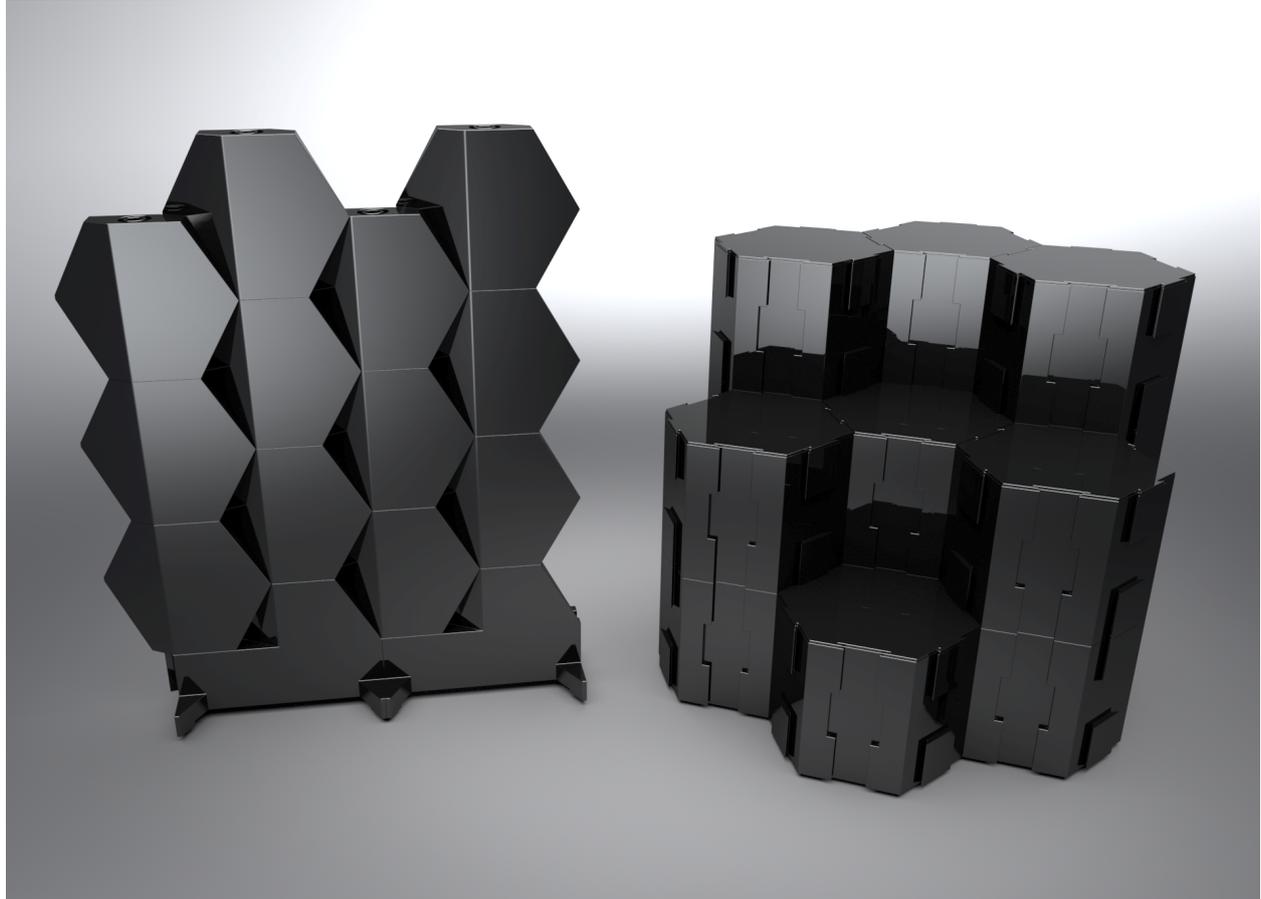
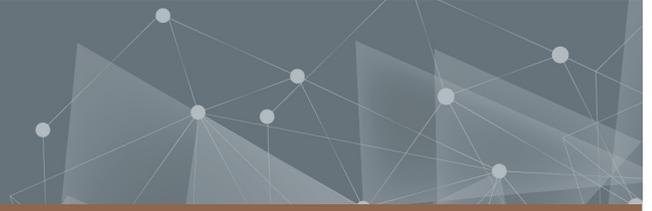




**CHALMERS**  
UNIVERSITY OF TECHNOLOGY



# Development of a Sustainable, Adaptable and Modular Room Divider for Residences.

Master's thesis in Product Development

**WILLIAM BAI**  
**EMMA VELIN**

**DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE**

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CHALMERS UNIVERSITY OF TECHNOLOGY  
Gothenburg, Sweden 2023  
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MASTER'S THESIS 2023

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WILLIAM BAI & EMMA VELIN

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Master's Thesis 2023

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# Abstract

With the rise of urbanization, there is a growing need for smart solutions in compact spaces and simplified renovation processes. A room divider is a creative design solution that fulfills both the ability to maximize space utilization and simplify renovations.

The development of a modular, adaptable, and sustainable room divider, emphasizes the integration of the room divider with the housing interior, aligning with the emerging trends of minimalism and biophilic design to enhance aesthetics and create an improved home environment. The modular, adaptable, and sustainable characteristics of the room divider have the potential to improve living standards in small spaces. The ease of usage and customization, coupled with the utilization of renewable materials, contribute to its broad market appeal and enhanced sustainability.

Using a design development methodology, the study explores various possibilities and systematically generates optimal concepts, resulting in two concepts. They feature a minimalist design with integrated biophilic elements, are modular and provide users with the flexibility to customize the room divider according to their preferences. Additionally, the use of a renewable material, pine, ensures a sustainable solution that aligns with environmental consciousness. The concepts are concept Vertical, which has the ability to rotate the modules, and concept Turning Puzzle which has the ability to be assembled in various configurations.

Keywords: urbanization, design, room divider, modular, adaptable, sustainable, minimalism, biophilic design.



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William Bai and Emma Velin, Gothenburg, June 2023



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# 1

## Introduction

This chapter describes a detailed overview of the project, including its background, research questions, problem analysis, purpose, demarcations, and outline of the report.

### 1.1 Background

Urbanization has been increasing over the last few decades and is expected to continue. According to United Nations (2018), urban areas are expected to house 60% of the global population, and a third will live in a city with a larger population than half a million. The increase in urbanization has caused problems and difficulties with the housing market, creating significant housing shortages and unaffordable housing prices in many cities. In Sweden, 204 out of 290 municipalities have reported a housing shortage, constituting around 87% of Sweden's total population (Boverket, 2022). Ninety-seven of these municipalities state that the main issue of its housing shortage is a scarcity of reasonably priced housing, implying housing will gravitate towards smaller spaces to be affordable for the masses.

According to 2020 statistics on household situations in Sweden, the majority, over 2.4 million households, are in apartments. 80% of all apartments are 80 sqm or smaller, amounting to over 2.1 million apartments, accounting for 40% of all housing. Smaller apartments constitute a substantial portion of the housing market and are expected to continue to increase. According to the statistics, between 2012 and 2021, there was an increase of around 403 000 apartments in total, 280 000 apartments were 80 sqm or less, constituting an increase of roughly 18.5% in 9 years, which might be due to both increased urbanization and housing scarcity (Statistikdatabasen, 2021b).

As a result, trends of finding smart solutions in confined living spaces have emerged as a response to housing scarcity (Baldwin, 2021). Trend movements such as tiny housing and micro apartments, which are apartments or houses usually within 35 sqm, are the use of creative design solutions essential to maximize the use of limited space, turning affordable housing that would conventionally be spatially minimal into a functional space where daily needs are satisfied (D'Silva, 2022).

Creative design solutions are not only essential for the possibility of maximizing the utilization of minimal space but can also promote and simplify renovations over new constructions. New constructions are less economically and environmentally

friendly than renovation and are responsible for 11% of the global carbon emission (World Green Building Council, 2019). According to Sifferlin (2012), it can take a new, energy-efficient building on average 45 years to make up for the damaging effects of climate change caused by its construction. The most frequent justification for building new rather than renovating an existing building is that it might be complicated and cause unexpected difficulties. Therefore, even though it is worse from an economic and environmental standpoint, it is typically believed to be simpler to demolish and rebuild (Delalic, 2020).

A room divider (a non-permanent wall) is a creative design solution that fulfills both the ability to maximize space utilization and simplify renovations. Changing a room's layout and adapting to its current function creates flexibility and enables multiple uses for a singular room, creating effective space usage in a constrained space. Improved sustainability from a room divider is reached by simplifying renovation, and its material choice. As mentioned, construction is responsible for 11% of global carbon emissions, primarily caused by the material used (World Green Building Council, 2019). The potential use of a modular room divider would allow the use of more environmentally friendly materials, and promote reusability, contrary to permanent walls that result in waste when modifications are inflicted on them. (ITG, personal communication, January, 2023).

## 1.2 Purpose

The project's purpose is to design and develop concepts for a sustainable, adaptable, and modular room divider primarily for living spaces.

## 1.3 Problem analysis

Room dividers are commonly used in office spaces but less in residential settings. One reason for this disparity could be the difference in floor plans. Offices, particularly those with open layouts, often prioritize flexibility and communication, which is why permanent walls and rooms are less prevalent. Adapting the space based on changing activities throughout the day is crucial. For instance, individual work that requires minimal distractions can benefit from room dividers that create privacy. In contrast, collaborative work that necessitates an open layout can be achieved by removing the dividers. Thus, room dividers have proven valuable in office spaces, particularly open layouts, as they allow for easy space transformation to suit different needs. (Tootell, 2022).

In contrast, room dividers are less commonly used in residential settings since the need for layout changes is typically less frequent. However, given the increasing trend of living in more confined spaces, there may be a growing need to transform the space according to the user's preferences, similar to office environments. The

specific preferences and functions desired for room dividers in housing settings differ from those in office settings and will require investigation to accompany these desires.

Designing a room divider that is sustainable, adaptable, and modular presents challenges in the development process which need to be considered.

Achieving sustainability involves selecting environmentally friendly materials and considering the product's lifecycle, including its end-of-use options.

Adaptability refers to the room divider's capacity to accommodate different settings. It requires understanding the circumstances in which people find themselves, determining the types of adaptability sought after, and finding appropriate ways to provide these adaptabilities.

Modularity refers to the ability to change. This includes change due to functional problems and the ability to adapt to changes in user preferences and circumstance. It involves investigating how to achieve change and ensuring the simplicity of making changes.

### 1.4 Research Questions

The research questions that will be investigated in the project are:

1. What and how are the user's housing circumstances?
2. What are the user's preferences in regard to a room divider?
3. How can a room divider's modular system adapt to the user's preferences?
4. How can a room divider with a modular system achieve improvements in sustainability?
5. What novel materials could be applicable for the product to improve sustainability?

### 1.5 Demarcations

The demarcations define the boundaries and limitations of the project.

The research and development of the room divider are based on housing, specifically people living in apartments.

Interesting Times Gang (ITG) has established the market size and demand. Thus, these are not investigated.

The project includes a cost assessment, however, the products' market competitiveness and prognosis are not regarded in the project.

The materials that are regarded as interesting to apply for the product are pri-

marily novel or unusual materials and material processes, which means information and data might be too restricted to be able to establish a definitive conclusion on what material is most suitable, furthermore, be able to test and verify the material. Therefore, a sustainable and suitable material with known properties is implemented to test and verify the concepts. The selection of what material to implement is not determined before or during the concept generation phase, implying the material's properties do not affect the design, instead appropriate material is applied to the detailed design.

The project does not include physical models or tests. However, a digital model is created and analysed. The final concepts and digital model describe the fundamental ideas and attributes of the product, and are restricted as a concept, not a final product ready for market.

## 1.6 Outline of report

The report covers the developmental process of developing, conceptualizing, and analyzing the final concepts. It is formatted chronologically to convey the work process and accomplishments throughout the project. The ten chapters are:

1. Introduction - The introduction chapter describes the background, purpose, problem analysis, research questions and demarcations.
2. Methodology - The methodology chapter covers the different methods used in the project.
3. Frame of Reference - The frame of reference chapter provides information about interior walls, architecture and design trends, biophilic design and materials.
4. Consumer and Market Analysis - The consumer and market analysis chapter describes who the consumers are and what is currently on the market.
5. Concept Generation - The concept generation chapter describes the different concept generation processes and their results.
6. Concept Selection - The concept selection chapter describes the different concept selection processes and their results.
7. Detail Design and Analysis - The detail design and analysis chapter describe the two final concepts and their analysis.
8. Discussion - The discussion chapter analyzes and reflects the results and developments of the project.
9. Conclusion - The conclusion chapter covers the answers to the research questions.
10. Recommendations - The recommendation chapter describes what further development is recommended.

# 2

## Methodology

This chapter describes the methodology for this project. The methodology comprises a development design approach that includes the phases and methods used in each phase.

### 2.1 Overview of Methodology

The project was conducted in five phases: Frame of Reference, Consumer and Market Analysis, Concept Generation, Concept Selection, and Detail Design and Analysis. These stages are sequentially presented in a workflow chart, as shown in Figure 2.1.



**Figure 2.1:** Overview of Workflow

The stages were designed to establish a structured framework for the project, providing a clear roadmap. This approach allowed the project to explore multiple possibilities and systematically generate optimal concepts.

### 2.2 Frame of Reference Study

Extensive research was conducted to enhance the understanding and bridge the knowledge gap within the project. This involved a thorough examination and reflections of articles and papers.

The subjects that relate to the development of a room divider were established as follows:

- Interior Wall
- Design and Architecture Trends
- Biophilic Design
- Material

### 2.3 Consumer and Market Analysis

The consumer and market analysis covers market segment identification, an interview study, a competitor benchmark analysis, and a patent analysis.

#### 2.3.1 Stakeholder Identification

Stakeholders were identified by evaluating who is affected by the product and how they are affected by it. The stakeholders are categorized into different types, specifically primary, secondary, tertiary and extreme, which describes in which to what extent they are affected.

#### 2.3.2 Market Segment Identification

Market segments were identified to identify groups with similar attributes and needs, for the product to be developed after. Geographical and demographic segmentation methods were chosen, considering factors of location and attributes of the segment. The identified market segments were translated into specific cases, and then used to determine who would be interviewed.

#### 2.3.3 Interview Study

An interview study was conducted with both users and experts. One user interview was conducted for each case established in the market segment identification. The user interviews provided a better understanding of their needs, which is used for the product specification.

Two expert interviews were conducted, an associate professor in the design and human factors department and an architect, to get better insight into the upcoming concept generation phase. Since the field of focus of the experts was vastly different, questions and discussion points prepared were adapted and accustomed according to the expert's expertise.

