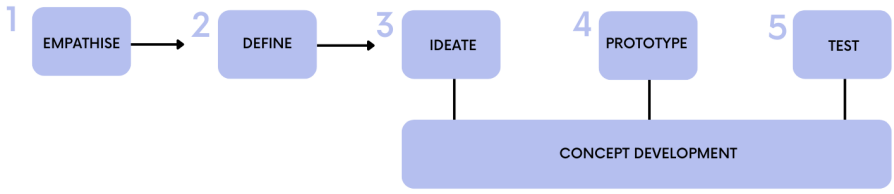

Figure 2: Design process outline

3.2 Development Tools

Rhino
Rhino is a software application utilised for the creation of both 2D and 3D models. This software is very effective for generating organic shapes. The selection of this modelling programme was based on its versatility in terms of functionality and its intuitive user interface.

Canva
The platform Canva will be utilised for the purpose of generating graphics. This platform includes numerous functions and features that facilitate the development of aesthetically pleasing illustrations.

3D-printer
The project will utilise a small 3D printer to efficiently produce rapid and miniature prototypes. The Ender 3 is the 3D printer utilised, known for its user-friendly interface.

4 Empathise

The design thinking process consists of five phases, the first being the Empathize phase. This section presents an outline of the initial phase of the project, which involved employing several techniques to empathize with the problem and consumers. Learning about the user and the issues the user faces is the aim of this stage. In order to accomplish this, research is made using benchmarks, observations, and interviews. The information gathered from the Empathize phase will serve as the basis for the Define phase, which will translate the information into user demands. This process was approached with a receptive mindset to gather a comprehensive understanding and diverse viewpoints.

Figure 2: Empathise phase

4.1 Research Methods

4.1.1 **Primary Research**

Seeking “real life” information from talking to the actual target market that has been selected is crucial for the designer. The primary researcher collects needs from the users. According to Hanington (2012), this is frequently seen as having greater significance than secondary-based research. Observation is a helpful research technique in user-centered design (UCD) to determine the actual requirements of the user accoriding to Tim Brown (Brown, 2019). Two distinct observation techniques were used: observation of the user and observation with empathy.

Observations of the user
The purpose of the Semistructured observation is to get fundamental data by watching without preconceived notions. The observation should be conducted in a methodical manner and well recorded, either written notes, pictures, or unedited video recordings. Following the observation, participants might be questioned to validate their activities (Hanington, 2012, p.120).

Two instances of semi-structured observations were carried out. The initial observation took place in the residence of a member of the target demographic, specifically an apartment. An end user granted permission to observe and examine the process of arranging their garments and accessories within their hallway furniture.This observation was conducted with the aim of gaining further insights into the individual's storage practices and, more importantly, the underlying motivations behind their decision-making.

The second semi-structured observation entailed observing the end user's interaction with their hallway furniture in their house, with their prior permission. This subsequent semi-structured observation followed a similar pattern to the initial one, however, while examining the initial observation, new inquiries arose. The second attempt provided more insights and served

as a valuable complement for gathering data on both apartments and houses.

Observations with empathy
The objective of empathy observation is to investigate the sequence of events that the end user undergoes, such as returning home from work and utilising their hallway furnishings, or leaving the residence to meet friends. Both of these scenarios involve engaging with the hallway furniture in one's home, but they do so in distinct manners. One effective method to understand how end users would use their furniture, the decisions they might make, and the emotions they would experience, is to empathise by seeing oneself in their position (Brown, 2019).

To acquire this data, nine observations were conducted with empathy in different households, with the consent of the respective end users. Five of these sightings occurred in apartments, while the remaining four occurred in houses. Three of the apartment observations were carried out by entering the units while wearing appropriate outside clothing, including gloves, a hat and a bag. The procedure of departing the apartment involved several steps: dressing outdoor clothing, accessorising, putting on shoes and last, collecting a bag.

The observations made in houses were carried out in the same way as to the observations conducted in apartments. Two observations were conducted while entering the house, while the other two were conducted after leaving the residence.

Interviews
Another useful primary research technique is to perform interviews. In order to identify unmet requirements, the objective was to gather more detailed and precise information on the users and their viewpoints. This strategy was chosen as a component of the UCD methodology, with an emphasis on comprehending the requirements of people when kepeing storage in a hallway as how the user uses the space. By employing probing and an open-ended question framework, unstructured interviews provide the interviewer more freedom to be curious and adaptable. According to Sharp, Preece, and Rogers (2019, p. 269–273), unstructured interviews have the advantage of frequently producing data that offers a thorough grasp of the subject and allows respondents to bring up points the interviewer may have overlooked.

The writer remotly conducted unstructured interviews with two Architectures, two interior consultants and 8 end users. These end users were either friends or family members of the designer. Each interview had a duration of around 20 minutes and was conducted using a set of predetermined questions. The interviewer may ask follow-up questions based on the participant's response. The questions mostly addressed the methods and reasons behind the participants' admired hallway storage solutions and functions, and how their hallway storage solutions and functions looked like today. The interview questions are located in Appendix A.3.

Visiting Ekbacken Studios
In order to gain inspiration, understand the aesthetic language, and obtain a greater comprehension of Ekbacken Studios' product assortment, a visit was made to see Ekbacken Studios' pieces of furniture. The types of furniture at Ekbacken studios were evaluated for how they were designed using 3D-printing as the manufacturing method. The organic shapes of the types of furniture and the way the collections seamlessly fit together were explored.

4.1.2 **Secondary research**

Rather than gathering original data directly from participants, secondary research makes use of already-existing data from sources like books, research papers, articles, and past projects (Hanington, 2012). Therefore, a secondary research was conducted by gathering data from websites and stores, tailoring the search terms to the specific information that needed to be found.

Benchmarking – hallway furniture

This project examined the market for preexisting products within the same market group. The decision was made to categorise the benchmarking into three distinct categories: full-function furniture, modular systems, and single-purpose furniture. These categories were selected in order to have a more comprehensive and precise understanding of the current market for hallway furniture.

Benchmarking - 3D-printed furniture

The decision was made also to include benchmarking of 3D-printed types of furniture. To obtain a deeper understanding of the different ways to produce 3D-printed pieces of furniture, not only hallway types of furniture were explored. This benchmarking allowed the designer to find inspiration for developing 3D organic shapes and utilize the potential of using 3D-printing as the manufacturing method.

Benchmarking – Dimensions
To determine the appropriate dimensions for the concept, a benchmarking analysis was undertaken on various products that impact the dimensions of hallway furniture. The benchmarking was performed on fully functional hallway furniture, hangers, and shoes. The results were then employed in the development of the final concept. Research regarding hight to ceiling was also conducted. The items that were used as benchmarks may be located in the table, and the outcome can be found in table 4.

4.2 Results

4.2.1 **Primary research results**

Observations of the user
The users' observations generated numerous noteworthy insights. One of the observations made was that the end user appeared confused when trying to locate their accessories, as they spread out over several compartments of the hallway furniture. Furthermore, it is worth noting that the user choose to place their bags on the floor next to their hallway furniture due to the limited storage capacity of their furniture. Based on these observations, it was determined that the users appeared to be experiencing stress due to their disorganised and unsorted belongings. The user felt overwhelmed when attempting to retrieve their jacket due to the number of jackets hanging on hooks, making it challenging to access.

Two key findings from these two observations of the users was:

- An unorganised hallway storage area resulted in stressful interactions, leading to an unpleasant experience.
- There is a need for storage of bags and easier access to outdoor clothing.

Observation with empathy
Employing empathy during observations proved to be an effective method for acquiring relevant data on people's interactions with hallway furnishings. An issue that arose in four of the observations was the absence of shoe storage in the hallway furnishings. At the same time, the shoes were abandoned on the floor beneath the clothing rack, hat shelf, or hooks, resulting in a messy appearance. Another notable discovery was that the hallway furniture had a lot of room for hanging clothes on a rack, but did not have sufficient space for bags and accessories. One of the observations presented a challenge in locating gloves due to the arrangement of the items. The gloves were divided and placed in separate baskets, which were positioned on a shelf approximately 180 centimetres above the floor. The baskets had to be removed and positioned on the ground to search for the gloves. The task of locating the gloves proved to be challenging and resulted in disorder as other items had to be removed from the baskets in order to find them.

There were around three occurrences during the observations where the clothes items were stacked on hooks and challenging to retrieve, resulting in dissatisfaction. In addition, in four instances, there was an absence of seating arrangements for the purpose of putting on and taking off shoes, resulting in an unpleasant posture during the procedure.

The primary distinction seen between hallways in apartments and houses was that the hallways in homes were generally more spacious compared to those in apartments. This realisation prompted the recognition that there were larger hallway furnishings available, offering a greater variety of storage possibilities compared to those found in the apartments.

The primary results obtained from the observations with empathy are as follows:

- It is vital to have multiple alternatives for storing clothing.
- Estimating the dimensions of the hallway is challenging.
- Convenient availability of accessories is essential for ensuring an enjoyable experience.

Interview with the end users
The information obtained from the interviews was helpful in understanding how the end user utilizes their hallway furniture, their hallway space, and

how they feel about their hallways. This research also resulted in data regarding what the user would like to have in a hallway in terms of storage, furniture, space, and feelings they would like to experience.

Interview with architectures
The interview provided valuable insights into the design of the hallway and the key considerations to be taken into account during its design process. This research also generated data on the prioritisation of hallway size during the design of apartments or houses. The architecture emphasised that hallways have a lower priority in terms of size compared to other rooms, often resulting in smaller hallways.

Interview with interior consultants
Through the interviews conducted with the two interior consultants, it became evident that the visual appearance of a hallway is essential. The consultants emphasised the need of having well-arranged hallways in order to create an inviting atmosphere. This is particularly important because the hallway is typically the first or last area people encounter when entering or leaving a home. One consultant highlighted that the hallway often serves as a transitional space connecting several rooms in many households. Hence, it is crucial to ensure sufficient storage capacity to enable the user to establish an organised hallway.

4.2.2 **Secondary research results**

Benchmarking hallway furnitures – Full-Function

The furniture pieces in this benchmark subcategory were Full-Function furniture, which meant that the user could obtain multiple storage solutions in a single piece of furniture to meet all of their hall storage needs. Most of the items that were assessed had a combination of clothes hangers, shoe storage, seating alternatives, and storage for smaller items. The number of storage possibilities varied throughout the items; although the majority employed open storage, some featured hidden storage. The benchmarked furniture featured a simple, classic, and industrial style, crafted from a combination of metal and wood. Figure – displays a summary of the objects that have been benchmarked. The associated references are displayed in Table 1.

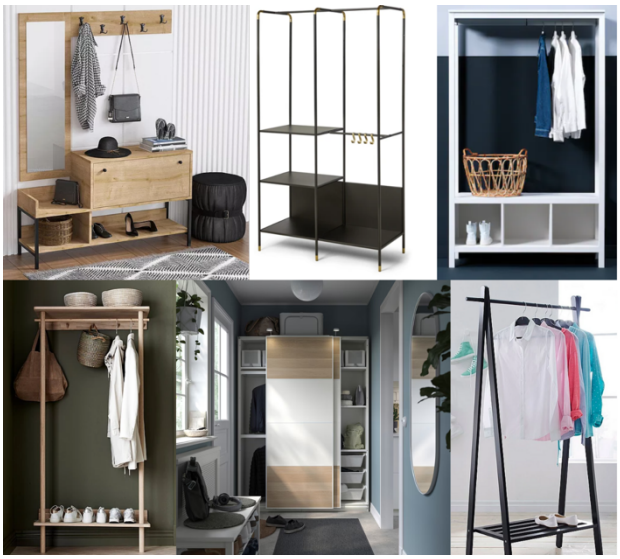

Figure 4: Full function systems

Table 1: Image sources for the benchmarked full function systems, image source listed from left to right.