The conducted interviews used the semi-structured method for both the user interviews and the expert interviews. Semi-structured interviews are characterized by having a general framework of themes of questions but a loose format allowing to be more exploratory to the respondents' answers. Starting and concluding questions are determined, but questions are adapted to the answers given, called follow-up questions or probing questions. This format allows the interview to be more exploratory in the respondent's opinions and provides a better understanding of the respondent. The framework however, keeps the interview within the theme, enabling comparison and analysis between multiple interviews. The interviews were approximately 45 minutes long (George, 2022).

The interviews were recorded and transcribed with the approval of the interviewees. Questions asked were assessed to be in line with ethical guidelines.

### **2.3.4 Competitor Benchmark Analysis**

Competitor benchmark analysis was conducted by researching different types of room dividers to obtain information on competitors and learn what products are in the market. Both solid and modular room dividers and their features were analysed. The information was utilized to identify features existing on the market to look for inspiration, standards that need to be met and potential areas for competitive advantage.

### **2.3.5 Patent Analysis**

Patents were analysed by researching in the patent database Espacenet (European Patent Office, 2023). The analysis was conducted in two iterations with two different keywords:

- Room Divider
- Temporary wall

The analysis provided an overview of the state of the technology and relevant patents. The patents were used as a source of inspiration and examined whether they were active to determine their potential impact on the project.

## **2.4 Concept Generation**

The concept generation involved creating a product specification, function analysis, and performing idea and concept generation.

### **2.4.1 Product Specification**

A product specification was created to provide a detailed list of what requirements are needed and what desires could be of value for the room divider. The requirements and desires were established from ITG, external research and the interview study. The product specification was used when generating concepts and for screening and selecting concepts.

### **2.4.2 Function Analysis**

To ensure that the concepts would be comprehensive, the product specification were analyzed and dissected to identify specific functions and sub-functions corresponding to each requirement and desire. These functions and sub-functions were then represented in a function tree, illustrating their connection.

It provided a structured framework that guided the idea generation phase and enabled systematic development of solutions.

### **2.4.3 Idea Generation and Evaluation**

The idea generation was used to generate different ideas and solutions for the functions and sub-functions.

The methods used were:

- **Brainstroming**

Brainstorming was used as an initial idea generation method (Osborn, 1953). It involved verbally pitching ideas with no restrictions. The brainstorming session generated solutions for the functions and sub-functions established in the functional analysis.

- **6 Thinking Hats**

The 6 thinking hats method was used to evaluate solutions (Wikberg-Nilsson, Ericson, & Törlind, 2021). The method includes looking at the solutions from the idea generation from six different perspectives which were:

- The white hat: The hat focuses on facts and logical thinking.
- The red hat: The hat relies on intuition and emotions.
- The black hat: The hat helps predict negative outcomes and encourages caution.
- The yellow hat: The hat looks for positive outcomes and promotes optimism.
- The green hat: The hat encourages creativity and generates many ideas while minimizing criticism.
- The blue hat: The hat is for management and organization, providing control and structure.

## 2.5 Concept Generation

Concepts were generated by combining solutions for the functions and sub-functions. The generated solutions for the functions and sub-function were documented in a morphological matrix to simplify the concept generation. The concepts were then generated in two phases:

- Individual Concept Generation: Concepts were generated individually by each author and aimed to incorporate a wide range of solutions by encouraging each individual to contribute their ideas.
- Thematic Concept Generation: To further expand the concept generation, a thematic approach was implemented. Concepts were generated according to themes. The themes chosen were biophilia, minimalism, family and co-living. Moodboards were created for the four different themes to serve as inspiration.

Following the concept creation phase, concepts were categorized based on their similarities.

A SCAMPER analysis was conducted to refine the concepts. SCAMPER stands for Substitute, Combine, Adapt, Modify, Put to other use, Eliminate or minimize, and Reverse re-engineer or rearrange (Wikberg-Nilsson et al., 2021). By applying the SCAMPER tool, the concepts underwent an evaluation to identify areas for improvement and ensure that similar concepts were streamlined or eliminated.

## 2.6 Concept Selection

The methods for the selection of the concepts were concept screening and selection, and concept refinement.

### 2.6.1 Concept Screening and Selection

Different matrices and methods were applied to ensure unpromising concepts were eliminated, and promising concepts were selected. The screening and selection process involved several matrices to assess the concepts. The matrices include:

- Elimination matrix: Concepts were evaluated against the requirements from the product specification, and those that did not meet all the requirements were eliminated (Almefelt, 2022).
- Pugh matrices: Concepts were evaluated based on established desires and a specified reference. Each concept was compared to the reference, and their performance was assessed as better or worse for each desire. The scores were then summed up, and the concept(s) with the lowest score(s) was eliminated. Two iterations of this process were conducted: one with a market product as the reference and another using the median-scored concept from the first iteration (Almefelt, 2022).
- Kesselring matrix: Concepts were evaluated on the desires and were scored from 1 to 5 on each desire. The desires were given a value scale, defining the requirement for each score. The importance of each desire was weighed using a simplified first-level Analytic Hierarchy Process (AHP). This process involved comparing the desires against each other to establish their relative importance as a percentage (Jagoda, Schuldt, & Hoisington, 2020). The scores were then calculated by multiplying the percentage by the assigned score for each desire. The scores for each desire were summed up to obtain a total score for each concept. The two highest scoring concepts were selected for further development, and the others were eliminated (Almefelt, 2022).

### 2.6.2 Concept Refinement

The remaining concepts were refined by resolving details not considered in the concept generation. Each component of the concepts was examined to consider what improvements could be implemented. Valued features in the concepts that were screened were considered to be combined or added to the remaining concepts.

## 2.7 Detail design and analysis

Digital prototypes were created to realize the final concepts. Computer-Aided Design (CAD) models were created to evaluate and analyse the remaining concepts.

### 2.7.1 Material selection

Materials were analysed using Ansys Granta EduPack (2023) to determine the appropriate material for the concepts. Materials were screened and selected based on the material-dependent requirements and desires from the product specification.

### 2.7.2 Technical Analysis

The concepts were analysed using Ansys Mechanical (2023) to determine if the requirements and desires for structural integrity were fulfilled and that the material selected was appropriate.

- **Static Structural Analysis**

The analysis evaluated the stress distribution on the concepts with the selected material. The evaluation determined if the concepts with the material implemented were feasible in a standing position.

- **Explicit Dynamics Analysis**

The analysis evaluated the equivalent strain when applying temporary forces. The evaluation determined if the concepts with the selected material could withstand external force.

### 2.7.3 Cost Assessment

A cost assessment was carried out to estimate the cost of the concepts. The assessment involved determining the manufacturing processes and evaluating their associated costs, including fixed costs, such as set-up costs, and variable costs, such as labor costs. The total cost calculation considered both the material costs and the manufacturing costs.

# 3

## Frame of Reference

This chapter provides a theoretical background for the project, introducing a selection of materials, design and architecture trends, and the basics of an interior wall. The materials section covers a range of interesting materials that may have potential applications. The design trends section explores various interior design and architectural trends that could be inspiring and informative for the project. The interior wall section describes an interior wall's typical composition and qualities.

### 3.1 Interior Walls

Since the intention of the project is to partly replace interior walls, it is necessary to reflect on the qualities and composition of a typical interior wall to determine what standard needs to be met. What qualities and composition of a typical interior wall are described, and its implications related to the project.

Interior walls are typically constructed using a frame of wooden beams. The frame consists of top and bottom beams that are usually secured to the ceiling and floor, while horizontal beams are attached to provide stability and serve as a foundation for the wall. The beams are attached using screws or nails, resulting in permanent damage when removed. Drywall is commonly used as the exterior material, and in some cases, insulation is placed within the gaps of the frame before attaching the drywall (Sole, 2022). This type of interior wall minimizes noise due to its materials and can be further enhanced with insulation.

The goal of achieving equal or superior qualities to that of an interior wall for the room divider can be summarized by emphasizing the following key aspects: the ability to construct and deconstruct without causing permanent damage, simplicity of installation, stable structure, and effective noise reduction.

### 3.2 Design and Architecture Trends

When developing a new project, paying attention to aesthetics is vital to create a product that fits seamlessly into users' home environments. Extensive research is necessary to identify current and future design trends. Since aesthetic preferences vary from person to person, it is essential to consider current and upcoming trends. This research focuses on the Western perspective, which is the focal point in this project due to geographical setting in the Nordic countries, which only applies to

parts of the world due to the differences in cultures and design and architectural trends.

Researching interior design trends across decades can provide insight into how trends have evolved. Factors such as global events and economic conditions have influenced the development of aesthetically pleasing homes. Therefore, understanding the historical context and current trends is important in developing a product with lasting aesthetic value.

From the 1960s to the 1970s, interior design featured bold colors. The era was characterized by complex hues, such as bold red, and the use of materials like plastic that significantly impacted the design industry. This period referred to as the psychedelic era, was part of the postmodernism movement, which emerged as a response to the aftermath of World War II. During this time, designers prioritized functionality and simplification, seeking to create a more positive and ideal living environment through home design (Fussell, 2021).

In the 1970s, interior design became more focused on self-expression while still using vibrant colors such as yellow and orange. This period was also when natural materials such as stone and plants were incorporated into the home environment. Moving into the 1980s and 90s, the trends shifted toward what is seen today in design. Pastel colors were used, and complimenting colors became more critical. Minimalism became the focus of the 90s, emphasizing simplifying the living standard and having a more neutral interior design. It involved fewer elements and colors and incorporated more materials from nature, such as wood panels and natural light (Cochrane & Heath, 2023).

In the twenty-first century, minimalism continued to be popular with a touch of vintage styling. During the 2010s, dark gray and bold colors were introduced, along with otherwise neutral colors. In the late 2010s and 2020s, more natural elements like wood, soft shapes, and neutral colors like beige, light green, and soft blue became popular. This increase in natural elements is related to society's shift towards more environmentally friendly design choices.

The coronavirus pandemic has heavily influenced the current trends in interior design. As people were forced to stay in their homes for extended periods, big open spaces became less desirable when people needed to work from home. With the ability to work from home now established, more people work part or most of their time from their homes. Future trends will likely incorporate more room dividers to divide and define spaces into work or living spaces in the home environment. Using sustainable materials and more natural elements will continue to be popular as people strive to feel more connected and sustainably friendly to the environment (Johnson, 2021).

From an architectural point of view, the impact of postmodernism was radical, as it inspired new eras focused on building extravagant forms and incorporating familiar and historical details and motifs, this period lasted from the mid-1900s to

the beginning of the 21st century, with concrete, steel, wood, and later polymers being the primary materials used.(Arora, 2022).

Incorporating nature into buildings, known as biophilic urbanism, is becoming increasingly popular to improve living standards and benefit the planet. Overall, architectural trends are shifting towards sustainability and environmentally friendly design, reflecting society's growing concern for the environment (BSBG, 2023).

The research reveals that design trends have been significantly influenced by global events. Notably, the transition from bold colors and intricate designs witnessed from the 1950s to the early 2000s has shifted to a preference for neutral tones and simplified aesthetics. This shift has resulted in the rise of minimalism within the design world while still acknowledging the significance of shapes and diverse geometries. It is anticipated that minimalism and neutral design will continue to be prominent in the years to come, with an added focus on incorporating nature and sustainability into both design and architectural trends.

### **3.3 Biophilic Design**

Biophilia is a hypothesis that human possesses an innate inclination to nature. It originates from human evolution, where humans learned and adapted from the nature around them rather than the human-created artifacts in the modern world.

Biophilia and its design patterns are examined not just because of their increase in popularity, as noted in Section 3.2, but also because of how well biophilic design encompasses the project. The motive behind the project is to design a product that can contribute to better sustainability and home environment. Biophilic design is about how nature and its elements can positively affect people and can be considered environmentally friendly since it often involves the use of natural, environmentally friendly materials. Therefore, a biophilic design is considered highly relevant to be implemented and investigated.

A study demonstrating humans' affiliation with nature was by Öhman (1986), who used pictures to examine reactions. The pictures displayed snakes, spiders, electric wire, and handguns. The study participants remained relatively indifferent toward the man-made artifacts while having a greater response to the images of the snakes and spiders. The study reveals humans' inherent tendency toward natural threats over human-created threats. It could, therefore, conversely be applied to other responses, such as a boost in creativity or a sense of calmness. (Kellert & Calabrese, 2015)

Biophilic elements and patterns in design can be found throughout history, even in the earliest human structures and artifacts, the sphinx in Egypt, bonsai in Japanese homes, or the hanging gardens in Babylon. The consistency of natural themes throughout history suggests integrating biophilic elements in design is not a new phenomenon, but the consciousness of the existence of a biophilic hypothesis has

been more attended to in the last decade, both among the public - since urbanization led to people's urge to reconnect with nature and people becoming more sustainably conscious - and research connecting neuroscience and design. Biophilic design patterns have been studied to have an impact on stress, cognitive performance, emotions and mood.

Biophilic design is strongly tied to locality. The locally available materials reflect the regional ecology, form and function reflect the local topology and climate. Identifying these differences can help with a compatible and appropriate design for its region. (Browning et al., 2014)

The extent of application of biophilic design and its biological responses is limited because of the limited exposure a room divider can provide, therefore the focus is not how much and many varieties can be incorporated, but rather how well executed the biophilic elements are applied. A single high-quality intervention that corresponds to the user's intent can have a larger impact than several smaller and lower-quality interventions that touch on several factors. (Browning et al., 2014)

While there are research endorsing biophilic design, there isn't a formula for how to correctly design according to biophilic design. The following points will describe biophilic patterns with the intent to assist and guide the design process. All patterns will not be included since a number of patterns are considered not applicable to the project.