Company name	***Product name***	***Link***
Mio Mobler	*Luca*	*Luca Klädförvaring | Mio*
Ellos home	*Ellos kladstallning tra*	*Ellos Klädställning Trä - Vit - Klädförvaring | Ellos.se*
Homeroom	*Hallmobel Nonso*	*Hallmöbel Nonso - Brun - Möbler | Homeroom*
IKEA	*HEMNES*	*HEMNES Open wardrobe, white stained, 120x50x197 cm - IKEA Austria*
IKEA	*PAX / MEHAMN*	*https://www.ikea.com/se/sv/p/pax-mehamn-garderobskombination-vit-dubbelsidig-vitlaserad-ekeffekt-s39432965/*
Ellos home	*Ellos Hallforvaring Denver*	*Ellos Hallförvaring Denver - Natur - Hatthyllor | Ellos.se*

Benchmarking hallway furnitures – Modular Systems

Modular Systems refer to systems composed of separate, independent modules or components. Multiple companies in today's market provide

modular hallway organizing solutions. Depending on the client's needs, the system's size and complexity could be adjusted because each component could be bought separately and installed together. This allowed the buyer to design a hallway interior that met their unique requirements, such as installing just a coat hook and hat shelf. The user could personalize the various storage unit heights with the furniture in addition to its modular design. Designing customized furniture that incorporates the principles of universal design.

Figure 5 illustrates how various unique storage units could be created using the benchmarked modular systems to make hall furniture. Related references are shown in Table 2 below. Shelf, drawers, shoe racks, knobs, hooks, mirrors, and magazine collectors were among the products offered by the rival. Wood and metal were the primary components of most of the systems. Specifically, depending on the intended look, different coatings were applied to oak, walnut, and ask. Overall, the furniture's design was simple and minimalistic, letting light in via the gaps or spaces between the wooden rods.

Figure 5: Modular systems

Table 2: Image sources for the benchmarked modular systems, image source listed from left to right.

Company name	*Product name*	*Link*
String	*Hallway H*	*Hallway H - String Furniture*
String	*Hallway K*	*Hallway K - String Furniture*
Norrgaveln	*COAT & SHOE RACK SNEDSTAG*	*Coat & shoe rack Snedstag - 140 cm - Norrgavel*
Norrgaveln	*CLOTHES STORAGE K27*	*Clothes storage K27 - Light grey & birch - Norrgavel*

Benchmarking hallway furnitures – Single Purpose

The furniture that was benchmarked in previous sections served a variety of purposes. This section only addressed the market for hall furniture that served a single purpose. This market sector gave the general idea that furniture was made in various styles. This was done to appeal to a broader audience, as customers could effortlessly mix and match various features and designs based on their personal preferences. Since they didn't have to satisfy many storage needs, the resulting furniture was far less complex. Smaller furniture items in every category, including coat hangers, sitting arrangements, shoe racks, hat stands, and various types of storage designed specifically for hallways, comprised this market segment. The furniture market was so large that it was impossible to identify any common styles or materials. In Figure 6, many materials, particularly wood and metal, are displayed. The associated references can be found in Table 3 below.

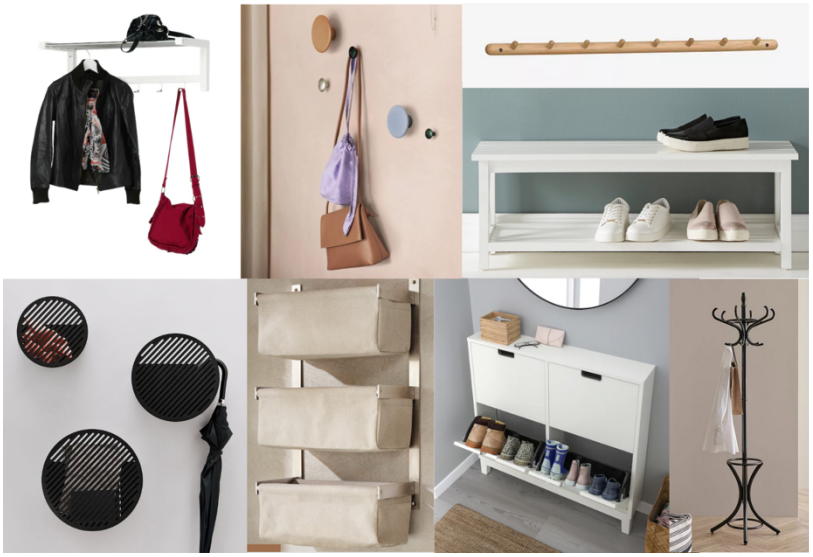

Figure 6: Single purpose furniture

Table 3: Image sources for the benchmarked single purpose furniture, image source listed from left to right.

Company name	***Product name***	***Link***
IKEA	*STÄLL*	*STÄLL Shoe cabinet with 4 compartments, white, 96x17x90 cm - IKEA Austria*
IKEA	*TJUSIG*	*TJUSIG Hat rack, white, 79 cm - IKEA Austria*
Granit	*Påshylla Stål med 3-pack påsar*	*Påshylla Stål med 3-pack påsar | GRANIT*
Designtorget	*Väggförvaring Diagonal*	*Väggförvaring Diagonal L svart (designtorget.se)*
Designtorget	*Krok Dot Keramik*	*Krok Dot keramik L Muuto | Handla möbler online | Designtorget.se*
Ellos home	*Ellos klädhängare cesar*	*Ellos Klädhängare Cesar - Svart - Klädförvaring | Ellos.se*
Ellos home	*Ellos Skohylla Kryss*	*Ellos Skohylla Kryss - Vit - Skohyllor | Ellos.se*
Homeroom	*Kroklist Milford*	*Kroklist Milford, 80 cm - Natur - Möbler | Homeroom*

IKEA	*STÄLL*	*STÄLL Shoe cabinet with 4 compartments, white, 96x17x90 cm - IKEA Austria*

Benchmarking - 3D-printed furniture
Upon doing a benchmark analysis of 3D-printed furniture, some fascinating designs were discovered that could provide inspiration for the concept development stage. There is a wide variety of furniture available, each with its own unique design. These pieces are created using a range of 3D-printing techniques and materials. An intriguing discovery was that certain pieces of furniture had a reduced layer height compared to what will be utilised in this project. This allows for the creation of complex designs where layers can be overlapped.

Ekbacken Studios

Figure 7: Ekbacken Studios products

Benchmarking – Dimensions

The findings of the dimensional investigation yielded numerous intriguing discoveries. Measurements were collected for the dimensions of the benchmark products, and the average height, width, and depth were computed. The findings are displayed in a table. The research on shoe size was excluded from the chart as it focuses solely on the largest shoe size, which determines the minimum depth required for shoe storage. The maximum feet size recorded was 40.55 centimetres, as documented by the Guinness World Records (2023). The requirements regarding ceiling height were also examined, and it was determined that according to Bostadsverket (2023), the minimum height should be 2.4 metres.

Figure 8: Benchmarking – Dimensions of shoe and clothing rack

Figure 9: Benchmarking – Dimensions of full functioning hallway furniture

Table 4: Benchmarking average dimensions.

Type of product	***Average Height***	***Average Width***	***Average Depth***
Full Functioning	192	133	45.5
Clothing rack	32	85	31
Shoe rack	43	82	37
Hanger			39

5 Define

To identify the many issues with the current solution, this section of the project compiles all the data gathered in the preceding stage and analyses it. All the data gathered during the empathize phase are combined and converted into user demands during the Define phase. To prioritize the needs, a function analysis matrix and various personas with their corresponding user experiences are developed. Using the information gathered from the Ideate phase, a final brief is created.

Figure 10: Define phase

5.1 Analysis of Data

Various analytic techniques were applied to the data in order to make it clear enough for usage and understanding in the preceding stage.

5.1.1 **How might we?... Questions**

What are the possible ways in which we could...? Open-ended inquiries are designed to gain a deeper understanding of specific areas that could be further investigated and potentially enhanced. The goal of using this method is to realise that there is more than one right answer at this point. In addition, it is a wonderful way to build a connection between the research's raw data and the subsequent design process (Szerovay 2022).
In order to support idea generation later on, this strategy was employed to obtain a wider basis. This was accomplished by going over the results and coming up with questions by first including "How might we" and then coming up with a question to address each major discovery. Subsequently, the questions that had similarities were categorised into cohesive themes.

Following are the themes and questions that were compiled using this method:

Functionality

How might we…

- …include storage and make it hidden?
- …create space for shoes?
- …include storag for outwear?
- …seating options?
- …attached the furniture?

Communicating idea
How might we…

- **…** to understand the purpose of the functions?
- …make the user understand the functions/mechanisms?

Engagement
How might we…

- …make the user understand where to storage shoes?
- …make the user understand where to storage accessories?
- …make the user understand where to storage clothing?

Ergonomics
How might we…

- …make sure the user can interact with the product in a convenient way?
- …create an easy way to interact without constraining the users body?

Aesthetic
How might we...

- ...create appealing products?
- ...make sure the product fits together with the existing product assortment of Ekbacken Studio?

5.1.2 **Coding of data**

In order to achieve comprehensive categorization in section, and to encompass all significant aspects of the challenges, the project group exclusively conducted further analysis of the research findings in this thesis. When converting a large amount of insightful responses from interviews and other research techniques into numerical values, referred to as codes, coding is a helpful tool. This kind of coding of research data can be done in two primary ways: the first focuses on comprehending the data that has been received by looking over the data and sorting through the many answers to determine which themes (codes) they belong to. The

alternative method seeks to validate through the process of discovering and generating.

The process involves extracting themes (codes) from available data and subsequently validating them through research, which can be classified into distinct categories (Kumar 2011).

When attempting to comprehend the issue and users, the first strategy discussed, known as Bottom-Up, was utilised as a source of inspiration. As a result, this element of the process's coding was motivated by it and involved identifying and evaluating frequent patterns as potential areas for improvement. Later in this project, when various problem areas need to be confirmed, the Top Down technique, which is the second approach described, will be employed (Olander 2023).

The findings of the investigation were categorised into distinct themes. The identified themes were seen as problematic areas that could be explored in order to enhance the concept.

Upon conducting a more in-depth analysis of the data, the following themes emerged:

- Untidiness
- Storage
- Aesthetic
- Function
- Accessibility
- Ergonomic

5.2 Functional Analysis

By analyzing the data from section 4.2, a functional analysis was conducted to generate a well-organized list that outlines the Specification of Requirements. This will need to be reviewed again in the future to compare with the solutions that are developed.

In this stage of the design process, functional assessments are frequently completed as a final step to get ready for the ideation phase (Stiftelsen Svensk Industridesign 2023), which is also used in this instance.

Specification of requierments

The set of requirements that the next solutions must adhere to is displayed in table 6. The earlier study and evaluations led to the essential and desired items being prioritised. The project's essential requirements, which were of importance for this thesis and would have a substantial impact, were regarded necessary. The desirable requirements, on the other hand, would be better addressed once the essential requirements are resolved. Since the product was functional for that purpose, the primary rating has already been established.

Table 5: Function Analysis

Verb	***Substantive***	***Rating***	***From***
Prevent	untideness	D	Interviews, observations
Facilitate	Storage	R	Interviews, observations
Invite	Familiarity	D	Interviews
Appear	Luxurey	D	Literature
Provide	Function	R	Interviews, observations
Clarify	Functions	R	observations
Offer	Storage	R	Interviews, observations
Allow	accesability	R	observations
Decrease	Messynes	D	Interviews
Appear	Contemporary	D	Literature
	R = Required	D = Desired	

These requirements were categorised into 3 main categories to further understand the user needs and to priortise these needs.

Table 6: User needs

Category	***User Needs***	***Rating***
Function	Possibility to store items in multiple ways	***
	Enables efficient storage options	**
	Enables space-efficient use	**
	Possibility of sitting down	*

Usage	Fits into the users existing hallway	***
	Allows mobility in hallway	***
	Enables user-friendly interactions	**
	Allows the user to adjust the product	*
	Possibility to customize the product	*
	Offer tidiness	*
Aesthetics	Fits into Ekbacken Studios product portfolio	***
	Provides an appealing design	***
	Creates a welcoming environment	**
	Possibility to keep items hidden	**
	Enables a spacious hallway	**
	Adds decorative elements	*

5.3 Personas

Personas can be constructed as fictitious characters based on the people in the target audience in order to discover and remember their requirements and wishes during the research and development process (Lowdermilk ,2013).