**Non-visual connection to nature** refers to all senses besides sight, including auditory, olfactory, haptic, or gustatory that would give a positive reference to nature. The sole sense that could be applicable to this project is haptic, the sense of touch. Touch of organic materials, such as stone or bark, can create a biophilic experience. For example, an act of touching a real plant has been shown to induce a sense of relaxation, as it causes a change in cerebral blood flow, which could give reason to believe that other haptic feedback from other organic elements would give similar results. The use of local natural material with a familiar texture, could in the case of the project create a biophilic experience, despite the limited contact a user has with the product. (Browning et al., 2014)

**Biomorphic patterns and forms** are symbolic implications of textures, shapes, and patterns existing in nature, that create a connection with nature. Why there is a visual preference for organic and biomorphic patterns and forms is not yet fully understood, but it is believed that the brain recognizes symbolic representations of life, even if it realizes it is not an actual representation. Biomorphic forms can be applied in two ways: as cosmetic decorative components or as an integrated part of structural or functional design. Both can be used in conjunction to improve the biophilic experience. (Browning et al., 2014)

**Material connection** is a connection with nature through materials that represent the local ecosystem or geology. The use of natural materials, such as wood or stone,

can elicit positive cognitive and physiological reactions due to their connection to nature, such as familiar textures and material knowledge. Although research on the health effects of natural materials is scarce, one study found that increasing the wood ratio to roughly 45% resulted in a more comfortable experience, dramatically lowering the participants' blood pressure. Color also has an impact on cognitive performance, green for example, the color most commonly associated with nature, improves creative performance. However, color preferences are to be considered, as it is impacted by culture and climate. People from warmer climates prefer warmer and brighter hues, whereas those from colder climates prefer cooler, less saturated hues, according to psychologist E.R. Jaensch (Sharpe, 1975). It is therefore suggested to implement local natural materials that could provide a sense of familiarity, and less saturated colors as the product is based on the Swedish market. (Browning et al., 2014)

## 3.4 Material

Materials are investigated to determine which ones could potentially be appropriate for the product. With a goal and a requirement for the final product to be sustainable, the materials that are investigated are considered sustainable. The different materials are divided into renewable and upcycled.

Describing and identifying the property of a material doesn't solely depend on the raw materials used, but largely on the processing and manufacturing methods. Therefore materials properties will initially be described in their natural state or in their typical processed state, and will afterwards be described using a material example from a company.

### 3.4.1 Renewable Materials

Renewable materials are made from renewable sources, that either by natural reproduction or other recurring processes regenerate themselves at a rate similar to that at which they are used by people (Stora Enso, 2023). The investigation of renewable materials was due to their potential sustainability when used appropriately. Given the range of renewable materials available, it was necessary to narrow down the focus. Two materials were chosen for exploration due to their unique properties and potential applicability to the product. While numerous materials are already established as interior materials, the decision was made to investigate less common but unique options. As a result, mycelium and cork were selected as materials with promising properties that could be beneficial for the product.

**Cork** is derived from the bark of the cork tree, where the bark is extracted with little to no harm to the tree. The unique characteristic enables the tree to regenerate its bark, ensuring a sustainable supply of cork without the need for deforestation. The ability to harvest cork while preserving the tree's health and longevity makes it an environmentally-friendly material choice. (Institut Catala Del Suro, 2023)

Once the bark is processed into cork material, it acquires several advantageous properties, primarily due to its porous structure. The porosity of cork results in low density, making it lightweight and enhancing the mobility of the product when applied. Additionally, the material's porous nature enables it to accumulate a high gas concentration, which contributes to its excellent thermal insulation properties. Moreover, the flexibility of cork allows it to withstand collisions without suffering damage or permanent deformation. Furthermore, its porous structure enables cork to function as a porous absorber, granting it acoustic qualities. (Institut Catala Del Suro, 2023). A particular company, Gencork (2013), has been able to develop a manufacturing process that allows the cork material to achieve an absorption coefficient of around 0.4 at 1000Hz, which is around the frequency of human speech. In comparison to plaster that is used for interior walls that has a coefficient number of 0.05 at 1000Hz (JCW Acoustic Supplies, 2023).

Gencork, a company based in Portugal, focuses on the use of cork wall panels. The material is 100% natural and recyclable, and by their processing methods, have been able to optimize the thermal and acoustic properties of the already implemented properties of the cork. The processing method entails the material going through an autoclave, injecting water vapor through cork pellets that expand and agglomerate with the resin of the cork itself (Gencork, 2013).

**Mycelium** is a root-like structure of fungi, consisting of thread-like hyphae. By growing out the mycelium, the root can create a self-supporting composite by inter-connecting the hyphae. Depending on the specie of the mycelium and the processing technique, the properties of the material can be altered.

Mycelium, as a material, has several desirable properties such as low density, excellent acoustic performance, and effective fire and thermal insulation when compared to other organic materials. Its porous structure provides acoustic and thermal capabilities, and it has been successfully used as insulation for walls. In terms of environmental impact, mycelium is considered to have a low environmental footprint as it requires minimal energy for growth and is biodegradable. Moreover, mycelium is safe for housing environments, as it does not cause allergies or emit toxins. (Karro & Leet, 2022).

Mogu Acoustics is a company creating acoustic panels entirely made of circular fungal mycelium covered with upcycled textile residue. It's biodegradable, naturally fire retardant, and non-allergenic with an acoustic absorption at 1000 Hz varying from 0.35 to 0.6. The material is produced by growing selected strains of mycelium substrate made from agro-industrial residue. The mycelium is inertized by slow drying, resulting in the final composite (Mogu, 2023).

#### 3.4.2 Upcycled Materials

Upcycled materials refer to the process of using by-products or waste to transform into new materials, that could be perceived as having a higher value, such as aes-

thetically or possessing improved properties.

Over the past 70 years, synthetic plastic has altered the use and consumption of products. Due to its high performance, flexibility, and low cost of production, the material has been used excessively, causing great damage to the environment. As a result, more development efforts have been put into more sustainable alternatives, alternatives that abstain from fossil fuels and enable biodegradability, unlike synthetic plastics. Bioplastics fulfill these requirements, by being either biobased or biodegradable. The shift of bioplastics that are based on renewable sources rather than fossil fuels certainly improved its sustainability but did impose issues that biofuels also had to undertake. The material used the most for the production of bioplastics is corn, a source that could be used for other means such as sustenance, which could be ethically conflicting. Additionally, growing crops requires land and water, causing deforestation, suggesting it isn't as sustainable as it seems (Cecchini, 2017).

Upcycling has therefore been raised as an alternative, using waste than specifically grown crops or extraction of raw material. Every year, the food industry produces millions of tons of waste that could be of potential use for the material, by recovering carbohydrates or cellulose fibers, that could form the basis of materials. The variety and the number of different waste materials possible are vast, from used coffee grounds from coffee shops to orange peels from fruit juice production (Cecchini, 2017).

**Ottan Studio**, a company based in Turkey, has created materials derived from diverse waste products, ranging from expired rice to grass and fallen leaves, with some composites consisting of up to 80% waste products. According to Ottan (2023), the material application possibilities are numerous, including interior wall applications, but are confined to indoor situations. The material is produced by initially cleaning the waste product, which is then dried and grounded into powder, to subsequently blend the powder with resin. As the waste materials naturally have texture and color, no further artificial coloring is required (Ottan Studio, 2023).

**Terroir**, a project by Nikolaj Steenfatt and Jonas Edvard, entailed making material from locally gathered seaweed in Denmark, with the goal of designing a material with character derived from the local cultural landscape. The seaweed is dried and powdered before being mixed with paper and boiled to achieve the adhesive effect caused by alginate, the brown algae's natural polymer. The material is, according to Steenfatt, a durable and robust material, albeit it is not specified how durable and tough it is. To showcase the material, the material was applied to furniture such as chairs, hinting that its qualities are suitable for interior use (Steenfatt, 2013b). Another project by Nikolaj Steenfatt called **Impasto** involved creating a biodegradable material using waste from wood and coffee processing. The raw waste products are mixed with pigments into a dough, and folded into sheets to be then shaped by vacuum forming. The material is also applied to furniture, signifying that it is appropriate for interior use (Steenfatt, 2013a).

**Colepetra** is a bioplastic material created by a dutch Designer Aagje Hoekstra made from beetles. The beetle is grown from mealworms, sustenance used for animals in the Netherlands. When the mealworm turns into a beetle and eventually dies, they are simply thrown away. Hoekstra found a way to utilize the beetles, by utilizing the shells of the beetle which contains chitin. Hoekstra was able to transform the shells to pure chitin, turning it into chitosan, which bonds better due to its variation in its molecular composition, to be pressed into the final material. Colepetra is waterproof and has been primarily used for decorative items (Howarth, 2013).

#### 3.4.3 Materials Discussion

Material selection for the product is highly influential on the product's attributes. The materials used will largely determine how environmentally friendly the product is and the aesthetic of its design. Various function capabilities, such as acoustics, will also be affected by the material selection. Therefore, the appropriateness of a particular material depends on its specific circumstances. With the product's goal of being modular, there is a plausibility of the option to a variety of materials to offer adaptability for the user as well as reach a broader market of users. Additionally, an interior room divider has less strict requirements compared to a standard wall, giving more leeway on what materials could be applicable.

The different materials described in this chapter are mainly considered exterior materials for the product, implying it's not considered materials for structural support. Foremost, the materials mentioned are presumably too expensive to comprise the whole product (ITG, personal communication, March, 2023). Secondly, the selection of materials is driven by their distinctive properties, such as environmental sustainability and uniqueness, rather than solely focusing on their structural strength. Many of the materials mentioned are considered more environmentally friendly than what is normally used for interiors currently. Cork can be harvested without deforestation; mycelium can be grown under very simple and easy conditions; upcycled materials transform and utilizes waste into useful materials. Furthermore, the materials' uniqueness makes them appealing to consumers, adding to their overall attractiveness. The attractiveness of its environmental quality is not only demonstrated as a description but also as a visual representation of environmental friendliness, such as upcycled materials giving an alternative aesthetic depending on what waste is used. By utilizing unconventional materials with exceptional environmental friendliness, the concepts could have the ability to distinguish itself from competitors, setting it apart as an innovative and sustainable option.

Regarding upcycled material, more information and data will be needed to confirm if these are suitable as a material for the product. Further development could be either to find a supplier or possibly develop an upcycled material that is appropriate for the local environment, corresponding to what is more commonly waste products in Sweden. The properties of upcycled materials depend on what kind of

manufacturing and what type of waste is used. Factors to consider include what local waste products could be used, and which of the waste products correlates with what properties are desired for the product. The mentioned upcycled materials all make use of locally produced waste products, therefore if producing an upcycled material is considered interesting, a collaboration with a local company to make use of their waste product, would not only result in producing sustainable material from waste materials locally, but also create a more stable and steady source supply.



# 4

## Consumer and Market analysis

This chapter presents the results of the Consumer and Market analysis, including the Stakeholder Identification, Market Segment Identification, Collected Information from Interviews, Competitor Benchmarking and Patent Analysis.

### 4.1 Stakeholder Identification

Stakeholders are individuals or groups who will be impacted by the product. There are various stakeholders involved, including architects, property owners, and contractors, who need to consider the implementation and potential effects of the product. However, for the purpose of this project, the primary focus is on consumers. Therefore, the most significant stakeholders assumed to be affected are users living in apartments, as they are expected to comprise the majority of potential consumers.

The potential users of the product were studied in order to gain a better understanding of what market the product should target. Table 4.1 illustrates the categorization of users into primary, secondary, tertiary, and extreme users. When gathering data about consumer needs, the respondent selection is determined by the identification of the product users.

**Table 4.1:** Categorization of type of users

Type of User	Actor
Primary User	People co-living in apartments
Secondary User	Guests
Tertiary User	Maintenance and cleaning persons
Extreme User	People co-living in compact housing

The primary users are people living in apartments, which will fully experience and interact with the product. Guests to the residence are considered the secondary users, and will largely experience and focus on the aesthetics of the product. Maintenance workers and/or cleaners make up the tertiary users and may use some of the product's features and accessibility, but not to its full extent.

The extreme users are those who are co-living in small compact housing and are more likely to interact with the product more frequently than the primary user. Due to the limited space, the product will need to be highly functional for extreme users. The extreme users will have to heavily interact with the product's modularity

and movability, as changes affect multiple people, making adaptation crucial when taking into account the preferences of various users.

Interviews were conducted with the primary users to determine their needs and requirements, and are chosen based on the criteria listed in 4.2. The secondary users are, as mentioned before, solely affected by the aesthetics of the product, which will be covered in the needs and requirements of the primary users. The tertiary users' needs and requirements will not be explored, even though parts of their needs and requirements are covered in the needs and requirements of the primary user. Instead, tertiary users needs and requirements will be considered in the design phase. Interviews with the extreme users will be conducted in order to better understand their wants and requirements as well as to observe for any discrepancies from the primary users.

### 4.2 Market Segment Identification

Identifying market segments is a strategy to identify groups of users or consumers with similar attributes or needs, to develop and present a product that the targeted group perceives the product's full value (Tarver, 2023). The identified market segment gives guidance on the product's needs and requirements and helps with the selection of interviewees.

Geographical and demographical differences between users were made using two separate parameters. Geographical categorization is based on the user's location, and demographical categorization is based on the user's attributes like age, household size, and living status (Tarver, 2023).

The living situation, particularly those who reside in apartments, was a chosen demographic segmentation. Apartment living has been identified as a factor that significantly influences a room divider's appeal because residents have stricter restrictions in using their available space.

Geographical segmentation is restricted to within Sweden, as ITG resides in Sweden and its primary market reach is within Sweden. Considering the demographic segmentation of people living in apartments and to reach a larger market of users, the three biggest municipalities in Sweden are selected, Stockholm municipality, Gothenburg municipality, and Malmö municipality. Together, these municipalities comprise a fifth of the Swedish population, around 1.9 million people, with a large percentage living in apartments (Statistikdatabasen, 2021d).

The three municipalities' most typical apartment type and size is 57 sq m, which has two rooms and a kitchen and is mostly found in inner cities. Apartments with three rooms and kitchens, with an average space of 78 sq m, are more prevalent in the suburbs of cities (Statistikdatabasen, 2016). As a result, the two different apartment kinds and sizes were chosen as the targeted market group, and its users, the residents of the apartment types, were identified.

Approximately 60-80% of people in the municipalities between the ages of 20 and 39 reside in apartments, with 30 to 39 being the most prevalent (Statistikdatabasen, 2021d). The household size for various apartment types was investigated to ascertain who resides in what apartment type and size. The typical household size in a two-room apartment with a kitchen, corresponding to the inner city case, is 1.5 people (Statistikdatabasen, 2021a). Since single parents with children are less prevalent than cohabitation without children, it can be assumed that two-room apartments with kitchens are more frequently occupied by two people in cohabitation without children or by a single person (Statistikdatabasen, 2021c).

Since women in Sweden give birth to their first child on average when they are around 30 years old, it is assumed that the inner city residents in this case are between the ages of 20 and 30 and do not have children (Statista, 2022). The typical household size in three-room apartments with kitchens, which corresponds to the suburbs case, is 2.5 people (Statistikdatabasen, 2021a). Due to the average age at which a firstborn child is born, it is believed that cohabitants with children between the ages of 30 and 40 most frequently reside in apartments with three rooms and a kitchen.

Three types of cases can therefore be concluded, with type A and type B deriving Market Segment Identification. Type C derives from extreme users. The extreme users are recognized as living in compact housing, therefore is the apartment type and area determined as smaller apartment area than type A, 1 room with a kitchen with two co-habitants. See Table 4.2.