A certain amount of consolidation is crucial, according to Hanington (Martin & Hanington, 2012). Designing for everyone leads to "unfocused or incoherent solutions" Personas have the potential to offer an optimal solution for consolidation by collecting typical behaviours in profiles that are meaningful and relatable.

Based on the gathered and analysed data, two distinct personalities were developed and utilised as a guide during the concept development stage (the outcome is shown in section 5.5).

5.4 Mood board

The design aesthetics, style, and context of the user can all be communicated by making a mood board. Combining photos, illustrations, or brand imagery can help the mood board achieve its goal of inspiring and graphically presenting a description of the user (Martin & Hanington, 2012). One mood board was generated and served as inspiration during the development phase for the various hallway furniture concepts. The outcome of the mood board is presented in section 5.6.

5.5 Result personas

The major research findings formed the foundation for the development of two personas. The observations generated valuable insights that were utilised to identify the frustrations and needs of the personas. The personas were selected as the target demographic for this project, specifically focusing on individuals residing in either an apartment or a house. The living arrangement was selected based on the disparities in storage space between living in a house and living in an apartment. Personas were employed throughout the concept development stage to establish a distinct understanding of the end user and their requirements.

Figure 11: Persona Melissa

Figure 12: Persona John

5.6 Result mood board

After completing extensive research on numerous websites, including Ekbacken Studios' website, analysing their photoshoots, and engaging in discussions with the stakeholder. The desired visual appearance for the hallway concept could be represented through the use of a mood board. The aesthetic appeal was deemed to be in line with contemporary organic forms. Given that Ekbacken Studios specialises in designing high-end furniture, this factor was also taken into account. The result of the mood board is displayed in figure 13.

Figure 13: Mood board

5.7 Reformulating the Brief

The development of the final concept required insights regarding storage possibilities and functionality, which were obtained through primary and secondary research. Consequently, the brief was revised and the current version expressly specifies the following: A unique hallway furniture design that offers versatile storage options and can be seamlessly integrated into customers' existing halls. The concept must align with Ekbaken Studios' product range and incorporate desired functionalities for end customers.

6 Concept development

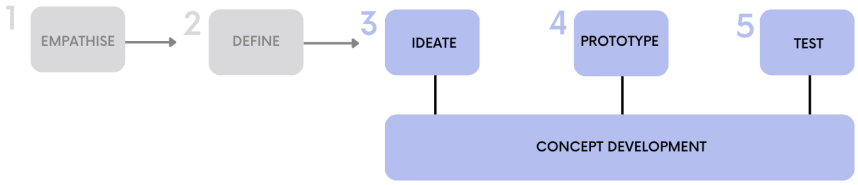

Figure 14: Concept Development phase

6.1 Ideate

For the analysts to brainstorm and produce various ideas for concepts that can then be implemented into prototypes, Ideate, as previously said, needs data to be collected. An open mind is crucial throughout this process (Brown, 2019). People taking part in this stage should consider how the comfortable components of their experience might be integrated with a UCD approach.

6.2 Concept Development

Prior to being combined into one final design, the concepts were explored within three key areas. To enable the team to concentrate solely on one feature at a time without having to sacrifice any ideas due to constraints from the other categories, the concept development was divided into three categories.

Based on the identified user demands displayed in table 6, the three primary categories that were selected were Usage, Function and Aesthetics.

6.3 Mindmapping

Mind mapping helps you understand difficult topics or situations with various components by visually organising them. Visual thinking tool mind mapping can help construct concepts and ideas when the relationships between several connected pieces of information are unclear. It allows us to externalise our mental knowledge in a nonlinear fashion to organise,

analyse, communicate, store, and retrieve information. Diagrammatic and visual mnemonics help understand and remember issue spaces (Martin & Hanington, 2012). Mind maps are a reflection of our non-linear thinking process and our ability to navigate difficult challenges that lack a clear and distinct sequence of stages. While we mould the data into meaningful themes and patterns, the map helps us to test and summarise hypotheses, establish and break connections, and think through other options.

The mind mapping started with setting a key theme question to keep the mapping process on track. Thereafter, a circle drawn around the subject in the center of a paper. Next step was to draw outward extensions from the map center and mark them with simple verb-noun pairs or noun clusters. The map gives words and images more importance as they reach the center. These are the main links. As primary links are identified, each will reveal more detailed secondary information. A line was drawn between primary and secondary connections. Free associations were made until all relevant information is represented. Update the map with new information. When all the information was on the map, it was pronounced finished. Strengthening concepts and their connections can lead to new knowledge and comprehension. The result is presented in figure 15 below.

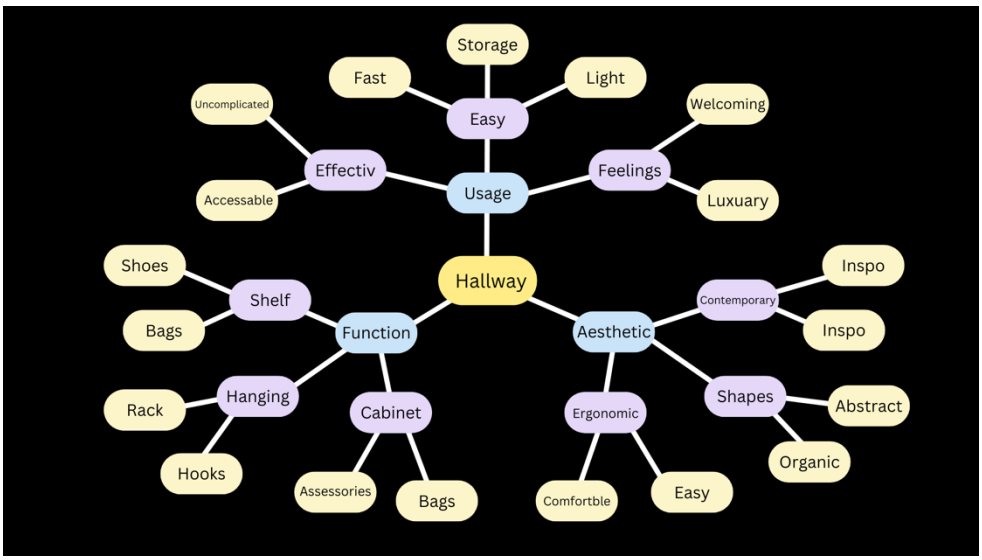

Figure 15: Mind map

6.4 Design Workshop

Design workshops are entertaining and effective at building stakeholders' creative trust and activity-based research engagement. Participatory design workshops for flexible modelling, brainstorming, and design team are common in generative research. In evaluation sessions, participants discuss ideas and offer suggestions for design refinement.

One of the methods utilised during the workshop was the XYZ-methode. The procedure was carried out by segmenting the labels of the customer's needs and drawing only solutions in these distinct sections. Every page features drawings from each participant, with a time limit of no more than five minutes per individual. The solutions can be provided as brief Swedish explanation texts or as sketches.

The design workshop was divided into three sections using two different approaches. Two participants engaged in the design workshop, one specialising in product design and the other working as a design consultant. The initial technique employed in the workshop is referred to as the XYZ approach, as proposed by Ulich Eppinger. Each of the three categories; function, usage, and aesthetic had a five-minute timer set for sketching. Furthermore, the group assessed these sketches using the 2x2 approach (Lewrick, Link, Leifer, 2020). The results are located in figure 16. The three solutions with the highest practicality and value were selected for the last part of the workshop after discussing the results. In the third segment, the user was given a total of seven minutes to further develop upon the initial three designs.

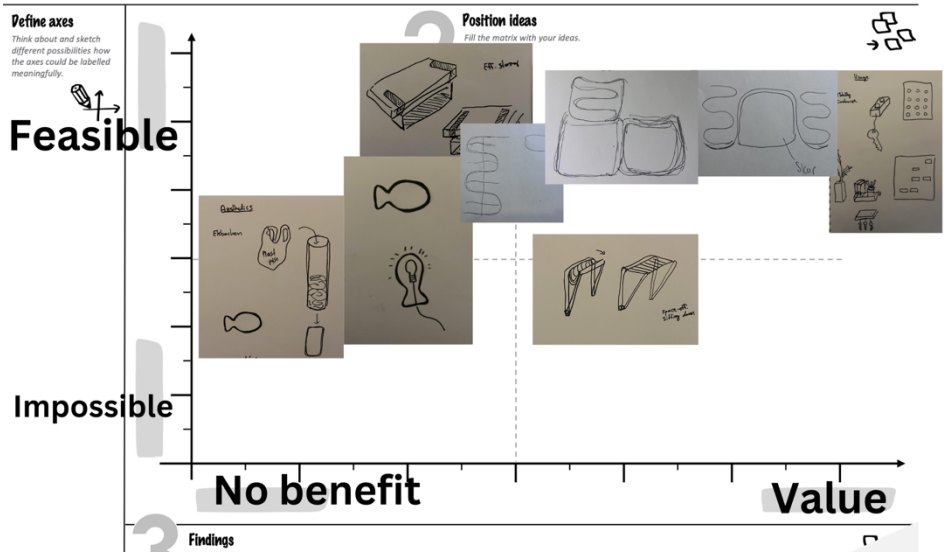

Figure 16: 2x2 approach results

6.5 Brainstorming

The purpose of the brainstorming process is to produce a lot of ideas and concepts. According to Tim Brown, some surveys shows that motivated individuals have the ability to produce a greater number of ideas within the same amount of time when working independently. According to other case studies, brainstorming is just as important for creativity as exercise is for heart health. Both sides have truth, as is so frequently the case. Ironically, brainstorming is a systematic method of deviating from established frameworks (Brown, 2019).

In the absence of rules, a group lacks a structure to facilitate collaboration, resulting in a brainstorming session that is prone to either becoming a highly organised gathering or a chaotic and unproductive exchange characterised by excessive talking and little listening.

IDEO has designated spaces specifically for conducting brainstorming sessions, with the rules explicitly displayed on the walls, one of which is "Defer judgement." Promote unconventional ideas. Maintain concentration on the subject matter. In my opinion, the most crucial principle among them is "Leverage the ideas of others." (Brown, 2019)

Martin & Hannington have developed some brainstorming guidelines in order to foster a secure environment where participants feel free to share their thoughts. Some of the guidelines are: to prioritising quantity above quality, refraining from making judgements, and building upon each other's ideas.

Keeping everything mentioned above in mind, multiple brainstorming sessions were held by creating sketches. The outcomes of the design workshop were utilised to further develop the concepts put forth by the participants. The primary objective was to examine the many categories already established: function, usage, and aesthetics. Each category was thoroughly examined, and then they were integrated to form complete concepts.

6.6 Parallel Prototyping

The usage of parallel prototyping allows the designer to quickly create several ideas and create low-fidelety prototypes of them in order to evaluate. One of the problems with designing is that the designer might favor an idea early on in the process, which prevents
the designer from fully exploring other design options. The technique called “parallel prototyping” enables several designs to be evaluated, and therefore the designers' attachment to a specific design decreases (Brown, 2019).

6.7 Testing

During the Test mode, one can ask the users for feedback on the prototypes you've made and further develop empathy for the target audience. Another chance to get to know the user is through testing; however, in contrast to the first empathy mode, this stage involves more problem framing and built testable prototypes. These two aspects tend to concentrate user involvement, but its important to not limit the "testing" efforts to finding out if users find the solution acceptable or not. Rather than giving up, keep asking "Why?" and concentrate on what can be discovered about the other person, the issue, and possible fixes.

6.8 Concept selection

Following the completion of brainstorming, mind mapping, design workshop and parallel prototyping, an initial assortment of concepts was chosen to undergo evaluation through user testing. Four concepts were chosen for user testing and transformed into miniature prototypes using a 3D printer, each concept consisted of a lower part and a upper part. They were chosen based on their diverse designs to obtain as comprehensive feedback as possible. All of these designs were based on their fulfilment of a minimum of two of the themes specified in table 6.

6.8.1 **User test 1**

Four individuals from the specific demographic were invited to evaluate the chosen hallway designs in order to gain a more in-depth understanding. The assessment was conducted by asking a sequence of questions to the participants. Afterward, the participants were given the task of evaluating the concepts based on three categories: Usage, Function, and Aesthetic. In order to evaluate them, the participants were provided with the chance to rate the concepts on a scale of one to four, where four indicated the maximum degree of alignment with the subject, and one the minimum.of alignment with the subject.

Subsequently, a comprehensive summary of the outcome from each category was generated to ascertain the most suitable concept overall. The results for each category for various concepts were also compared in order to obtain a more profound comprehension of the advantages and disadvantages.

The input from the questions was also assessed to analyse various parts of the concepts and acquire a more comprehensive grasp of the users' feelings and opinions.

Concept 1
The user appears to have a clear understanding of the utilisation of the lower section of Concept 1. However, the customers believed that the lower section could be more effectively utilised as a TV stand. The participants appreciated the lower part's utility, as it offers plenty of space for storage

and the option to incorporate baskets for item organisation. The lower part's aesthetics were deemed to have a slight 1960s appearance. The study revealed that the users found the visual appeal of the lower section to be pleasing.

Based on the testing result, the top part of Concept 1 demonstrates an average level of usefulness. The top part serves many purposes, including functioning as a clothing rack, featuring hooks and a shelf for accessories. Additionally, the 3D-printed components provide accommodation for accessories and storage space for items. The design of the top part appeared to be more complex, resulting in a visually hefty appearance. Another notable discovery about the top part was that consumers expressed a preference for symmetry, as they believed it generated a sense of peacefulness.

Figure 17: Concept 1

Concept 2

Concept 2 yielded further intriguing discoveries from the user testing. The lower portion was primarily regarded as a freestanding piece of furniture. The customers encountered difficulty comprehending the storage method due to the unconventional shape of the lower part. The lower half of the furniture had a more decorative style, resembling a bureau rather than a central piece of hallway furniture. They highlighted that the dimensions of the furniture were excessively large to align with the hallway concept, and its form compromised its practicality.

The upper portion provided comparable results in terms of the Usage and function categories, similar to concept 1. The upper section has various purposes, including functioning as a clothing rack, featuring hooks, and

providing a shelf for accessories. The 3D-printed components were considered as a potential solution for additional storage. However, the users discovered that the size of the design was insufficient to conceal anything. Users expressed doubts regarding the limited capacity of the 3D components, which could result in their accessories being displaced and dropping into the floor. Another noteworthy remark indicated the potential for their accessories to become trapped within the furniture due to the nature of the 3D-printed shape.

Figure 18: Concept 2

Concept 3

Concept 3 was developed to facilitate modularity. The results of the design workshop indicated that additional investigation into modularity would be beneficial. The parts can be vertically stacked or horizontally arranged, resembling a puzzle-like configuration. The results of the end-user testing indicated that the participants found it straightforward to comprehend the process and location for storing their belongings within the concept. On the contrary, the users encountered a deficiency in the provision of hanging facilities for garment items, such as jackets and coats. In terms of aesthetics, the users found it visually appealing and enjoyable, however they felt it was somewhat excessive for their halls.

Following a conversation with Ekbcken Studio, they provided input indicating that this furniture appeared intriguing and had potential for further expansion outside the scope of this thesis.

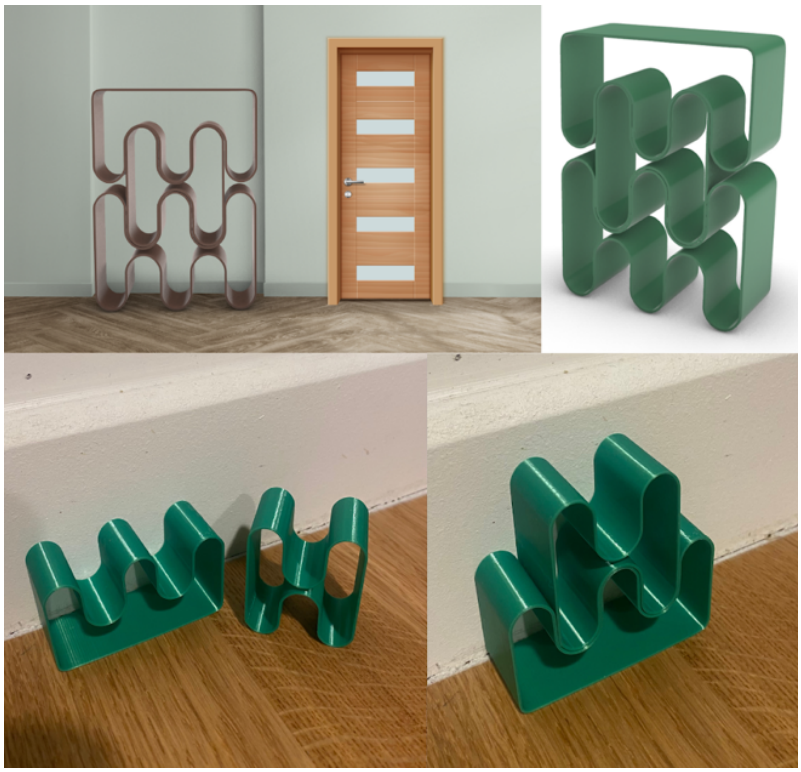

Figure 19: Concept 3

Concept 4

This design was shaped to accommodate a smaller storage area. This design enables storage to be housed within the extended section and also to be hanging in the openings. The user tests revealed that comprehending the storage process was effortless, nevertheless, the storage choice proved to be less practical due to its limited capacity for accommodating numerous items. Additionally, there is a possibility that coats may come into contact with the floor when they are hung up, as this solution does not extend to a significant height on the wall. The customers perceived the looks of this furniture to be more suitable for a child's room rather than for usage in a hallway.

Figure 20: Concept 4

Results user test 1
User testing 1 produced multiple interesting discoveries. The following table displays the outcome of the ranking of the corresponding concept.

Table 7: Results user test 1

Category	***Concept 1***	***Concept 2***	***Concept 3***	***Concept 4***
Function	10	11	9	10
Usage	12	11	9	8
Aesthetics	13	14	8	5
Result	35	36	26	23

The findings indicate that concept 1 achieved the highest overall ranking, with concept 2 following closely behind. Concept 1 exceeded concept 2 in the categories of Usage and Function, but concept 1 surpassed concept 2 specifically in the category of aesthetics. Three participants found the upper component of concept 2 to be perplexing in terms of the utilisation of the 3D-printed pieces. The participants expressed that they would have challenges in acquiring objects, which led them to actively avoid doing so.

The participants perceived that the storing functions of concept 1 and concept 2 were comparable. Nevertheless, it was evident that concept 1 provided greater capacity for keeping objects due to the fact that the 3D-printed elements of the upper components could function as shelves on the organic shapes. Regarding the bottom component, concept 1 was deemed

by two participants to be more viable for storing a greater quantity of objects compared to concept 2. The participants were unsure about how to keep all of their shoes due to the unconventional forms of concept 2.

In contrast, concept 2 outperformed concept 1 in terms of the aesthetic category. The reason for this was the large and unwieldy look of the upper portion of concept 1, which did not align with the design of the lower component. Although concept 2 had a more cohesive design aesthetic, it nevertheless failed to captivate all of the participants due to its lack of attractiveness.

Concept 3 and concept 4 saw a notable decrease in scores, which can be explained to various factors. Concept 3 featured a modular system, however it did not provide the option to hang coats and jackets, which the participants much desired. Additionally, concept 4 suffered from a storage area that was inconvenient and lacked space efficiency. The visual appeal did not receive a high rating due to the participants perceiving the concept as "clumsy," which resulted in a lack of a welcoming sense.

Concept 4 was deemed impractical as hallway furniture due to its insufficient and lacking storage capacity. On the other hand, the concept was associated with mobility in the corridor. Simultaneously, the participants emphasised that the absence of storage space would lead to a messy corridor, with shoes and bags likely being placed on the floor, thereby reducing the available space in the hallway.

6.8.2 **User test 2**

The findings from the initial testing were incorporated into the prototypes of Concept 5, Concept 6, and Concept 7. These solutions are specifically designed to provide additional room for shoe storage. Another design iteration prioritised enhancing the accessibility of the stored objects while still maintaining an inviting ambiance for the furniture pieces. Both of these elements were identified as user requirements during the Idate phase. The role of providing storage for hanging clothing, bags, and accessories is maintained due to their high level of importance to users. The furniture hallway concept was developed utilising 3D-printing as the primary manufacturing method. The designs prioritise simplicity in organic shapes to enhance practicality.

Concept 5
Concept 5 is the outcome of the iterative design process that started with Concept 1. Based on the user testing results, it was determined that the upper component in concept 1 had high ratings across all three categories. However, it was noted that the upper section was somewhat bulky. Consequently, the choice was taken to select one of the parts. This section was repositioned horizontally along its length, as opposed to its prior vertical orientation. To facilitate coat and jacket storage, it was determined that three racks would be installed on the upper section. These racks allow for the convenient storage of accessories by providing the option to attach hooks.

Regarding the lower section, it was decided to maintain the overall design while enhancing its organic form. This was done to improve its compatibility with the Ekbacken Studios portfolio. Given that the concept remains highly regarded for its usage and functionality, the whole design should adhere to these two criteria.

Figure 21: Concept 5

Concept 6
Concept 6 incorporates organic curves to provide more unconventional and innovative hallway furniture compared to traditional designs typically encountered during the empathise period. The traditional hallway furniture exhibits a more angular appearance with distinct edges. Regarding the category Usage, user testing revealed that the upper half of the item is well-suited for storing various things due to its organic design, which acts as a

divider. In contrast, it appears that accessing the things may provide a challenge. The consumers found the function of hanging clothes to be easily comprehensible and enjoyable. In terms of aesthetics, the abundance of organic shapes appears excessive, leading to a bulky and complex appearance.

Users found it challenging to store stuff in the lower section. The customers expressed concern with the storage of multiple pairs of shoes, noting that using this furniture piece may lead to a disorganised appearance. In terms of aesthetics, the organic curves of the bench give it the appearance of a piece of furniture that could be suitable for a living room setting, for instance. They found that the shapes did not evoke a sense of welcome, which is one of the user requirements.

Figure 22: Concept 6

Concept 7

Concept 7 is a modified version of concept 2, where the upper portion has been altered to reduce the size of the shapes and make them less bulky. They possess internal compartments that facilitate concealed storage. The inclusion of concealed storage was identified as a crucial requirement by the user during the ideation phase and was considered essential. The concealed storage enhances the hallway's appearance of neatness, so fostering a more inviting ambiance.

The lower half was designed to retain a spacious storage area while reducing the overall height of the piece. The circular form draws inspiration from Concept 2, while the overall shape takes inspiration from Concept 1. The shapes are intentionally kept simplistic to avoid complexity, leading to a bulky design that disturbs the user.

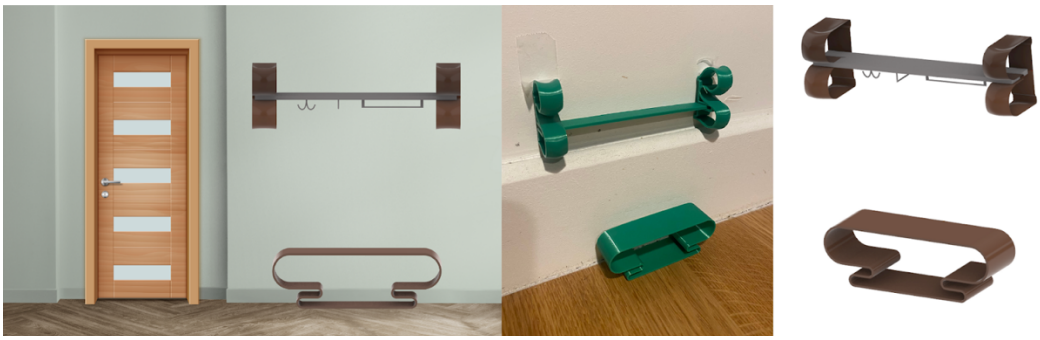

Figure 23: Concept 7

Results user test 2

The following table presents the outcomes of the ranking from the four participants in user test 2.