**Table 4.2:** Definition of cases

Case	Apartment Area	Apartment Type	Habitants
Type A	c. 57 sq m	2 rooms with a kitchen	2
Type B	c. 78 sq m	3 rooms with a kitchen	3
Type C	< 57 sq m	1 room with a kitchen	2

Due to a lack of integrated statistics, some coarse assumptions needed to be made in order to identify an assessable market segment. For instance, it is incorrect to assume that all cohabitators at age 30 would have their firstborn, yet this assumption was necessary to distinguish the residents in the 2 different cases.

## 4.3 Collected Information from Interviews

The information retrieved from the interviews is presented here. Two expert interviews and three user interviews, one from each case, were conducted.

To summarize and categorize the information retrieved from the various user interviews, three themes were established: Aesthetics, Functionality and Current Housing Circumstances. The information gathered from these themes was examined and presented in each of its respective themes.

### 4.3.1 Experts

The insights and information gained from the expert interviews are presented here.

#### **Associate professor in Industrial Design Engineering**

An interview with an associate professor in Industrial design Engineering was conducted, to gain more insight into how and what to think of when trying to create a user-friendly design. The associate professor in question research primarily focuses on user-centered design and how to achieve circularity.

Starting off, usability and its correlation to sustainability were discussed. A product being sustainable is certainly advantageous, but the belief that a product can convince people to act for sustainability solely for the sake of sustainability is most often not enough. The product needs other advantages in order to convince people to purchase the product, which primarily is dependent on its usability depending on what kind of product. When relating to the project, a room divider will not succeed with its only benefit being sustainable, but either has to perform better in other areas compared to the market or be distinct with advantages in addition to its initial purpose. A thought brought up related to user usability was the potential size of the room divider. A big obstacle to buying a large product is finding a way to conveniently remove the product. A possible approach could be to make the room divider compactable by allowing it to be stored away. Another possibility is the ability to be transferred, relating to circularity, and not necessarily having to own the wall itself. Instead, have the alternative to rent, however, will integrating service and logistics into a product increase the complexity and rather becomes a development of a business model than a product.

Continuing on circularity is how upcycled materials have gained more traction. Waste is something that has not widely found a use yet, but through upcycling could be found applicable to materials. The issue with upcycled material, which is further explored in Section 3.4.2, is it is novel and needs more research, as well as the issue with the larger scale of production since there is no well-established source for manufacturing waste.

## Architect

An interview with an architect was conducted to gain a better understanding of the existing housing situation, what features are important for developing a living space, and what is to come in the future. The architect in question works primarily with wood and its different kinds applicable to houses.

Due to housing contributes significantly to climate change, efforts are being undertaken to make the housing sector as sustainable as possible, for example, by using wood instead of concrete, which was a common material for houses from the 1930s through the 1980s. Sustainability is also studied in terms of health factors, such as how the usage of materials, in this case wood, might affect people's well-being and health. Culture also has a large significance in how a room can affect a person well being and their connection to it. In the Nordic countries, people are usually grown up with forests and therefore have an affiliation or have a higher sentimental value for pinewood compared to other cultures, whereas clay or tiles can have more significant value. This coincides with biophilic design, which is discussed in Section 3.3.

They haven't seen any specific trends in new building materials in response to sustainability trends other than wood, and hence foresee trends in more variety in sustainable materials, such as recycled or reused building materials.

When asked which direction housing is heading, the response was that housing is becoming more expensive, as is square footage. People are living in smaller living spaces, which has increased the popularity of collective housing, particularly in larger cities. The development in housing has therefore been to find solutions to make smaller living spaces more efficiently used and how to create enjoyable living spaces that consider multiple people. A part of the solution could be the adaptability and changeability of living spaces, allowing people to utilize the same area for multiple purposes. One way to achieve this is by working with volume instead of area. Creating area for housing is more expensive than creating volume, which has modified how compact apartments efficiently use space by working vertically instead of horizontally, which can be of value when further exploring solutions and concepts for the project.

### 4.3.2 Users

In order to compare the user and see whether there are any variations between the three cases, an identical set of questions was used for all three user interviews. The interview explores under what circumstances the user is in regard to their living space, their attitude toward their apartment, what they would like to change and how they interact with their existing walls. The interviewees have the opportunity to voice their difficulties regarding their overall housing situation. The next set of questions explores their function preferences, thus what functions they would prefer for a room divider. Coming up with functions for a wall can be challenging and a distant thought for many, discussions were therefore encouraged by the interviewers,

to aid and stimulate the interviewee to think of potential ideas. Aesthetic-related questions were backed up with images to illustrate and inspire the interviewees about what a hypothetical room divider can look like, such as variances in texture, shapes and form. The last set of questions touches on assembly and modifications, what and how changeability is considered important, and in what circumstances change would occur.

**Current housing circumstances** refer to the respondents' present housing situation as well as their perception of their housing and its circumstances. Since all three of the residences featured an open floor plan, with the kitchen and living room connected, there were few complaints about the floor planning, as an open floor plan has fewer limits on furnishing and provides for greater freedom in decorating and layout. However, there were some complaints about the size and amount of rooms. Users of types A and C, who live in more compact homes, had issues with the area, while users of type B had issues with the number of rooms. Users of types A and C are concerned about the usage of their own space; they wish to increase their area or make better use of the space they have. User B, on the other hand, wants to increase the number of rooms in order to accommodate a growing family. Of course, this implies that the user wishes to make better use of their existing space as well, but in this scenario, the primary function of a room divider would be to screen off and divide space, to provide an extra room.

Users of type A and C who want more space or wanted to make better use of their space saw a problem with installing a room divider. Inserting a room divider into an already limited living situation would make it even more restricted and constrained. The problem is not just the preconceived belief that a room divider's main purpose is to divide rooms, but also that installing a room divider would take up more space rather than providing a more efficiently utilized space.

Furthermore, a problem could be that the current furnishing and layout users have not considered having a room divider, and thus adopting in the current furnishing could be viewed as undesirable. It is consequently critical to provide context and examples of how to utilize the room divider in order for users and consumers to understand and recognize the product's applications. For example, the user from type A discusses utilizing a sofa to divide the area between the kitchen and living room, which served as a room divider in certain ways but was not consciously thinking of it as such due to preconceptions. Another strategy is to target real estate that has a better understanding and awareness of planning and may be able to design around it.

One out of the three users had renovated their residence, user from type C, because of a second person moving in. The sleeping alcove in the residence was fitted for a bed for a single person. As a result, they had to renovate, which included moving a door to make room for a bed for two. The small apartment was initially only suitable for a single person since a door had been misplaced. While this is not a misplaced wall, it does demonstrate how confining and significant details, especially those that are permanent, can be. Modularity and adaptability may be a solution.

The utilization of walls was discussed, including what they now use their walls for and how they use them. The most prevalent types of elements on the wall were paintings, posters, shelves, and mirrors. Two of the users wanted to put up more on the walls but were discouraged by how time-consuming it was. The user of type B recalls how tedious it was to install what they wanted on the walls, especially concrete walls. Having to have the correct tools, since different types of walls necessitate different tools, the mess it causes, and having to putty when the holes are no longer in use. These considerations are assumed heightened when it is a temporary residence, as there may be limitations on what can be done with the walls, as well as issues about whether it is worthwhile. All three users investigated alternatives to drilling and nailing, such as adhesives. These were adequate for smaller objects, but not for heavy ones such as mirrors or larger paintings. The tedious work to put things up does signify that a simplified method is needed.

Other than the floor plan and the use of walls, acoustic and sunlight challenges were mentioned. Because the residence unit was adjacent to a road, the user in type C complained about traffic noises. Even though only one person mentions it, traffic noise is assumed to be a prevalent problem in urban areas. People will have to live closer to traffic and will be more affected by noise pollution as populations become more dense (United Nations, 2018). The sunlight issue was highlighted by both users A and B, who had issues with sunlight entering and only getting sunlight from one side of the flat. The issue was that putting up a room divider would potentially block off the little sunlight they get.

When investigating the prioritization of **functions**, a list was provided for them to rank. Acoustics, storage, and easy assembly were ranked highest, while the source of electricity was ranked lowest. Acoustic qualities have an impact on both external and internal noise sources. Noise from appliances, such as dishwashers or washing machines, can contribute significantly to noise, but so can noise from televisions or people conversing. Working from home, according to users A and C, could be difficult and complicated if the other resident was also home, as there are only a limited number of rooms to isolate from the other resident.

Due to that storage space is limited in more compact residences, storage may be more important to users A and C. However, User B claims that if a room divider was allegedly installed for a children's room, storage may be useful for tidiness.

User A and C ranked easy assembly high, whereas User B ranked it lower. Because its areas are more limited, it was more desirable with a simple assembly for users in more compact residences. The consumers from A and C stated that they did not want the wall to be up at all times because it would feel more confined, but rather would prefer the choice and easy accessibility to assemble and disassemble when needed. The user from B, on the other hand, found it was not as useful to put up and down the wall because the user had less of a space issue. Instead, the wall would be up for longer periods of time.

When addressing assembly and its importance further, compactability was brought up. Compactability was also perceived to be of more value to users in more compact residences, in terms of how frequently they would need to store the room divider, while user B saw less value since it would not be stored as frequently. Stability was instead a larger concern for user B, since they would have the intention to install the room divider in a children's room.

Furthermore, functionality of form and shape adaptability was examined. Users in more compact residences preferred the ability to change the size of the height, such as having a half wall, as it creates a less confined experience. The demand for having interesting shapes and forms was expressed as desirable, but not if it results in taking up more room.

In terms of **aesthetics**, a key consideration for all users is that it matches the rest of the interior design. Interior design can vary greatly from person to person, but since this project only considers Sweden, what interior design it could be can be narrowed down. In Chapter 3 which mentions the locales influence, implies the interior, from a biophilic standpoint would be made of wood, as this is the most common material in northern Europe. It is also claimed that people from colder climates prefer cooler, less intense colors, both of which correspond to the users' preferences and interiors. Earthy, more "dull" colors were preferred over more "fragrant" colors by all users. When asked about what their interior looked like, it consisted of a lot of wood and greenery, which coincides with biophilic theories about aesthetic preferences.

From the user interviews, a consumer needs list could be created, shown in Table 4.3. The list shows what users have expressed as needs. These needs are inserted into the requirement specification.

**Table 4.3:** User Needs List

<b>Number</b>	<b>User Need</b>
1	Customizable Exterior
2	Allow Light to Pass Through
3	Acoustic properties
4	Storage Capabilities
5	Easy Assembly
6	Compactable
7	Appealing aesthetic
8	Design Suitable for Home Environment

## 4.4 Competitor Benchmarking

A thorough competitor benchmark analysis was conducted to gain insights into the market and competitors. This analysis helped to identify the technologies and features already available in the market, to explore potential areas for competitive advantage. A total of 15 products were thoroughly examined and classified into nine distinct categories, which include the type of room divider, price, size, placement, material, recyclability, attachment, assembly, use-case, and other features. The products and categorization are presented in detail in Table 4.4. By analyzing these key factors, a comprehensive understanding of each product's unique qualities was gained.

The research covered various segments of the market for standard room dividers, including different types of screens, solid solutions, and modular solutions. The primary function of all the products examined was to divide space while providing screening for vision, sound, or dust. The products were marketed for a diverse range of use cases, including construction sites, warehouses, offices, homes, and temporary settings such as expos or pop-up stores. The multi-functional room dividers were the ones that provided customization and flexibility in their setup. Some products could be arranged as straight walls, while others could be shaped into curves or unique forms to suit specific needs. Additionally, these products offered other functional aspects, such as soundproofing capabilities and the ability to expand height and width.