Table 8: Results user test 2

Category	***Concept 5***	***Concept 6***	***Concept 7***
Function	8	6	11
Usage	9	5	10
Aesthetics	9	4	11
Result	26	15	32

The results indicate that idea 5 was easily comprehensible in terms of storing the consumer goods, however its functions were rather confusing. The user comprehended the instructions regarding the storage of accessories and the hanging of clothing in the upper section. Regarding the lower half, the user test indicated that users found it clear in terms of usability. However, there were concerns raised about potential limitations in storage capacity due to its design.

For concept 5, The upper part's aesthetic appearance was admired, however it appears to be more of an artistic creation rather than a practical piece of furniture. The lower section's appearance was deemed to resemble a "quirky bench" that was better suited as a complementary element to the hallway concept rather than a central piece. The lower part's shapes appeared intriguing, although they might be excessively unconventional to seamlessly integrate into the customers current halls.

Upon examining the questions posed during user test 2, it became evident that the functionalities of idea 6 were perplexing in regards to the storage of accessories, shoes, and even larger objects like bags. The participants were concerned about using the concept, and three expressed concerns that their possessions could be hard to locate in the expanded cavities of the upper component. Thus, it was determined that concept 6 did not meet the criteria of being user-friendly. All participants in the user test expressed that they were not attracted to the aesthetic of the concept. Consequently, this indicates that the user's requirement for an appealing design was not met.

While Concept 7 was rather simple to comprehend in terms of storing items in the upper section, the 3D-printed components appeared to be insufficiently spacious for accommodating larger items like bags. The users did not like the visual appeal of the upper half in terms of aesthetics. The usage category received a moderate rating due to its comprehensibility, with the exception of the concealed storage aspect. The upper part's functionality received high praise due to its versatility in accommodating various types of clothing and accessories through many hanging options. Nevertheless, the consumers desired additional options for concealing and storing items.

The lower section of concept 7 demonstrated its capacity to provide ample storage for footwear, handbags, and potentially even containers that might discreetly conceal various goods. The customers found the functions, such as storage, easy to comprehend and the lower part convenient for seating. The lower part's aesthetics were highly recognised, with people seeing its integration into their current corridor. The users perceived the lower half as having a "simplistic design" that was not overly complex.

6.8.3 **User test 3**

Upon analysing the outcomes of user test 2, significant feedback was gathered and further examined. One of the outcomes revealed that the participants expressed dissatisfaction with the aesthetic and functional aspects of the upper section of idea 7. Consequently, a decision was made to develop an alternative concept that would more effectively meet the requirements of these categories.

User test 3 was done and evaluated in a manner consistent with the two prior user tests. In this user test, there were two concepts, one of which being concept 7. Concept 7 was chosen since it had the highest score during user test two. For this particular user test, the number of participants was reduced to three, in contrast to the prior tests which had four participants.

Concept 8
Based on the feedback from previous user tests, concept 8 was developed. Concept 8 is mainly a modified version of concept 7. The lower portion of Concept 6 provided the basis for the entire design, the design of both components is also influenced by concept 6, achieved by rotating the design of the 3D-printed parts by 90 degrees while maintaining the proportions of the B-shaped forms.

With the B-shaped components specifically designed to incorporate storage space compartments for accessories, the design enables for easier access and organisation. The upper component serves numerous storage functions, including a clothing rack, hooks, and a shelf. These features was highly valued by participants during user testing of previous prototypes. Concept 8 was designed to fulfil the user's desire for mobility in the hallway category.

The 3D-printed lower component is designed to be an exact mirror image of the higher component, ensuring symmetry. The decision was made to produce an aesthetically pleasing design that appeared well-structured, thereby evoking a sense of peacefulness. Due to the user's expressed desire for shoe storage during the emphasised phase, a shoe rack was added to the lower compartment. In order to prevent the accumulation of filth from shoes in the 3D-printed material, the design has a separate shelf made of a different material for storing shoes. The lower compartment also has smaller spaces for storage to optimise the available storage space.

Figure 24: Concept 8

Results user test 3

The following table presents the outcomes of the ranking from the three participants in user test 3.

Table 8: Results user test 3

Category	Concept 8	Concept 7
Function	5	4
Usage	5	4
Aesthetics	6	3
Result	16	11

Upon analysing the findings from User test 3, the was the last user test conducted. Concept 8 was selected for further refinement and development into the final concept. This choice was reached based on an evaluation of the rating outcome and the responses provided by the participants. It was evident that, in the Function category, participants said that both concept 7 and concept 8 offer various storage possibilities for the upper section. However, when considering the Usage category, concept 8 appeared to provide easier access to the 3D-printed parts for storing accessories.

The participants expressed a strong preference for the lower compartment of concept 7 and concept 8. However, in terms of aesthetics, concept 8 received higher appreciation. All participants agreed that concept 8 would be a desirable addition to their hallway as a piece of furniture. Both concept 7 and concept 8 provide shoe storage capacity, however, a drawback of concept 7 was the potential for dirt from the shoes to become caught between the layered springs of the 3D-printed material. The presence of dirt can pose challenges in terms of removal and potential injury to the material, as shoes have the capacity to introduce both mud and water.

7 Further Development of Final Concept

The decision was made to investigate the proportions, mechanical design of attachments, and hidden storage of the chosen concept, concept 8, during the Further Development phase. In order to accomplish this, both physical and digital prototypes were developed to identify the optimal design for the concept.

7.1 Sketch Mockup

During the initial stages of the Final Concept phase, basic physical prototypes were created to provide a tangible representation of the concept's proportions. Thus, this phase primarily aimed to determine the ideal height for the furniture that effectively maximised the room's vertical space while preserving its overall proportions. The decision was made to construct the prototype using the proportions depicted in Figure .

The measures were derived from the dimensions of the competitor's hallway furniture, and constraints imposed by sizes for items such as hangers and shoes.

Figure 25: Overall dimensions used for sketch-mockup

Figure 26: Sketch mockup

The findings from the sketch mockup demonstrated that an individual with a height of 170 centimetres may effortlessly reach the clothing rail. The shoe shelf can accommodate around five to six pairs of shoes, while the space below can hold a maximum of four pairs. Based on the selected length of the upper and lower component, it was determined that the shoe storage was adequate. The decision was made based on the data from the empathise phase, which involved evaluating current hallway furniture and analysing their dimensions. Additionally, the decision was influenced by the results of interviews, which revealed that 70 percent of the participants and their family owned six pairs of shoes that they used everyday. The upper component's height from the floor was accessible to an individual with a height of 170 centimetres. If the upper part were positioned at a higher level, it could pose challenges for individuals who are shorter than 170 centimetres. Hence, the height of the upper section was considered adequate. However, as the bottom and upper components are distinct, the final user has the option to position the upper component at a greater level. Placing the upper component too low is not advisable as it may reduce the available space for hanging outdoor clothing.

The height of the two pieces was sufficient, but to accommodate larger goods, it would be preferable to increase the height by six centimetres.

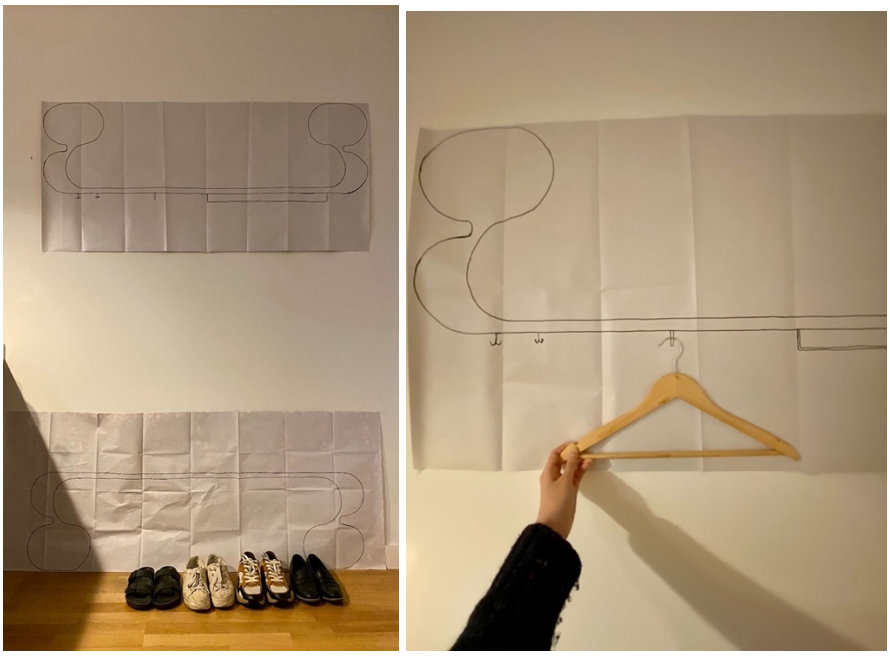

Figure 27: Sketch mockup

To determine the exact placement of the hooks, the clothing hanger was utilised to position the inward clothing rail and the clothing rail that runs along the length, which is A. The clothing hanger measures 35 centimetres in length, which is considered a standard size according to the study department. The distance between clothing rail B and the hooks, as well as the second rail, measures 18.5 centimetres. As shown in the figure, the distance between items is insufficient, which may lead to potential collisions between the stored garments and goods, so making them difficult to access. Consequently, it was decided to reduce the length of rail A from 54 centimetres to 48 centimetres. The combined length of rail A and B is 78 centimetres. According to the storage study by Elfa, notably in the 3.4 Furniture Industry area, it was concluded that the clothing rail should have a sufficient length and should not be too short.

Alternatives materials

Through the continued refinement of the final concept, it became evident that alternative materials will be employed for constructing the cabinet, clothing rail, attachments, and shoe shelf. Consequently, analyses were carried out to evaluate various materials that could be utilised for these components, while also adhering to Ekbacken Studios' principle of maintaining a minimal carbon impact. An analysis was conducted on the market for multiple materials, resulting in a functional analysis. The result is displayed in table 9.

Table 9: Alternative materials and their CO2/kg emissions.

Material	CO2/kg
SSAB Zero Steel	0
SSAB fossil-free Steel	0
HYDRO: Low carbon aluminium	4
HYDRO: CIRCAL 75R aluminium	2.3
HYDRO: CIRCAL 100R aluminium	0.5

7.2 Development of Cabinet Solution

Execution 1

The initial implementation of the integrated cabinet had corner placements in both the top and bottom sections. The cabinet was specifically crafted to seamlessly integrate into the B-shaped section, functioning as concealed storage for smaller objects. Nevertheless, it was concluded that further improvements should be implemented to the side storage. This choice was determined by the analysis of user feedback obtained from extensive testing of the full-scale paper prototype. A user faced challenges with the side storage due to the user trying to store bags and larger clothing pieces such as jackets. Given the findings of the idate phase, it became evident that consumers required spacious concealed storage, not just for smaller objects. Further exploration was conducted on the design. The output of execution 1 is shown in figure 28.

Figure 28: Execution 1 of cabinet solution

Execution 2

The design iteration following the first execution aimed to incorporate a more spacious area for concealed storage, as this was identified as a crucial user requirement and deemed essential based on user testing. Another objective of this implementation was to prioritise accessibility, as the users expressed their want to efficiently store their belongings and feel comfortable in their halls. These factors were also crucial for achieving a better organised corridor, which would consequently enhance its welcome environment. Hence, the cabinet is positioned within the upper section, which has been expanded to provide additional storage capacity. The cabin's location provides enhanced accessibility as it eliminates the need for the user reach down in order to put away their belongings. The outcomes of execution 2 are displayed in figure 29.