**Table 4.4:** Categorization and detailed information about 15 products on the market.

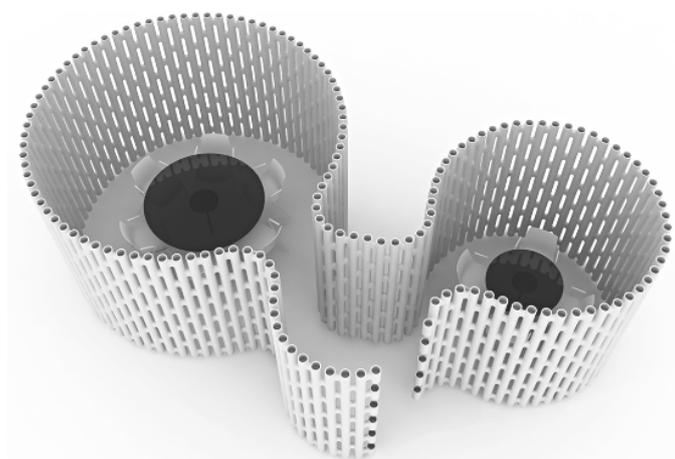
Company	Model	Type	Price [Kkr]	Size [m]	Placement	Material	Recyclability	Attachment	Assembly	Use - Case	Other features	Reference
Leif Arvidsson AB	LA Skärmvägg SPECIAL	Screen	2 243,75	3,6 x 2,7	Floor to ceiling	Weave	Not found	Pressed against floor and ceiling	Telescopic arm	Construction sites	Can be rolled for easy transport	<a href="https://www.leifarvidsson.se/la-skarmvagg-special-3-60-x-2-70-m?article=CJKCAIA55eFhEhEwAD7aLGFV2A4KCKUkYvE4UmDMTF2H8hNEFA2">https://www.leifarvidsson.se/la-skarmvagg-special-3-60-x-2-70-m?article=CJKCAIA55eFhEhEwAD7aLGFV2A4KCKUkYvE4UmDMTF2H8hNEFA2</a>
TM Interior	TM - Boardvägg	Easy mountable wall	1992	2,4 x 0,6	Floor to ceiling	Chipboard	Recycleble	Pressed against floor and ceiling with friction strip	One piece	Home	No	<a href="https://www.tmbromobellin.se/produkter/3917/m-imgrvagg-hogt-240cm-36x60-60cm.html">https://www.tmbromobellin.se/produkter/3917/m-imgrvagg-hogt-240cm-36x60-60cm.html</a>
IKEA	SIDORNA	Screen	2840	1,5 x 1,6	Floor	Cardboard and PET	Made of 78%	Standing on feet	One piece	home and Office	No	<a href="https://www.ikea.com/se/sv/p/sidorna-skarmvagg-gras-s7938618/">https://www.ikea.com/se/sv/p/sidorna-skarmvagg-gras-s7938618/</a>
Swiftwall	SWIFTWALL	Easy mountable wall	Not found	Can be stacked	Floor	ABS	Recycleble	Strip to floor	Stackable	home and Office	Sound Absorbing	<a href="https://swiftwall.com/swift-wall-pro/">https://swiftwall.com/swift-wall-pro/</a>
AJ	LUGN	Screen	3618,75	1 x 1,4	Floor	MDF	Recycleble	Standing on feet	One piece	home and Office	Sound Absorbing	<a href="https://www.ajproduktier.se/kontor-konferens-ljudampning-avskarmning/skarmvagg-skarmvagg-aj">https://www.ajproduktier.se/kontor-konferens-ljudampning-avskarmning/skarmvagg-skarmvagg-aj</a>
WallStack	WallStack	Modular Wall	Not found	can be stacked	Floor	Wood	Recycleble	Standing on floor	Stackable	Home, Office and Expo	Hangers	<a href="https://www.wall-stack.com/">https://www.wall-stack.com/</a>
diyversify	Pony Wall Room Divider	Modular Wall	7200	can be stacked	Floor	Resistant Fiberglass	Recycleble	Standing on floor	Stackable	Home, Office and Expo	No	<a href="https://diyversify.com/products/everblock-room-wall-room-divider">https://diyversify.com/products/everblock-room-wall-room-divider</a>
EverBlock	EverBlock Simple Wall Kit	Modular Wall	6779,94	can be stacked	Floor	Polypropylene	Recycleble	Standing on floor	Stackable	Home, Office and Expo	No	<a href="https://www.everblocksystems.com/everblock-simple-wall-kit/">https://www.everblocksystems.com/everblock-simple-wall-kit/</a>
Yanko Design	Flexible Wooden Room Partition	Screen	Not found	Expandible	Floor	Wood	Recycleble	Standing on floor	One piece	Home, Office and Expo	Can change form	<a href="https://www.yankodesign.com/2020/12/05/these-flexible-wooden-room-partitions-expand-up-to-15-ft-4-in-the-fold-in-5-min-10-">https://www.yankodesign.com/2020/12/05/these-flexible-wooden-room-partitions-expand-up-to-15-ft-4-in-the-fold-in-5-min-10-</a>
IMT	Free Standing Walls	Modular Wall	Not found	can be stacked	Floor	Steel and different (glas and Wood)	Recycleble	Strip to floor	Stackable	Office and Warehouse	No	<a href="https://immodularwalls.com/solid-wall-partitions-partial-height-walls/#sgid=pagal_1403_1&amp;pid=3">https://immodularwalls.com/solid-wall-partitions-partial-height-walls/#sgid=pagal_1403_1&amp;pid=3</a>
Flexible Wall	Flexible Wall	Screen	Not found	Expandible	Floor	Paper	Recycleble	Standing on floor	One piece	Home, Office and Expo	Can change form	<a href="https://www.moreinspired.com/en/articles/57-flexible-wall">https://www.moreinspired.com/en/articles/57-flexible-wall</a>
LINK	LINK	Modular Wall	1975	can be stacked	Floor	PP	Recycleble	Standing on floor	Stackable	Home, Office and Expo	Can change form	<a href="https://mivaal.com/ingagas/product-link-system/">https://mivaal.com/ingagas/product-link-system/</a>
QuickSpace	Flexible Partitions	Screen	Not found	Not found	Floor	Polypropylene	Recycleble	Standing on floor	One piece	Office and Warehouse	Inflatable	<a href="https://quickspace.eu/en/applications/flexible-partitions/">https://quickspace.eu/en/applications/flexible-partitions/</a>
Designboom	Modular Acoustic Partition System	Modular Wall	Not found	Expandible	Floor	Pressed recycled hemp	Recycleble	Standing on feet	Stackable	Home, Office and Expo	Sound Absorbing	<a href="https://www.designboom.com/designboom-habit-laver-design-scale-modular-acoustic-partition-system-12-04-2016/">https://www.designboom.com/designboom-habit-laver-design-scale-modular-acoustic-partition-system-12-04-2016/</a>

Furthermore, these multi-functional room dividers were built using modular components, allowing easy customization and expansion. They often came equipped with extra built-in features like easy-to-hang shelves or hangers. In comparison, screens and solid products typically only provided screening capabilities and did not offer multiple features.

When choosing between solid walls with feet or modular systems with added features, it is essential to consider the limitation in the functionality of each option. While solid walls offer limited options for customization and variety in appearance, they are often more affordable due to more streamlined mass manufacturing. On the other hand, modular systems require more complex manufacturing processes, which can result in a higher price point and be more challenging to assemble. Examples of the two different versions is presented in Figure 4.1 and 4.2, one solid structure from IKEA and a modular room divider from LINK, more information about these products can also be found in Table 4.4.



**Figure 4.1:** IKEA (2023): Standard room divider, solid structure with feet (Dimension screen: W 0.15 m x H 0.16 m).



**Figure 4.2:** Movisi (2023): Modular room divider with multipurpose features (Dimension module: W 0.288 m x H 0.216 m).

The materials used in these products vary from wood, steel, glass, paper and plastic. However, most room dividers today focus on recycling and using recycled materials, which aligns with the increasing trend toward sustainability in the market. Most modular systems are designed with reusability in mind, making it easy to change and reuse parts. In addition to the benchmark study, the research explored different opportunities for building a room divider. This included examining concept stage room dividers and homemade solutions, which led to exploring several innovative ideas.

The findings emphasized the modular ability of room dividers to serve multiple purposes, such as expanding to incorporate a desk and chair to create a workplace within the divider. Some room dividers also could open up parts of the wall for aesthetic purposes and greater flexibility. An example of this feature and a multi-purpose modular room divider can be seen in Figure 4.3 and 4.4.



**Figure 4.3:** Williamson (2012): Multi-functional room divider with incorporating desk and chair.



**Figure 4.4:** YuQiang & Partners (2023): Room divider with open up feature.

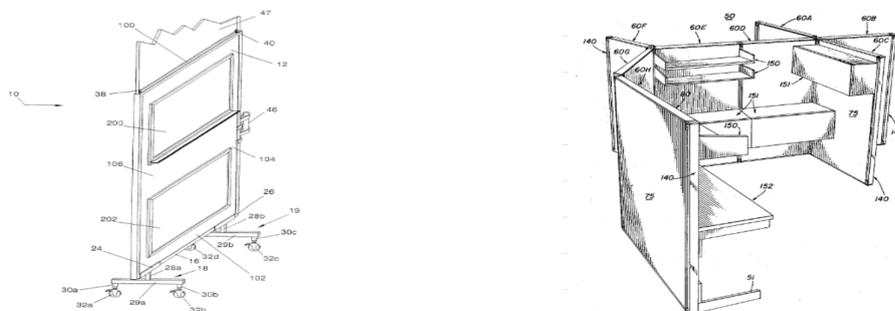
When examining homemade designs, it was discovered bookshelves were often used as a room divider, with implemented containers added for additional storage and functionality. Other designs incorporated woven fabric within a wooden structure, along with plants, to create a room divider that was not entirely solid, providing greater visual interest and a connection with nature.

Based on the benchmarking analysis, the room dividers offered customization, flexibility, soundproofing capabilities, and the ability to expand in height and width. These multi-functional room dividers were primarily built with modular components, which made them easily customizable and expandable. In line with the growing trend towards sustainability, most products in the market today focus on recycling and using recycled materials. To establish a competitive position within the market alongside the existing researched products, the product should match or exceed the current offerings of room dividers. The key areas of focus to achieve this are centered around prioritizing the design and functionality of the room divider. This implies creating a product that serves multiple purposes and meets diverse consumer needs. Emphasis is placed on adaptability, ensuring that the room divider can fit into different environments and fulfil various user requirements.

### 4.5 Patent Search and Analysis

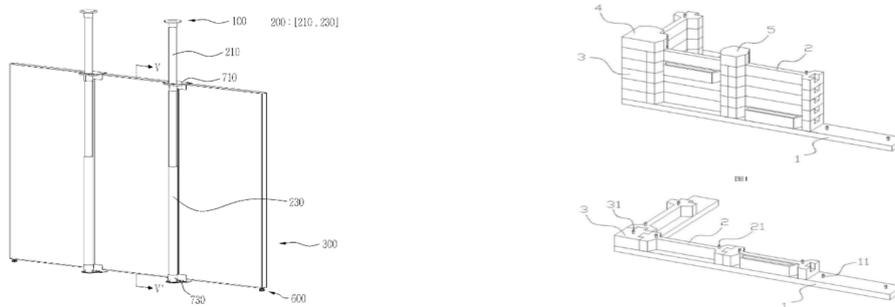
The analysis' primary objective is to investigate newly invented and existing inventions by researching in the patent database European Patent Office (2023). A variety of patents were investigated and found throughout the patent study.

Keywords, including "room divider," and "temporary wall," were used in the searches. A total of 104 patents were found to be related to the project and helpful in terms of inspiration for the development of the project, and are listed in Appendix A. Patents gathered from the initial search using the keyword "room divider", generated room dividers using either wheels or feet-inspired designs to be portable. The attachments of the room dividers varied; some were stabilized by the use of a base plate, while others were attached to the ceiling that either could be moved, slid, or fixed. Moreover, the search identified patents with built-in shelves and doors. An example of these features as patents can be seen in Figure 4.5.



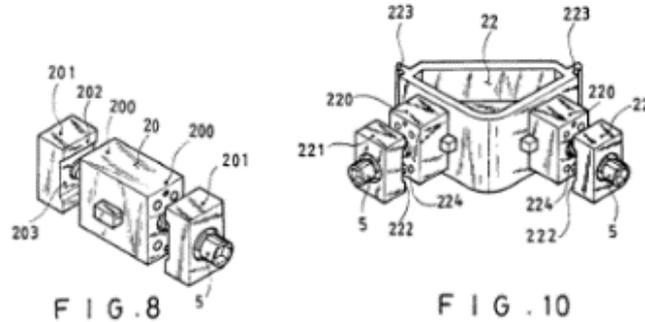
**Figure 4.5:** Left patent US6598649B1 (2003): Room divider with wheels. Right patent US3871435A (1975): Room divider with integrated shelves.

The results from the second keyword, "temporary wall", generated patents featuring different designs. Interesting patents with modular structure were discovered as well as a patent with built in height extensions, these features are presented in the patents shown in Figure 4.6.



**Figure 4.6:** Left patent KR102343617B1 (2021): Temporary wall with height extension. Right patent CN210622474U (2020): Temporary wall with module-based structure.

In addition to that, the search discovered various attachments for a room divider with multiple parts. One finding is a patent featuring an adaptable attachment function that can be applied in two directions. This patent, is presented in Figure 4.7.



**Figure 4.7:** GB2290846A (1996): Attachment for different directions

An investigation was conducted to determine the active status of the patents and assess their potential impact on the project. In cases where no specific information regarding the status of a patent was found, an assumption was made that all patents published within 20 years from the project's end date are considered active.

The five patents presented in this chapter are deemed to be the most affecting to the project. Three of the five patents discussed in this chapter were published in the early 21st century and are assumed to be active. Considering these three patents during the concept generation process is important to avoid any potential violations when generating similar solutions. On the other hand, the remaining two patents were published in the late 20th century and are assumed inactive.



# 5

## Concept Generation

This chapter will present the Product specification, Function analysis, Idea generation and Evaluation, and the Concept Generation.

### 5.1 Product Specification

A product specification was created to provide a detailed description of the required specifications and preferences that would be useful for the room divider, and can be seen in Table 5.1. The requirements and desires were established by the project's objectives, the team, the users and/or ITG.

The product specification was divided into 9 different categories: Modularity, Mobility, Robustness, Safety, Visuals, Sustainability, Geometry, and Maintenance. The specification was either set as a requirement or a desire, meaning that if it's a requirement it has to be fulfilled, while desires are beneficial if fulfilled, but are not required to be. The desires were graded on their importance to either have high or low prioritization. The desires are in later stages, in concept selection, weighted against each other to get a more detailed grade.

To keep the design space as open as possible and not restrict the concept generation phase, the requirements set were to the absolute necessary to keep the number as low as possible.

Why the requirement or desire was set is explained and described in the justification. In the verification, how the requirements or the desires are examined if its fulfilled or not, is described. A number of the requirements or desires were quantified, while others were absolute. The requirements or desires that were quantified are explained here:

- **Maximum weight of 15kg:** Arbetsmiljöverket states that daily or frequent lifts should not be over 15kg, to prevent the risk of injury (Arbetsmiljöverket, 2023).
- **Withstand 277 N force without losing stability:** Since the desire derives from the context of children, a child's weight is determined to be used for reference. The normal weight for a 12-year-old is 40kg. When leaning, assuming 45 degrees, the resulting horizontal force is around 277 N. (Granquist, 2019)
- **The assembled height of the room divider can be 2.4m/2.7m:** The standard height for housing is 2.4m, and the standard for public premises is

2.7m. The room divider must be able to adapt to those heights in order to have the option of covering from floor to ceiling. (Boverket, 2020)

- **Acoustic absorption coefficient over 0.05 at 1000Hz:** Traffic noise, the biggest source of noise pollution in Europe, has generally a frequency of around 1000Hz (European Environment Agency, 2017) (Rochat & Reiter, 2016). The product should be able to acoustically perform better than an indoor wall, a plaster wall, that has around an absorption coefficient of 0.05 at 1000Hz (JCW Acoustic Supplies, 2023).

Vague or more unclear requirements are further explained here:

- **Attachable and detachable modules:** Modules should be attachable and detachable to enable change of modules to extend the longevity of the product, for when modules get damaged, and when preferences or circumstances change.
- **Adaptable height/width:** The product can accommodate the different needs and circumstances of users and their housing. It implies the size can be changed both in height and width.
- **Compactable:** The product can reduce in size when non-assembled, to simplify storage and movement of the product.
- **Intuitive relocation:** The product can be moved and relocated without difficulties, such as avoiding having to use tools.
- **Assembly and disassembly should be intuitive:** Assembly should be possible without the use of instruction and requires a minimal amount of steps to assemble.
- **Minimal variation during physical impact:** The product should be able to withstand impacts without the product getting noticeable exterior problems or function failures.
- **Able to change form/shape:** Form is variances in its height that changes the silhouette of the product. Shape is variances in its depth that change the structure in a three-dimensional aspect.
- **Easy to maintain:** The product can be easily maintained, meaning cleaning and maintenance of functions is possible and simple.

Various regulations that could have an impact on this project were examined. There were no explicit regulations or restrictions discovered during this investigation. Despite this, safety standards have been established to guarantee that the product can be used safely.

Table 5.1: Product Specification

Chalmers		Document type: Requirement Specifications		
Issuer: Bai &		Project: Room Divider		
Created: 2023				
Criteria	Priority	Justification	Evaluation	
<b>1. Modularity</b>	High(H) / Low(L)			
1.1 Attachment				
R1 Attachable and deattachable modules		User personalization	Engineering assessment	
D1 Attachable without the use of tools	L	User accessibility	Engineering assessment	
1.3 Adaptability				
R2 Adaptable height		User personalization	Engineering assessment	
R3 Adaptable width		User personalization	Engineering assessment	
R4 Customizable exterior		User personalization	Engineering assessment	
<b>2. Mobility</b>				
2.1 Assembly				
D1 Easy to change modules	H	User accessibility		
D2 Assembly and disassembly possible by 1 person	H	User accessibility	Design assessment	
R1 Assembly and disassembly possible by maximum 2 persons		User accessibility	Design assessment	
R2 Assembly and disassembly is intuitive		User accessibility	Design assessment	
2.2 Movability				
R3 Easy to handle		User accessibility	Design assessment	
R4 No permanent damage on the interior when moved		User preferences**	Simulation	
D3 Intuitive relocation	L	User accessibility	Design assessment	
D4 Compactable	H	User accessibility	Design assessment	
R5 Maximum 15 kg per module		User accessibility	Weight assessment	
<b>3. Robustness</b>				
D1 Minimal variation during physical impact	L	Prolong lifespan	Impact simulation	
D2 Minimal age defects	L	Prolong lifespan	Material assessment	
D3 Withstand 277 N force without losing stability***	L	Product safety	Impact simulation	
D4 Module attached and detached a minimum of 20 times	H	Prolong lifespan	Stress simulation or test	
<b>4. Safety</b>				
R1 Minimize health hazard		Health standards	Material assessment	
R2 Minimize fire hazard		Safety standards	Material assessment	
D1 Minimize cutting hazard	H	Safety standards	Design assessment	
D2 Minimize pinching hazard	H	Safety standards	Design assessment	
<b>5. Visuals</b>				
D1 Appealing aesthetic	H	Market prerequisite	Assessed by experts	
R1 Design suitable for a home environment		Market prerequisite	Assessed by experts	
D2 Allow light to pass through	L	User preference	Design assessment	
<b>6. Features</b>				
D1 Acoustic absorption coefficient over 0.3 at 1000Hz	L	User preference	Material assessment	
D2 Storage capabilities	L	User preference	Design assessment	
<b>7. Sustainability</b>				
6.1 Material				
D1 Made of renewable material	H	Environmental sustainability	Material assessment	
D2 Made of recycled material	L	Environmental sustainability	Material assessment	
D3 Made of recyclable material	H	Environmental sustainability	Material assessment	
D4 Minimize amount of different materials	L	Simplify recycling	Design assessment	
R1 Easy to separate different materials		Simplify recycling	Engineering assessment	
<b>8. Geometry</b>				
8.1 Adaptability				
R1 The assembled height of the room divider can be 2.4m		Market standard	Design and measure assessment	
R2 The assembled height of the room divider can be 2.7m		Market standard	Design and measure assessment	
D1 Able to change form	L	User personalization	Engineering assessment	
D2 Able to change shape	L	User personalization	Engineering assessment	
<b>9. Maintenance</b>				
D1 Easy to repair	L	User accessibility	Design assessment	
D2 Easy to maintain	L	User accessibility	Design assessment	

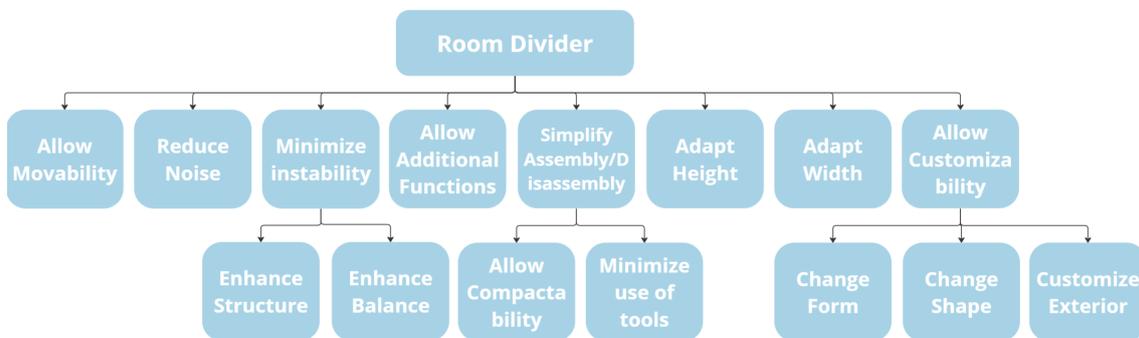
\*\*from interviews

\*\*\*child leaning

## 5.2 Function Analysis

To create comprehensive concepts, the product specification is translated into functions and sub-function corresponding to the requirement and desires. Not all requirements and desires are translated into functions, since some requirements are either material dependent or can not be translated to a function that can be solved with a design solution, such as "minimal age defect" that is material dependent, which will not be considered until after the concept stage. The functions are used for idea and concept generation, where solutions for each of the functions are generated, which are then combined to create a full concept.

A functional tree analysis was conducted to illustrate the interconnections between various functions and sub-functions clearly, the function tree is presented in Figure 5.1.



**Figure 5.1:** Function tree representing the dissected functions and sub-functions.

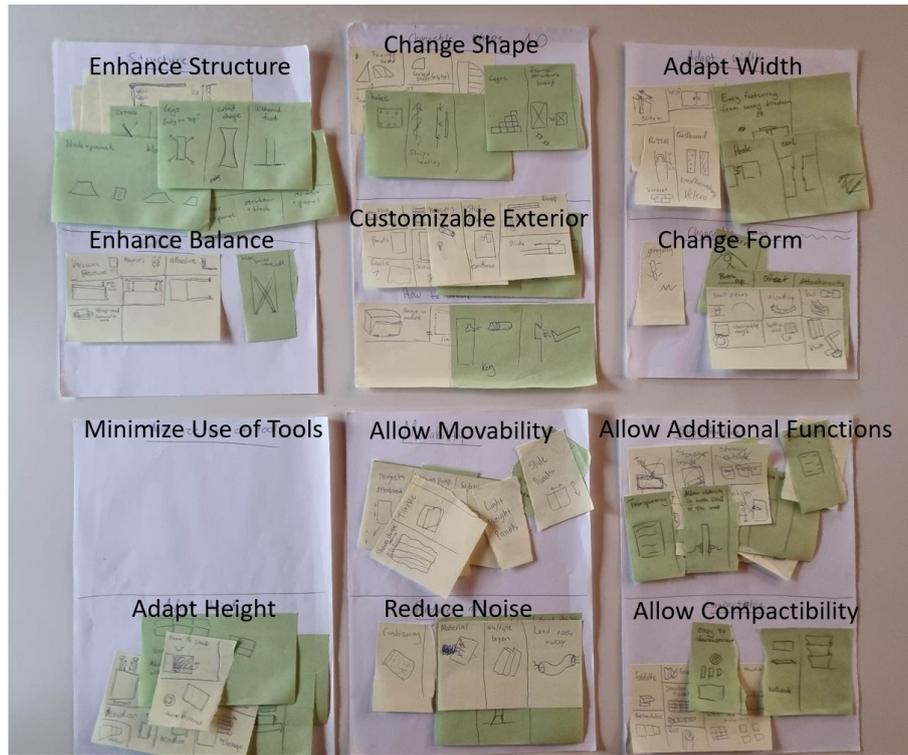
The function analysis resulted in identifying three primary functions and nine sub-functions, all represented in the function tree. However, it is worth noting that some of these functions can include multiple desires rather than a single distinct requirement or desire. For instance, the function "allow additional functions" includes desires such as allowing light to pass through, storage, and other potential features.

## 5.3 Idea Generation and Evaluation

This chapter explains the processes used to create different ideas for the concepts, including generating solutions for functions and sub-functions, and was done by using both external and internal sources. The external sources were research done on current technologies and products to explore what solutions are currently available, such as patent analysis and competitor benchmarking seen in Chapter 4. The internal sources were different creative idea generation methods, which were Brainstorming and 6 thinking hats. The solutions from the idea generation were created according to the functions and sub-functions established in the Function Analysis. Each idea generation method explores each of the functions and sub-functions, generating solutions for them. The generated solutions are then combined to create a full concept.

### 5.3.1 Brainstorming

The brainstorming session was conducted and discussed for each of the 11 different functions and sub-functions, resulting in 129 generated solutions and sub-solutions. An overview of the generated solutions can be seen in Figure 5.2. The function "Minimize use of tools" was considered in the other functions, and was therefore not generated specifically.



**Figure 5.2:** Overview of the solution generated in the brainstorming session.

### 5.3.2 6 Thinking Hats

The "6 thinking hats" idea creation process is used to examine and investigate solutions from different perspectives, where each of the six hats represents a perspective (Wikberg-Nilsson et al., 2021). The blue and green hats were not investigated.

The "blue hat" involves managing and discussing the decision-making process. It was chosen not to be used since the decision-making and concept development processes had already been decided.

The "green hat" represents creative thinking and idea exploration, and was therefore determined to not be required as they were already covered during the brainstorming session.

Since the hats are applied after the first idea generation method, brainstorming, it is used for both generating new solutions and reflecting on the existing solutions

created from the brainstorming. Thoughts and reflections are explained for each of the hats.

Red hat involves feelings and instincts, meaning opinions are expressed without the need of having to explain and justify logically. The main discussion surrounding the red hat revolved around how complex solutions appeared to be more problematic than useful when compared to simpler solutions, with the conclusion being the simpler a solution is that yet serves its functions, the better.

Yellow hat involves perceiving and looking at solutions in the most positive light and emphasizing the benefits of the solutions. It allowed to recognize benefits, why it was beneficial and if its benefits could be applied on other solutions. The discussion led also to solutions that seemed quirky and sometimes unnecessary, to have other advantages or functions it could fulfill.

Black hat involves assessing risks, employ judgmental thinking and expressing concerns on the solutions. More complex ideas were criticized for having too many uncertainties to be a feasible solution.

White hat involves reflecting on the knowledge and information gathered, but also what information and knowledge are missing and how to solve that. How to gain stability without having any permanent solutions were lacking in information, thus it was further explored but not evaluated until Chapter 7.

The six thinking hats process resulted in the elimination of certain solutions due to their high level of complexity or similarity to other solutions. As a result, these solutions were combined and improved upon, ultimately leading to more effective and streamlined solutions.

Following the session using the Six Thinking Hats technique, a total of 15 solutions were either eliminated or combined, as they were deemed to be similar. This left us with 104 remaining solutions that we can further evaluate and consider.

### 5.4 Concept Generation

Following the idea generation method, generating solutions for each sub-function, holistic concepts could be created by combining a solution from each sub-function. By using a morphological matrix, holistic concepts can be created systematically (Almefelt, 2022).

The morphological matrix was divided into parts, specifically 4 different sub-categories, which are used to decide on the composition of the concept, the matrix can be seen in Appendix B. Compositions were implemented as it was noticed in the initial attempt of generating concepts, that all the sub-functions could either not be used in combination or had the option to be either combined or be stand-alone without combining with some of the functions. Instead of randomly deciding to neglect

sub-functions, compositions were implemented. The compositions explain how the composition of the concept will be, signifying what sub-categories are and are not required. Four different compositions were available, consisting of the options of 4 different sub-categories, whereas 1 is General which is always included. The different compositions included are:

- Base Structure + Module + Panel
- Base Structure + Module
- Module + Panel
- Module

The concept generation was done using four different approaches, which were "Individual Concept Generation", "Thematic Concept Generation", "Categorize and Combine Concepts" and "SCAMPER". The reason why concepts are generated in different segments and methods, is due to the amount of possible different concepts, over eight million number of concepts, which would not be plausible to generate and screen. Therefore, these four different segments are to make sure that the concepts are diversified and different factors are considered.

#### **5.4.1 Individual Concept Generation**

Individual concept generation involved individually by each author creating concepts for each of the different compositions. A limited time was set to create full-scale concepts for each of the different compositions. Twenty concepts were sketched and created.

#### **5.4.2 Thematic Concept Generation**

To diversify the concept generation, and also focus on factors that were considered important, a thematic concept generation was performed, which is to create concepts according to a theme. The themes chosen were minimalism, biophilia, family and co-living. Minimalism was chosen as it is considered to be a trend in Western interior design, explained in Chapter 3. The discussion in the red hat section also refers to simple solutions being more attractive than complex ones. Biophilia was chosen similarly to minimalism, a rising design trend, but also in correspondence to the purposes of the project, which involves promoting a more sustainable alternative and improving people's well-being. Family involves the nature of loved ones living together. Since a primary market segment group is 2 persons with one child, a focus in this theme is living with children. Co-living, which could be interpreted interchangeably with family, has its focus rather on collective housing, on people living together not necessarily by choice. While collective housing is not included in any of the primary market groups, it is coinciding with the research analysis from both the interview with the architect, and the market segment analysis, presented in Chapter 4, which indicates that people are needed to reside in more compact living situations and alternative solutions are needed such as collective housing.

To stimulate and inspire what the different themes represent, each theme was illustrated by mood boards, which can be seen in Appendix C. The thematic concept

generation generated 8 additional full-scale concepts, but also separate designs and ideas, that were taken into consideration in the next two segments.

### 5.4.3 Categorization and Combination of Concepts

The concepts generated from both the individual and the thematic concept generation, are categorized into groups on their similarities. The groups of concepts are named and evaluated, where they are combined if it was deemed that the combined concept would be an improvement but still kept the identity of the concept. The result was 6 groups with respective names for each group for the main function in the concepts, these were, "Ladder", "Retractable", "Horizontal", "Vertical", "Cubes" and, "Other Shapes". An additional group were also added named "Design", where additional features and aesthetics were gathered that could be implemented on all the concepts. The groups and combinations of concepts can be seen in Figure 5.3.



**Figure 5.3:** Categorization of the generated concepts

### 5.4.4 SCAMPER

Scamper is an acronym for Substitute, Combine, Adapt, Modify, Put to other use, Eliminate or minimize and Reverse re-engineer or rearrange (Wikberg-Nilsson et al., 2021). This method aims to improve the concepts by applying different approaches referenced in the acronym. Since, as mentioned before, creating all the possible concepts for each of the sub-functions is impossible, SCAMPER is applied to assure and revisit the concepts if improvements are possible. Each approach is used for each

concept, where each concept is discussed with all the solutions for the sub-functions and the other concept present, allowing a more comprehensive discussion. The final amount of concepts after SCAMPER was nine concepts.