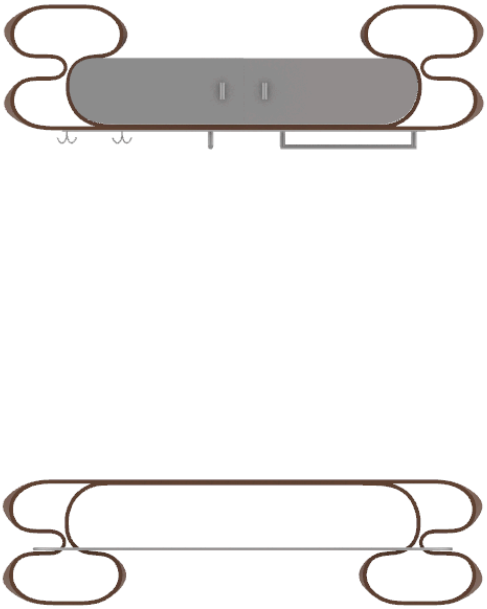

Figure 29: Execution 2 of cabinet solution

7.3 Development of attachments

To ensure the security of the upper portion, it was determined that an attachment solution was necessary. During the development process of the many design concepts, various attachment designs have been investigated. This measure was essential due to the unavoidable constraints of the 3D-printed material, which limits the possibility of drilling or cutting. Such actions can induce delamination between the layers of the print. Hence, the attachment is specifically engineered to come into contact solely with the 3D-printed material and serve as a support during its installation on the wall. Extra attachments are fastened to the rear of the Cabinet, adjacent to the wall.

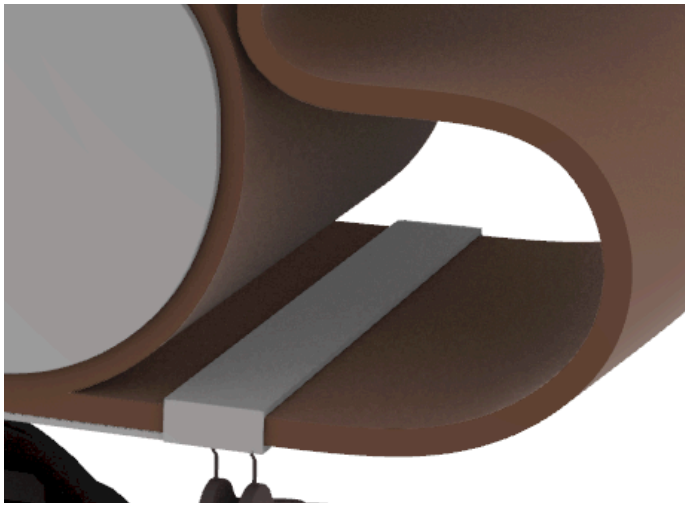

Figure 30: Attachment solution

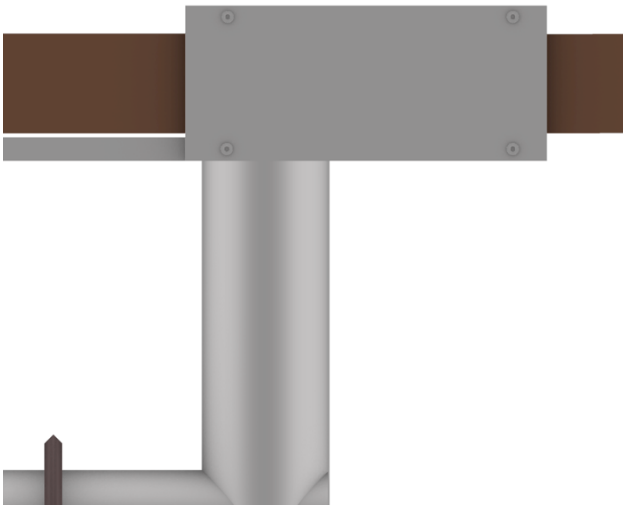

Figure 31: Detailed picture of attachment

8 Final Concept

The ultimate iteration of the conceptual design Concept 8 is a furniture concept designed for hallways, offering plenty of storage for a wide range of items. By utilizing partially exposed and concealed storage, the design achieved a sense of both openness and organization when entering the hallway. According to Consumer Insight, the organic shape of the concept brought a unique and personalized element to an otherwise dull environment.

8.1 Overall Design

The material used for the 3D-printed parts is PENYLON, which is the material type that Ekbacken Studio currently uses. For the cabinet, the material steel was chosen because of its low carbon footprint and its durability. The shelf that is incorporated into the bottom part is also made out of this steel.

The furniture was specifically crafted to align with the aesthetic of Ekbacken Studios product line. The 3D-printed parts are made from PENYLON, the material of choice utilized by Ekbacken Studio. The material used for the cabinet is steel due to its minimal carbon footprint and high durability. The shelf integrated into the lower section is also constructed from the same steel. This concept of designing lasting hallway furniture contributes to a more sustainable approach to furniture purchase, aligning with the requirements of the Consumer Purchase Act's section on sustainability. The ultimate rendition of the furniture is displayed in Figure 33.

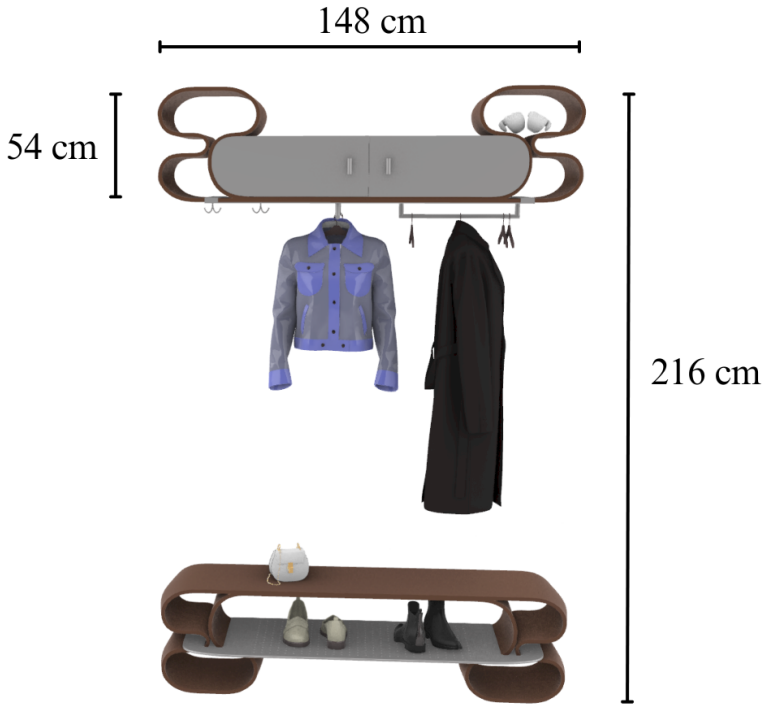

Figure 32: Overall dimensions of final concept

Figure 33: Final Concept

8.2 The Clothing Rail

The clothing rail offers multiple storage alternatives, since it was determined necessary after evaluating the user's needs. The choice to incorporate hooks was based on the findings from the empathised phase and user testing. During the observation of users, it became evident on three occasions that relying solely on hooks as a storage option posed challenges in retrieving garment items. By incorporating both hooks and two distinct

clothing rails, it facilitated convenient storage and retrieval of clothing, bags, and accessories, hence leading to a more organised hallway. According to the storage study by Elfa, notably in the Furniture Industry section, it was concluded that the clothing rail should have a sufficient length and should not be too short. Therefore, the installation of two rails, rail A measuring 40 centimetres and rail B measuring 48 centimetres, resulting in a total rail length of 88 centimetres, was deemed adequate for building a hallway furniture piece that could fit into the user's existing passageways in terms of size. The rail's height and position were established using benchmarked products and data collected during the primary research. This decision was made following the evaluation of the height using a sketch mockup.

Figure 34: Clothing rail

8.3 The cabinet

The cabinet was specifically built to have concealed storage, as it was identified as a crucial requirement by customers during the first assessment process and subsequently validated through user testing. The cabinet is designed to maximise storage capacity while adhering to the limitations imposed by the dimensions of the 3D printers and the overall aesthetic of the design. The cabinet is constructed from low-carbon steel sourced from SSAB, with the aim of creating a hallway design that is fully functional and has a low-carbon footprint. The Cabinet is specifically intended to be inserted into the 3D-printed component, enabling concealed wall mountings at the back of the cabinet. Further details regarding these attachments are provided in section 8.4. The cabinet's colour can be tailored to the customer's preferences, enabling a more individualised look for their hallway. Due to the cabinet's elevated position from the floor, the handles were intentionally designed to protrude from the furniture, facilitating convenient usage. The handles are designed with simplicity to seamlessly integrate with the furniture and evoke a welcome aesthetic.

Figure 35: Closed cabinet

Figure 36: Open cabinet

8.4 The attachments

The attachment is fastened to the rear of the cabinet using a hatching solution. The second component of the attachment is secured to the wall. The attachment is constructed from low-carbon steel sourced from SSAB, aligning with the principles of Ekbacken Studios. No strength evaluations are performed in this thesis as it focuses on a conceptual level. The ultimate configuration of the attachments can be seen in figure 37.

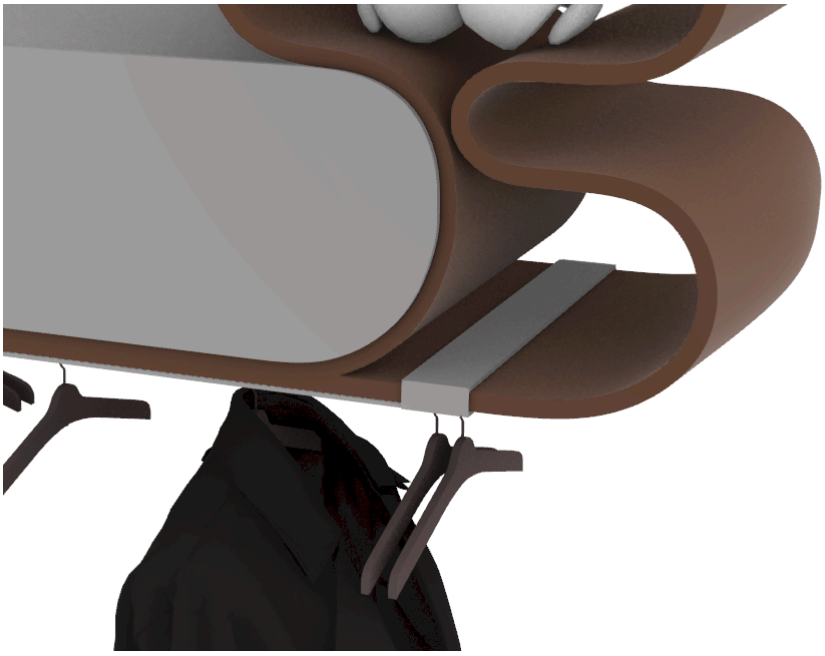

Figure 37: Final attachment solution

8.5 The shoe shelf

The implementation of the shoe storage system led to the creation of a shoe shelf made from low carbon steel sourced from SSAB. After analysing the user's requirements, it was concluded that a minimum of 70 percent of the participants and their families possessed at least six pairs of shoes that they regularly use. Consequently, they stated a need for shoe storage. As a result, it was determined to incorporate a shoe storage solution that maximised the available space within the given dimensions of the final design. The shelf is positioned at a height of 27 centimetres above the floor. Additionally, there is sufficient space beneath the shelf for storing shoes, thereby enhancing the spaciousness of the hallway while fostering a sense of organisation for the user. A maximum of nine pairs of shoes can be stored in total.

Competitor products and shoe measurements were benchmarked to ensure sufficient shoe storage. The results led the development of the shoe shelf with a specific width and depth. The shoe shelf possesses a greater depth compared to the 3D-printed furniture that encircles it. This deliberate

design choice aims to reduce the amount of material required for 3D-printing, thereby minimising the printing duration and resulting in a more expansive hallway. To prevent filth from accumulating on the shoe shelf, tiny holes were added to the shelf. Figure: Illustrates the shoe shelf.