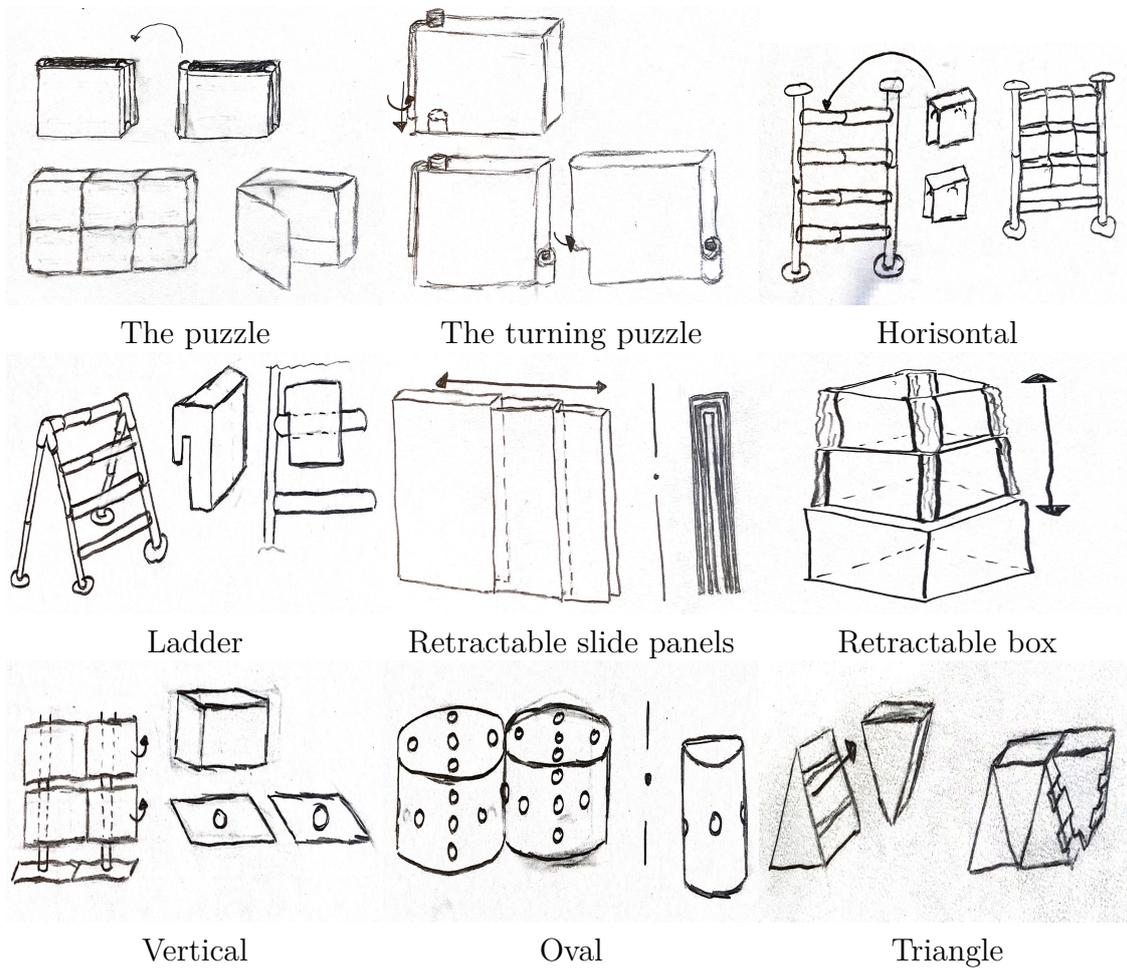
### 5.4.5 Concepts before Concept screening

The nine remaining concepts are considered to be diverse, and are briefly explained here and can be seen in Figure 5.6.

- **The puzzle:** The puzzle has the composition of Module + Panel. The modules can be opened to allow storage. The modules are attached laterally by inserting the extruded side with the opening of the second module, and laterally using rails that are slid into.
- **The turning puzzle:** The turning puzzle has the composition of Module + Panel. The modules are attached using a short threaded hole, which is then screwed on with another module. The threaded holes are extruded from the sides, allowing vertical attachment, and on top, allowing lateral attachment. Panels are attached with plugs into the holes of the modules.
- **Horisontal:** Horisontal has the composition of Base structure + Panel. The base structure is comprised of telescopic beams, both laterally and vertically. The vertical telescopic beams are pressed against the ceiling and floor to gain stability. The lateral telescopic beams are attached to the vertically telescopic beams. The panels are attached to the vertical telescopic beams using clips.
- **Ladder:** Ladder has the composition of Base structure + Panel. The base structure is comprised of vertical telescopic beams and lateral beams, which attach to the vertical beams. The beams are set up in a ladder structure, where the panels are hung on the lateral beams on each side of the ladder.
- **Retractable slide panels:** Retractable slide panels has the composition of Base structure + Panel. The base structure is rails fastened on the ceiling and floor. The panels, which have a height from floor to ceiling, are slid in the rails and can be moved in translation. Panels are hollow and open on one side of the panel, allowing the panels to be retracted into each other. Works in a similar way as sliding doors.
- **Retractable box:** Retractable box has the composition of Module. The modules are compressed into each other, similar to Matryoshka dolls, by using flexible material on the edges of the modules. When expanded, the top module is wedged into a slit on the bottom module.
- **Vertical:** Vertical has the composition of Base structure + Modules. The base structure is comprised of base plates and beams attached. The modules have a hole, which is put through the beam on the base plate. The beams can be built laterally, allowing more modules to be attached laterally. The base plates are attached vertically in the same way jigsaws are attached.
- **Oval:** Oval has the composition Modules. The modules are oval, and have several holes enabling attachments, such as shelves etc. The sides of the modules are extruded, which allows vertical attachment. The holes on the top, and extrusion on the bottom of the modules allow lateral attachment.
- **Triangle:** Triangle has the composition Modules + Panels. The modules are

## 5. Concept Generation

triangular prism, and are attached with rails, both vertical and lateral. The front of the module can be attached to panels also using rails.



**Figure 5.4:** Sketches of the nine concepts

# 6

## Concept Selection

This chapter explains the concept selection, which includes concept screening and selection, and concept refinement.

### 6.1 Concept Screening and Selection

To systematically select a promising concept, decision matrices are used. The decision matrices provide a structural overview and documentation of the information behind each decision, and explain and support each decision made. The decision matrices used are Elimination matrix, Pugh matrix, and Kesselring matrix, and resulted in two concepts from the initial nine concepts.

#### 6.1.1 Elimination Matrix

The first screening was the elimination matrix, as shown in Table 6.1, which identifies and eliminates concepts that do not meet the requirements specified in the product specification (Almefelt, 2022). Each concept is assessed for each of the requirements and is marked as either fulfilled or not fulfilled. If any of the requirements are not fulfilled, the concept is eliminated. Three concepts did not fulfil the requirements: Retractable box, Ladder and Retractable slide panels.

Retractable box and Retractable slide panels did not fulfill three of the requirements, although different sets of requirements. Retractable box did not fulfil "Customizable Exterior", "Design suitable for home environment" and "Easy to separate different materials" requirements because its retractable function involved excessive complexities.

Retractable slide panels did not fulfil "Adaptable height", "Easy to handle" and "Maximum 15 kg per module" requirements because of its solutions of having to fasten them to the ceiling and floor, making them more permanent, restricting their adaptability, and resulting in having larger modules.

Ladder did not fulfil four requirements, which were "Easy to handle", "Maximum 15 kg per module", "Assembled height of the room divider can be 2.4m" and subsequently "Assembled height of the room divider can be 2.7m" requirements, mainly because of its bulky and complicated construction.

Three concepts were eliminated, resulting in six remaining concepts.

**Table 6.1:** Elimination matrix

	Modularity				Mobility				Safety	Visuals	Sustainability	Geometry		Comment:	Decision:	
	Attachable and detachable modules	Adaptable height	Adaptable width	Customizable exterior	Assembly and disassembly possible by maximum 2 persons	Assembly and disassembly is intuitive	Easy to handle	No permanent damage on the interior when moved	Maximum 15 kg per module	Minimize health hazard	Minimize fire hazard	Design suitable for a home environment	Easy to separate different materials			The assembled height of the room divider can be 2.4m
Concept:	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
Vertical	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Retractable box	+	+	+	-	+	+	+	+	+	+	-	-	+	+	Deviation from requirement	-
Horizontal	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Triangle Slides	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Oval Turn	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
The Puzzle	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
The Ladder	+	+	+	+	+	-	+	-	+	+	+	+	-	-	Deviation from requirement	-
The Turning Puzzle	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+
Retractable Slide Panels	+	-	+	+	+	-	+	-	+	+	+	+	+	+	Deviation from requirement	-

### 6.1.2 Pugh matrix

The second screening was the Pugh matrix and was conducted to evaluate the concepts by comparing their performance with respect to the desires from the requirement specification, against a reference (Wikberg-Nilsson et al., 2021). The evaluation and screening were conducted in two iterations with two different Pugh matrices. The first was with reference to a product already on the market, and the second reference was set to one of the generated concepts with the median score from the first iteration.

The first iteration of the Pugh matrix was an evaluation of the generated concepts compared to a product on the market, Wallstack. Wallstack is a system of modular partition walls that allows for the folding and stacking of walls without requiring any tools (Wallstack, 2023).

Following the evaluation, the "Horizontal" concept was eliminated as its score was far below that of the reference product. However, the remaining concepts that achieved equal or better scores than the reference were not eliminated in this iteration. The horizontal concept's unstable and complex construction posed difficulties in assembly, limited its adaptability, and compromised its balance, resulting in its elimination.

Table 6.2 presents the Pugh matrix. The greyed-out desires, desires not considered in the PUGH matrix, are material dependent. As described in Demarcations, the material will not be applied until the detail design phase.

**Table 6.2:** Pugh matrix with the reference of a competitive product

		Pugh Matrix						
Category	Criteria	Wallstack	Vertical	Horizontal	Triangle Slides	Oval Turn	The Puzzle	The Turning Puzzle
<b>Modularity</b>	Attachable without the use of tools	0	0	0	0	0	0	0
	Easy to change modules	0	0	1	0	0	0	0
<b>Mobility</b>	Assembly and disassembly possible by 1 person	0	0	-1	0	0	0	0
	Intuitive relocation	0	0	-1	0	0	0	0
	Compactable	0	-1	0	-1	-1	-1	-1
<b>Robustness</b>	Minimal variation during physical impact							
	Minimal age defects	0	0	0	0	0	0	0
	Withstand 258.66 N force without losing stability	0	0	-1	0	0	0	0
	Module attached and detached a minimum of 20 times	0	0	0	0	0	0	0
<b>Safety</b>	Minimize cutting hazard	0	0	0	-1	0	0	0
	Minimize pinching hazard	0	1	-1	1	0	1	1
<b>Visuals</b>	Appealing aesthetic	0	1	1	1	1	1	1
	Allow light to pass through	0	1	1	0	0	0	0
<b>Features</b>	Acoustic absorption coefficient over 0.3 at 1000Hz							
	Storage capabilities	0	0	0	0	0	0	1
<b>Sustainability</b>	Made of renewable material							
	Made of recycled material							
	Made of recyclable material							
	Minimize amount of different materials	0	-1	-1	0	-1	0	-1
<b>Geometry</b>	Able to change form	0	1	-1	0	1	0	1
	Able to change shape	0	0	0	1	0	0	0
<b>Maintenance</b>	Easy to inspect	0	0	-1	0	0	0	0
	Easy and resistant to cleaning	0	0	-1	0	0	0	0
	$\Sigma +$	0	4	3	3	2	2	4
	$\Sigma -$	0	-3	-9	-2	-2	-1	-2
	$\Sigma 0$	0	11	6	13	14	15	12
	<b>Total</b>	<b>0</b>	<b>2</b>	<b>-5</b>	<b>1</b>	<b>0</b>	<b>1</b>	<b>2</b>
<b>Decision</b>		<b>Eliminated</b>						

A second iteration of the Pugh matrix was conducted to further screen and evaluate the concepts. The matrix evaluated the remaining concepts, with the "triangle slides" concept from the first iteration, which received the median score, serving as the reference.

Based on the evaluation, one concept achieved a higher score, one scored lower, and the rest had equal scores compared to the reference. The concept with the lowest score, "The Puzzle," was eliminated. The reason the concept "The Puzzle" was eliminated was primarily because of its lack of aesthetic appeal, as its plain shape was considered worse than of the reference. Table 6.3 presents the Pugh matrix for this iteration.

The four remaining concepts that scored equally or higher were left in the screening process and were further considered in the next screening, the Kesselring matrix. A total of two concepts were eliminated from the Pugh matrix.

**Table 6.3:** Pugh matrix with the reference set to the median concept

Pugh Matrix						
Category	Criteria	Triangle Slides	Vertical	Oval Turn	The Puzzle	The Turning Puzzle
<b>Modularity</b>	Attachable without the use of tools	0	0	0	0	0
<b>Mobility</b>	Easy to change modules	0	0	-1	0	1
	Assembly and disassembly possible by 1 person	0	0	0	0	0
	Intuitive relocation	0	0	0	0	0
	Compactable	0	0	0	0	0
<b>Robustness</b>	Minimal variation during physical impact					
	Minimal age defects					
	Withstand 258.66 N force without losing stability	0	1	0	0	1
	Module attached and detached a minimum of 20 times	0	0	0	0	0
<b>Safety</b>	Minimize cutting hazard	0	1	1	0	1
	Minimize pinching hazard	0	-1	0	0	0
<b>Visuals</b>	Appealing aesthetic	0	0	0	-1	0
	Allow light to pass through	0	1	0	0	0
<b>Features</b>	Acoustic absorption coefficient over 0.3 at 1000Hz					
	Storage capabilities	0	0	0	0	1
<b>Sustainability</b>	Made of renewable material					
	Made of recycled material					
	Made of recyclable material					
	Minimize amount of different materials	0	-1	-1	0	0
<b>Geometry</b>	Able to change form	0	0	1	0	1
	Able to change shape	0	0	0	0	0
<b>Maintenance</b>	Easy to inspect	0	0	0	0	0
	Easy and resistant to cleaning	0	0	0	0	0
	$\Sigma +$	0	3	2	0	4
	$\Sigma -$	0	-2	-2	-1	0
	$\Sigma 0$	0	12	13	16	13
	<b>Total</b>	<b>0</b>	<b>1</b>	<b>0</b>	<b>-1</b>	<b>5</b>
	<b>Decision</b>				<b>Eliminated</b>	

### 6.1.3 Kesselring matrix

To select the final concepts, a Kesselring matrix was created to conduct a more detailed scoring and evaluation of the remaining concepts. The purpose was to examine the concepts more nuanced and further narrow down the concepts to be developed further in detail.