Figure 38: Shoe shelf

8.6 Storage for smaller items

The curved structure of the top and bottom sections enables efficient storage of small items within the B-shaped extremities of the 3D-printed material.These storage facilities function as the main location for storing smaller objects, while also providing the user with the option to keep larger items in the cabinet. The primary objective of this storage solution is to facilitate convenient access of accessories and provide additional capacity for storing various goods.

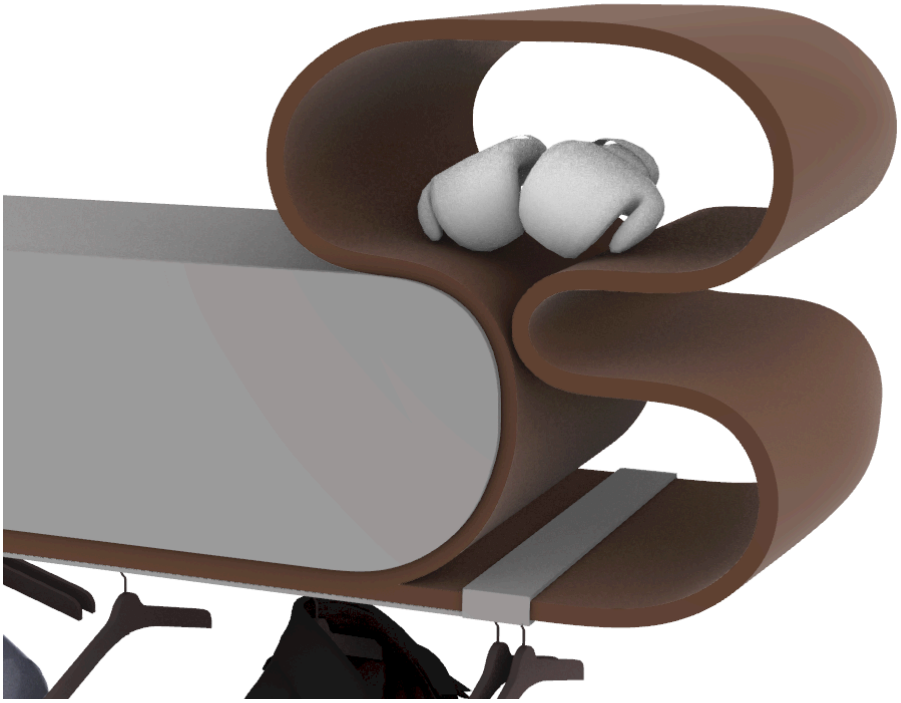

Figure 39:Small storage

9 Discussion

This chapter will analyse the ultimate concept in relation to the theoretical framework and context. The analysis will examine the impact of the design approach on the outcomes, as well as the chosen methodologies. Ultimately, a summary of how the project addressed the research inquiries will be provided.

9.1 Fulfillment of Project Goal

The Master Thesis project aimed to create a hall furniture idea that aligned with the company's design and appealed to their target audience. To explore, create, and develop a hallway furniture concept, the project used

the Design Thinking process. Since this project involved a process with a lot of rapid prototyping and iterative processes, this method was considered as the most proper approach. The main manufacturing method used for the hallway concept has been a driving aspect throughout the design phase.

After implementing the Design Thinking approach, the result was the development of a comprehensive hallway concept. The final concept is highly compatible with Ekbacken Studio's portfolio, owing to its visually pleasing appearance, the practicality of its design, and its versatility in use. Regular discussions were conducted with Ekbacken Studios to ensure that the progress of product development aligned with their expectations. In order to ensure that the hallway concept would align with the customer's requirements, an in-depth study was conducted to gain a deep understanding of the customer's needs and the current market situation. A variety of approaches were utilised to generate a wide range of design concepts and ensure that the design adequately matched the customer's requirements.

9.2 Fulfillment of User Needs

During the initial phase of this thesis, research was undertaken to comprehend the client requirements, analyse the current market, and acquire other significant insights. The acquisition of data was conducted through primary and secondary research. The primary research comprised interviews and observations conducted with the target audience. This research acquired significant insights that were utilised to assess customers' requirements. Given the 20-week timeframe for the project, the quantity of participants in the observations and interviews was considered sufficient. Nevertheless, the outcomes could have exhibited greater diversity if a larger number of observations or interviews had been conducted. An other factor that may have influenced the research findings is the specific geographical region in which the study was conducted. The secondary research includes benchmarking, examining fully operational hallway concepts, analysing individual pieces of hallway furniture, and studying 3D-printed furniture.

Assessing the requirements during the concept development phase was difficult because of the specifics involved in the production of 3D-printed furniture. Due to the constraint of avoiding any overlapping sequences, the design possibilities for the furniture are restricted. The presence of organic shapes poses a challenge in developing a versatile concept that fulfils the

requirements of both Function and Usage categories. The dimensions of the 3D-printer posed a constraint during the concept development phase, as the maximum width and length fell short of what was required for a fully integrated piece of furniture encompassing both the upper and lower parts. To meet the user's requirement of storing shoes, accessories, and coats, it was decided to design two separate pieces that would fit within the dimensions of the 3D printer.

The Usage category was assessed to fulfil the requirements, as it facilitates convenient storage access, is user-friendly, and offers numerous storage capabilities, resulting in a more organised corridor. The final idea was determined to fulfil the user's requirement for movement in the hallway. This is because the concept's depth is not beyond that of hallway furniture available in the market, as confirmed by the analysis of observational data. The fulfilment of fitting into the users' preexisting hallway was likewise determined to be satisfied, based on the same reasoning as the aforementioned user demand. The ultimate design additionally enables customers to personalise the product by selecting the colour of the steel components.

Moreover, the categorization function was also considered fulfilled. By conducting user testing and keeping personas in mind during the design process, a diverse range of storage possibilities was incorporated into the final concept. The ultimate design enables the storage of clothing, whether hidden or visible, provides choices for storing bags, and includes spaces for accessories. Items can be stored on the upper surface of the cabinet and the upper surface of its bottom section. If more storage space is required for accessories, baskets can be placed on these surfaces. Additionally, it is possible to hang items on the hooks. The user's requirement for enabling space efficiency is fully implemented throughout the entire final idea. For instance, if there is a need for more shoe storage, one can put them underneath the shoe shelf. The 3D-printed extruded components function as a storage solution for smaller goods, satisfying the user's need for an efficient and easily accessible storage choice.

After conducting user tests and holding meetings with Ekbacken Studios, it was determined that the aesthetic category met the user's requirement for an attractive design that aligned well with Ekbacken Studios' portfolio. The concept's organic shapes seamlessly integrate into Ekbacken Studios' product portfolio. The user's requirement for enabling concealed storage is

also fulfilled, because of the integration of the cabinet. Consequently, the ultimate design promotes a sense of welcoming as the hallway furniture facilitates organisation. Due to its distinctive design featuring organic shapes and the manufacturing technique employed, the concept could also be regarded as a decorative addition to the hallway. By incorporating multiple storage features into the final design, the hallway can be made to appear more expansive. This is because the bags and shoes, which would otherwise be scattered around the room, now have designated storage areas.

9.3 Reflection

Design Process
The design process has been non-linear, characterised by numerous valuable ideas, and the refinement of the concept has undergone multiple iterations. The selected methodology for this master thesis project was the Design Thinking Process, which employs a User-Centered approach. The selected methodology was appropriate for this project as the creation of many concepts required numerous prototypes with iterative design. The stages of prototyping and testing yielded a significant quantity of data for assessment, which in turn drove the development of new concepts. Overall, the selected methodologies proved effective in this project and delivered a satisfactory outcome.

An obstacle encountered in the development of the hallway concept was the need to make compromises in order to create a functional design that also has visual appeal for the user and could be integrated into Ekbacken studios' range of products. One of the compromises made was to simplify the organic designs in order to prioritise practical tasks, such as providing sufficient space for shoes.

The limitations imposed by the printer's dimensions caused a challenge in creating a concept that adequately met the user's requirements inside a single piece of furniture. Thus, it was determined at an early stage to generate conceptions comprising two separate parts.The decision was taken based on the user's requirement for multiple storage functionalities, as well as the findings from the empathise phase, which indicated that the users desired the ability to hang garments and store shoes. Another user need was the implementation of a seating space, which was considered less

significant. This user demand could be more easily satisfied by making a lower component.

The 3D-printing technique employed by Ekbacken studios firmly restricts the overlapping of layers. During the design process, it was important to take into account this additional constraint in order to create a hallway furniture concept that aligns with their 3D-printing technique. Moreover, the production technique occasionally posed challenges in creating a practical design that maintained visual alignment with Ekbacken Studios' product assortment.

Selected tools

Rhino

Rhino was chosen as the primary tool for creating 3D models of the concepts. The Software was selected due to its exceptional adaptability in swiftly and effortlessly creating elaborate organic forms. The software offers a wide range of features and is highly intuitive for users. Although it can be challenging to rectify a mistake, doing so may result in additional effort as there is a possibility of having to redesign the task. An alternative software that could have been appropriate for this job is a computer-aided design (CAD) product like Solidworks or Creo. The drawback of these software programmes is in the limited design flexibility when it comes to sculpting complex organic forms.

Selected methods

Observations of the user

Conducting observations of users engaging with their hallway furniture proved to be an effective method for obtaining valuable insights about their needs. The observations yielded comprehensive insights about the user's sequence of actions when entering and exiting their hallway, both from work and when going to meet friends. This facilitated a more profound comprehension of the users' emotional state within the hallways, the challenges they encounter, and the specific areas of the hallways requiring additional investigation. By including semi-structured observations, a deeper understanding of the user's mental process was revealed. This was beneficial as it can be challenging to determine at what point in the process of utilising hallway furniture the user may encounter an unpleasant experience. Upon discovering the instances where consumers experienced negative emotions towards their behaviours, it facilitated the provision of feedback for enhancing the final concept.

Observation with empathy

According to Tim Brown, it is crucial for the designer to personally feel the consumers' perspective in order to gain a comprehensive understanding. By exploring multiple hallways throughout various residences, a comprehensive collection of data could be acquired, revealing insights that may not have been anticipated through alternative means. One initial intriguing discovery was the significant variation in hallway sizes observed, making it challenging to establish early dimensions for the concept. Another notable discovery was the absence of shoe storage. Out of the nine halls seen, only four of them had a shoe storage option. On the contrary, all participants reported their preference for having a designated space to store their shoes during the interviews. The results of the observations conducted with empathy could vary based on the observer's individual characteristics. Given the potential differences in attitudes towards specific stages of the process, there may be variable advantages or disadvantages associated with the observed hallway furniture. However, conducting primary research using different methods can potentially mitigate this difficulty due to the enormous amount of data collected.

Secondary research

By conducting a benchmarking analysis, an in-depth understanding of the current market in terms of the types of furniture often used in hallways, their appearance, and the functions and purposes they perform. Through the analysis of several 3D-printed furniture pieces, insights were gained into the potential integration of organic shapes in design and the practicality of varied shapes.

Personas

The two personas that were created facilitated a knowledge of the users' behaviours and requirements. They provided great inspiration throughout the creative process that resulted in the final concept. By consistently being mindful of the consumers' wants, the attention may be directed towards the essential functionalities required for the ultimate concept. Both personas encountered a shortage of storage and need additional space for accessories as well as larger objects like bags. Considering the necessity for storage space, it was determined that it is also one of the essential requirements for the user. In addition, both personalities expressed a preference for a well-structured hallway. This was achieved by incorporating distinct storage areas for larger goods like bags and garments, as well as smaller compartments for accessories such as gloves and hats.

Brainstorming
The brainstorming sessions yielded a substantial number of initial design concepts and facilitated rapid and effortless sketching. This approach is an excellent technique to initiate and enhance one's ability to generate a wide range of thoughts. This serves as a favourable initial step to prevent the unwanted preference of a single thought, which may thereafter become challenging to relinquish. If a single proposal is given favour at the first phase of the project, there is a risk that other excellent ideas may be disregarded and not thoroughly examined, resulting in missed possibilities for even better ideas that align more effectively with the user's requirements. This strategy was employed throughout the whole Concept development duration, as design iteration was necessary following user testing.

Mindmapping
Mind mapping was employed to gain an in-depth understanding of the user requirements, organised into three primary categories. This approach proved to be quite effective in comprehending the classifications and supporting the systematic organisation of crucial domains for future exploration during the design process. After the mind map was established, it facilitated the design process by helping to maintain focus on the crucial design areas and ensuring that the necessary user requirements were fulfilled.

Design workshop
During the exploration of alternative concepts for the hallway, it was determined that user input was essential for the development of diverse hallway ideas. A design workshop is an excellent method for exploring many design possibilities and enabling participants to enhance each other's ideas. This approach facilitates the development of concepts by incorporating insights from evaluating the generated ideas, thereby generating new concepts depending on the feedback received.

The XYZ-method was employed at the preliminary phase of the Design Workshop. This method is an excellent strategy for stimulating participants to generate ideas rapidly. To prevent participants from becoming fixated on a single idea, this sketching session offered them the opportunity to think creatively and encouraged a sense of security during the process of producing concepts. The findings demonstrated the efficacy of this

approach in generating concepts productively, while also capturing the overall user requirements within the designs.

Moreover, the workshop yielded novel insights that had not been thoroughly explored in the first period of development. An exciting idea was to further investigate a modular hallway concept, in an innovative manner. Although this was intriguing, it was further enhanced during the concept generating phase. The findings of the user testing indicated that the modular principles were highly intriguing, but were considered rather impractical. This limitation may arise due to the constraint imposed by the selected manufacturing technology, as 3D-printing prohibits the overlapping of printed layers. The exploration of modular systems was hindered by the aesthetic design. It became evident during the development phase that incorporating organic shapes posed challenges in achieving a practical final design.

Prototyping & testing
The prototypes were subjected to user testing through a process of questioning the users, who were given the opportunity to view and engage with the prototypes. The utilisation of parallel prototyping facilitated the generation of a substantial quantity of ideas during the ideate phase, which could then be rapidly examined through user testing. This method proved to be highly effective in achieving fast outcomes and acquiring significant understanding to finalise the ultimate concept, while simultaneously satisfying the customer requirements and adhering to Ekbacken Studios' aesthetic principles. The user testing of the prototypes was crucial as it provided essential feedback to guide subsequent design iterations. The user testing yielded valuable insights regarding the significance of concealed storage and the versatility of providing many methods for storing objects. Consequently, a cabinet equipped with doors was introduced, along with hooks and a clothing rack. Another significant discovery was the users' desire for clear guidance on where and how to store their shoes. The task was complex because the aesthetics were primarily focused on organic shapes, making it difficult to accommodate a significant space for shoe storage. The prototypes were crucial in providing a tangible representation of the components, allowing for a comprehensive understanding of their physical appearance, touchable characteristics, and visual perspectives from various angles.

9.4 Future work

Given that this thesis is solely focused on a conceptual level, there are several aspects that may be taken into account for future research. An issue worth exploring in detail is the assessment of the strong attributes of the Final Concept. It is necessary to assess the attachments of the cabinet solution through calculations or FEM analyses to ensure their sufficient rigidity in supporting both the weight of the furniture and the contents contained within it. Additionally, it is possible to assess the minimum thickness necessary to do this. The seating area is another component of the Concept that should be subjected to Finite Element Method (FEM) analysis or estimated. The lower half must have adequate seating capacity to support a person without experiencing structural failure or sustaining any damage. Performing analysis on 3D-printed items can be challenging due to the limited coverage of material properties and the complexity of conducting Finite Element Method (FEM) analyses on the printer's layered structure.

Following the completion of the analysis, the next step would involve the production of a first full-scale prototype of the Concept, which would then be subjected to testing with users belonging to the target demographic. Once the product is operational, it becomes simpler to ensure its appropriate functionality and identify any potential drawbacks through comprehensive user testing. This task was omitted from the project due to its incompatibility with the project's time constraints.

Upon completion of the production of a fully developed product, the ultimate measurements can be determined. The height from the ground to the bottom of the upper portion can be determined by attaching it to the wall. In order to make a decision, it is also necessary to consider the length and height of the cabinet, as well as the lengths of the racks. It is recommended to examine the ergonomic quality of the grip on the cabinet door of the concept, as it will be regularly held.

10 Conclusion

HOW DOES MODERN HALLWAY FURNITURE LOOK?

Contemporary hallway furniture exhibits a diverse range of designs, each tailored to serve a certain purpose. The analysis conducted for this project revealed that hallway furniture typically falls into three categories: fully functional hallway furniture, hallway furniture with a single purpose, or modular solutions. All of them possess functionalities that enable a form of storing capability and are available in different dimensions. Another observation in today's market is the widespread use of rectangular-shaped hallway furniture that lacks forms that are organic. Hence, the ultimate design of this project exhibits a distinctive aesthetic that sets it apart from the current offerings in the hallway furniture market.

WHAT STRATEGIES MAY BE IMPLEMENTED TO ENHANCE THE OVERALL EXPERIENCE FOR CONSUMERS PURCHASING SUSTAINABLE FURNITURE?

- What strategies may be employed to attract customers to select environmentally-friendly high-end furniture?

Various tactics can be employed to improve the entire experience for consumers when buying sustainable furniture. One of these strategies is to provide information about the product's environmental friendliness. There are multiple approaches to do this. One option is to ensure that the website provides comprehensive information on the product's environmental attributes. Another strategy is to actively promote this information in physical stores. Lastly, it is crucial to present the information in a straightforward manner to ensure that customers understand how the product is environmentally friendly. Merely producing ecologically-conscious luxury furniture may not suffice to entice consumers. To attract people into purchasing a luxury goods, various strategies might be implemented. One of these measurements is examining consumer requirements and assessing them to design furniture that is visually appealing, functional, and practical.

WHAT STRATEGIES MAY BE IMPLEMENTED TO ENCHANCE THE MANUFACTURING PROCESS FOR HALLWAY FURNITURE?

Prior to producing hallway furniture, it is crucial to comprehend the specific needs and requirements that the furniture piece must fulfil. Otherwise, the manufacturing process may encounter challenges if the furniture has a complex structure without the necessary practical features. It is important to have a clear understanding of the materials utilised in the manufacturing process of hallway furniture. The manufacturing process of 3D-printed furniture is significantly influenced by the material used. This is due to the fact that the 3D printer operates at specific temperatures, has different nozzle sizes for extruding the material, and requires a specific bed temperature to ensure the stability of the print during the procedure. All of these factors must be assessed based on the furniture's design and the chosen material. In order to optimise the manufacturing process, it is crucial to conduct preliminary tests by printing smaller prototypes. This allows for a thorough examination of how the material behaves during the procedure and enables the identification of any potential printing defects. By taking this approach, it is possible to prevent expensive errors in terms of financial resources, time, and emotional distress.

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APPENDIX

A.1 Project plan and outcome

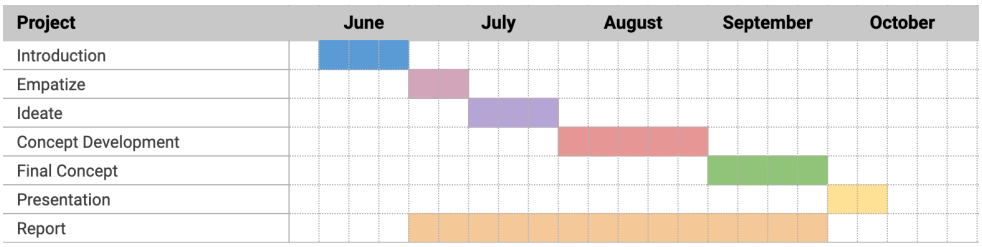

Figure A1: Project Plan

The project plan depicted in Figure A1 illustrates the distinct stages of the Design Thinking process, together with the scheduled time for presentation and report.

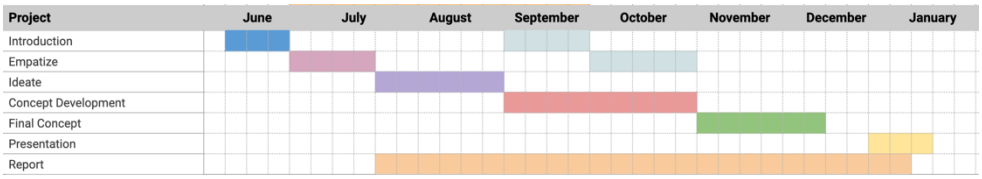

Figure A2: Performed activities

The activities depicted in Figure A2 align with the activities outlined in the intended project plan, indicating the actual duration of each phase.

A.2 Observations

Locations: Hallways in apartments and houses.
Methods: Observations of the user
Process: Visited hallways form people in the target group. Observation will be carried out by observing the person from the target group entering their home coming home from work or an activity.
Goal: Understand the behaviour of the target group and their needs while interacting with thair hallway furnitures.

Guiding framework:
Observe:

- The behaviour of unloading accessories
- The behaviour of storing accessories
- The behaviour of storing shoes
- The behaviour of storing outdoor clothing
- The emotions the person is experiencing

Locations: Hallways in apartments and houses.
Methods: Observation with empathy
Process: Visited hallways form people in the target group. Observation will be carried out by observing the hallway and interacting with the hallway furnitures.
Goal: Understand the behaviour and the needs of hallway furnitures while interacting with different types of hallway furniture settings..

Guiding framework:
Observe:

- The behaviour of unloading accessories
- The behaviour of storing accessories
- The behaviour of storing shoes
- The behaviour of storing outdoor clothing
- The emotions the person is experiencing

A.3 Interviews

All questions were written in Swedish since the interviews where conducted in Swedish. The questions below was stated in the original language not to lose meaning in translation.

Interview with the end users

Goal: Gather primary direct statements of individuals' experiences, viewpoints, attitudes, and impressions.

1. Hur gammal är du?
2. I vilket län bor du i?
3. Vilken typ av bostad bor du i?
4. Hur många personer bor i ditt hushåll?
5. Hur stor hall har du i din bostad?
6. Vad för typ av förvaring vill du ha i en hall?
7. Har du accessoarer du vill förvara?
    a. Om ja, vad för typ av accessoarer?
8. Hur hanterar du smutsiga kläder (dåligt väder)?
9. Vad får dig att måbra i en hall?
10. Vad behöver man i sin hall för att den ska vara komplett?
11. Hur många par skor skulle du vilja förvara, på ett ungefär?
12. Hur många jackor skulle du vilja förvara, på ett ungefär?
13. Hur många väskor skulle du vilja förvara, på ett ungefär?
14. Vad är viktigt för dig när du köper en hallmöbel?
15. Har du något du känner att du vill tillägga?

Interviews architectures
Goal: Understand the importance of the layout of a hallway.

1. Vad för typ av projekt har du tidigare erfarenhet av?
2. Hur gör ni för att förstå användaren/Kunden och deras behov?
3. Har du tidigare designat en hall eller jobbat med en hall?
4. Hur gick du tillväga för att bestämma måtten/storleken på hallen?
5. Vad är viktigt att tänka på när man designar en hall?
6. Hur fördelar man yta till hallen?
7. Brukar ni integrera möbler i arkitekt designen?
8. Arbetar ni tillsammans med inredare?
9. Hur bestämmer ni känslan rummen ska ha?
10. Vill du tillägga något?

Interview with interior designer
Goal: Understand how interior designers work with customers in order to fulfill their needs of a hallway.

1. Har du arbetat med hallinredning tidigare?
2. Hur ser en genomsnittlig hall ut enligt dig? (inredning, storlek)
3. Vad är viktigt att tänka på när man inreder en hall?
4. Vad är användarvänlig design enligt dig?
5. Vad är viktigt att tänka på kring förvaring?
6. Hur gör ni för att förstå användaren/Kunden och deras behov?
7. Hur bestämmer ni känslan rummen ska ha?
8. Vill du tillägga något?