The Kesselring matrix is based on a scoring system which uses weighted desires. Each desire has a value scale from 1 to 5, where every concept receives a score based on its performance, which is then calculated with the weight of the desires and added up (Almefelt, 2022).

The weights were calculated with a simplified version of an analytic hierarchy process (AHP), where the desires are compared and evaluated against each other from a scale from 1/9, extremely less important to 9, extremely more important, where 1 is equal importance (Jagoda et al., 2020). It resulted in desires receiving a percentage of importance for comparison. The simplified AHP is presented in Table 6.4.

Table 6.4: First-Level Analytical Hierarchy Process

Desires	First-Level Analytic Hierarchy Process																							Total:	Weights:	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23			
Attachable without the use of tools	1	1	0,33	3	5	7	5	5	5	1	5	7	1	7	5	8	0,14	1	0,14	4	6	6	1	1	84,62	0,075
Easy to change modules	2	3	1	3	7	5	6	6	5	4	5	7	3	7	5	8	3	5	3	6	7	7	3	3	112,00	0,100
Assembly and disassembly possible by 1 person	3	0,33	0,33	1	7	5	5	6	5	1	5	6	1	7	5	8	3	5	3	7	7	7	3	3	100,67	0,090
Intuitive relocation	4	0,20	0,14	0,14	1	0,25	0,33	0,33	0,33	0,14	0,33	0,33	0,17	3	2	4	0,14	0,20	0,14	0,20	0,33	0,33	0,20	0,20	14,46	0,013
Compactable	5	0,14	0,20	0,20	4	1	0,50	0,50	0,50	0,25	0,50	0,50	0,20	3	2	4	0,20	0,33	0,20	3	5	5	0,33	0,33	31,89	0,028
Minimal variation during physical impact	6	0,20	0,17	0,20	3	2	1	1	0,33	0,20	0,33	0,50	0,14	3	2	4	0,14	0,20	0,14	0,25	3	3	0,33	0,33	25,48	0,023
Minimal age defects	7	0,20	0,17	0,17	3	2	1	1	0,20	0,20	0,33	0,50	0,17	4	3	5	0,17	0,25	0,17	2	2	2	0,33	0,33	28,18	0,025
Withstand 258.66 N force without losing stability	8	0,20	0,20	0,20	3	2	3	5	1	0,33	0,50	1	0,25	6	4	7	0,20	0,33	0,20	3	3	3	2	2	47,42	0,042
Module attached and detached a minimum of 20 times	9	1	0,25	1	7	4	5	5	3	1	4	3	0,33	3	2	4	0,25	0,50	0,25	5	5	5	3	3	65,58	0,058
Minimize cutting hazard	10	0,20	0,20	0,20	3	2	3	3	2	0,25	1	2	0,25	6	4	7	0,25	0,50	0,25	2	4	4	3	3	51,10	0,046
Minimize pinching hazard	11	0,14	0,14	0,17	3	2	2	2	1	0,33	0,50	1	0,20	5	3	6	0,25	0,50	0,25	2	3	3	2	2	39,49	0,035
Appealing aesthetic	12	1	0,33	1	6	5	7	6	4	3	4	5	1	8	6	9	0,50	2	0,50	5	6	6	2	2	90,33	0,081
Allow light to pass through	13	0,14	0,14	0,14	0,33	0,33	0,33	0,25	0,17	0,33	0,17	0,20	0,13	1	0,33	4	0,20	0,25	0,20	0,25	1	1	0,25	0,25	11,40	0,010
Acoustic absorption coefficient over 0.3 at 1000Hz	14	0,20	0,20	0,20	0,50	0,50	0,50	0,33	0,25	0,50	0,25	0,33	0,17	3,00	1	5	0,25	0,33	0,25	0,33	3	3	0,33	0,33	20,77	0,019
Storage capabilities	15	0,13	0,13	0,13	0,25	0,25	0,25	0,20	0,14	0,25	0,14	0,17	0,11	0,25	0,20	1	0,17	0,20	0,17	0,20	0,33	0,33	0,20	0,20	5,39	0,005
Made of renewable material	16	7	0,33	0,33	7	5	7	6	5	4	4	4	2	5	4	6	1	5	1	6	6	6	3,00	3	97,67	0,087
Made of recycled material	17	1	0,20	0,20	5	3	5	4	3	2	2	0,50	4	3	5	0,20	1	0,20	2	1	1	0,33	0,33	45,97	0,041	
Made of recyclable material	18	7	0,33	0,33	7	5	7	6	5	4	4	4	2	5	4	6	1	5	1	5	5	5	3	3	94,67	0,084
Minimize amount of different materials	19	0,25	0,17	0,14	5	0,33	4	0,50	0,33	0,20	0,50	0,50	0,20	4	3	5	0,17	0,50	0,20	1	0,33	0,33	0,20	0,20	27,06	0,024
Able to change form	20	0,17	0,14	0,14	3	0,20	0,33	0,50	0,33	0,20	0,25	0,33	0,17	1	0,33	3	0,17	1	0,20	3	1	1	0,33	0,33	17,14	0,015
Able to change shape	21	0,17	0,14	0,14	3	0,20	0,33	0,50	0,33	0,20	0,25	0,33	0,17	1	0,33	3	0,17	1	0,20	3	1	1	0,33	0,33	17,14	0,015
Easy to repair	22	1	0,33	0,33	5	3	3	3	0,50	0,33	0,33	0,50	0,50	4	3	5	0,33	3	0,33	5	3	3	1	1	46,50	0,041
Easy to maintain	23	1	0,33	0,33	5	3	3	3	0,50	0,33	0,33	0,50	0,50	4	3	5	0,33	3	0,33	5	3	3	1	1	46,50	0,041
Sum Total:																							121,41	1,000		

The value scales illustrate how the desires are quantified, specifying what each value of the weighted desire represents. The value scale spans from 1 to 5, however are absolute desires set as either 1 or 5. The value scales and their definitions are presented in Table 6.5.

Table 6.5: Value Scales

Desires:	Value Scale				
	1	2	3	4	5
Attachable without the use of tools	Use of tools	-	-	-	No use of tools
Easy to change modules	>6 steps	5 steps	4 steps	3 steps	2 steps
Assembly and disassembly possible by 1 person	Not possible by 1 person	-	-	-	Possible by 1 person
Intuitive relocation	Unintuitive relocation [1]	-	-	-	Intuitive relocation
Compactable	(+)20%	(+)10%	0%	(-)10%	(-)20%
Minimal variation during physical impact	<1000N	1000N	1500N	2000N	>2000N
Minimal age defects	<5 years	5 years	10 years	15 years	>15 years
Withstand force without losing stability	<150 N	150 N	200 N	258 N	>258 N
Module attached and detached a minimum of 20 times	<40 times	40 times	60 times	80 times	>80 times
Minimize cutting hazard	4	3	2	1	0
Minimize pinching hazard	4	3	2	1	0
Appealing aesthetic	1	2	3	4	5
Allow light to pass through	Light able to pass through	-	-	-	Light not able to pass through
Acoustic properties	<0.1	0.1	0.2	0.3	>0.3
Storage Capabilities	Storage capabilities	-	-	-	No storage capabilities
Made of renewable material	<20%	40%	60%	80%	100%
Made of recycled material	<20%	40%	60%	80%	100%
Made of recyclable material	<20%	40%	60%	80%	100%
Minimize amount of different materials	5 materials	4 materials	3 materials	2 materials	1 material
Able to change form	Not able to change form	-	-	-	Able to change form
Able to change shape	Not able to change shape	-	-	-	Able to change shape
Easy to repair	Not easy to repair	-	-	-	Easy to repair
Easy to maintain	Daily maintenance	Weekly maintenance	Monthly maintenance	Yearly maintenance	No maintenance

From the AHP, which evaluates the weight of each desire, the five most important desires were:

- Easy to change modules
- Assembly and disassembly possible by 1 person
- Appealing aesthetic
- Made of renewable material
- Made of recyclable material

## 6. Concept Selection

The two latter desires are material dependent, and will therefore not be considered in the Kesselring but rather in the detail design phase.

The desire "Assembly and disassembly possible by 1 person" were scored 5 by all concepts, what differentiated the score of the concepts were the desires "Easy to change modules" and "Appealing Aesthetic". Turning Puzzle scored a 5 on both of the desires, and is thus the highest-scoring concept.

Vertical scored a 5 on "Appealing aesthetic" while Triangle scored a 3, and vice versa on "Easy to change modules", resulting in a very similar scoring, with Vertical barely edging out Triangle in the overall score.

Oval scored lower overall, a 3 on "Appealing Aesthetic" and a 4 on "Easy to change modules", which resulted in the lowest scoring concept. The result from the Kesselring was two concepts eliminated, Triangle and Oval, with the remaining two, Vertical and Turning puzzle, being the two final concepts, the Kesselring matrix can be seen in Table 6.6.

Two concepts were selected due to that the two highest scoring concepts greatly differed from each other, and provided different qualities.

**Table 6.6:** Kesselring matrix

Kesselring matrix											
Concepts →		Ideal		Triangle		Vertical		Oval		Turning Puzzle	
Criteria	w	v	t	v	t	v	t	v	t	v	t
Attachable without the use of tools	0,075	5	0,375	5	0,375	5	0,375	5	0,375	5	0,375
Easy to change modules	0,1	5	0,5	5	0,5	3	0,3	4	0,4	5	0,5
Assembly and disassembly possible by 1 person	0,09	5	0,45	5	0,45	5	0,45	5	0,45	5	0,45
Intuitive relocation	0,013	5	0,065	0	0	5	0,065	5	0,065	5	0,065
Compactable	0,028	5	0,14	3	0,084	2	0,056	2	0,056	2	0,056
Minimal variation during physical impact	0,023	5	0,115								
Minimal age defects	0,025	5	0,125								
Withstand 258.66 N force without losing stability	0,042	5	0,21								
Module attached and detached a minimum of 20 times	0,058	5	0,29								
Minimize cutting hazard	0,046	5	0,23	3	0,138	5	0,23	5	0,23	5	0,23
Minimize pinching hazard	0,035	5	0,175	3	0,105	3	0,105	3	0,105	3	0,105
Appealing aesthetic	0,081	5	0,405	3	0,243	5	0,405	3	0,243	5	0,405
Allow light to pass through	0,01	5	0,05	1	0,01	5	0,05	1	0,01	1	0,01
Acoustic properties	0,019	5	0,095								
Storage capabilities	0,005	5	0,025	1	0,005	1	0,005	1	0,005	5	0,025
Made of renewable material	0,087	5	0,435								
Made of recycled material	0,041	5	0,205								
Made of recyclable material	0,084	5	0,42								
Minimize amount of different materials	0,024	5	0,12	5	0,12	4	0,096	4	0,096	5	0,12
Able to change form	0,015	5	0,075	5	0,075	5	0,075	1	0,015	5	0,075
Able to change shape	0,015	5	0,075	5	0,075	5	0,075	5	0,075	5	0,075
Easy to repair	0,041	5	0,205	5	0,205	5	0,205	1	0,041	5	0,205
Easy to maintain	0,041	5	0,205	4	0,164	3	0,123	4	0,164	3	0,123
T = Σ ti		4,99		2,549		2,615		2,33		2,819	
T / Tmax		1,00		0,51		0,52		0,47		0,56	
<b>Ranking</b>		-		3		2		4		1	

## 6.2 Concept Refinement

The final two concepts were further refined and designed more in detail. Every component of the concepts and what potential improvements could be implemented were examined. Adjustments and changes to the concepts will be briefly explained, and what the changes and adjustments resulted in will be explained in detail in Chapter 7.

For Vertical, the shape of the modules was investigated and examined on what other shapes could be aesthetically pleasing and provide a coherent pattern when multiple modules are united. The beams were slightly remade, for a better design between the modules and to improve the rotation of the modules. The base was changed, to increase its compatibility with different types of foundations and to have a more uniform design that is consistent with the design of the modules.

For Turning puzzle, the lateral attachment between modules was changed to the attachment from the concept "The puzzle". To retain the ability to be attached in different directions, the shape was changed. A new vertical attachment was implemented to concur with the new design.



# 7

## Detail Design and Analysis

In this chapter, detailed designs for the two remaining concepts will be presented. It concludes with the material selection, the analysis results, and cost assessment.

### 7.1 Detail Design

The two remaining concepts are presented with descriptions of their aesthetics, assembly and features.

### 7.2 Vertical

The concept Vertical is comprised of 3 different components; base, module and beam. The sizes of the components are 0.3 m x 0.45 m x 0.24 m, 0.3 m x 0.35 x 0.08 m and 0.3 m x 0.04 x 0.04 m respectively. The three components can achieve different arrangements, an example is presented in Figure 7.1.

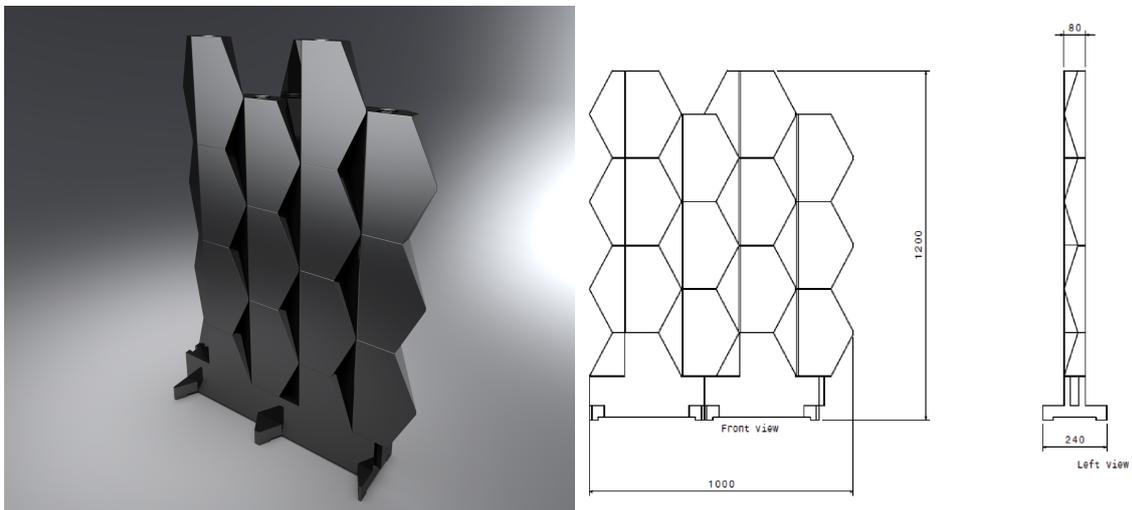
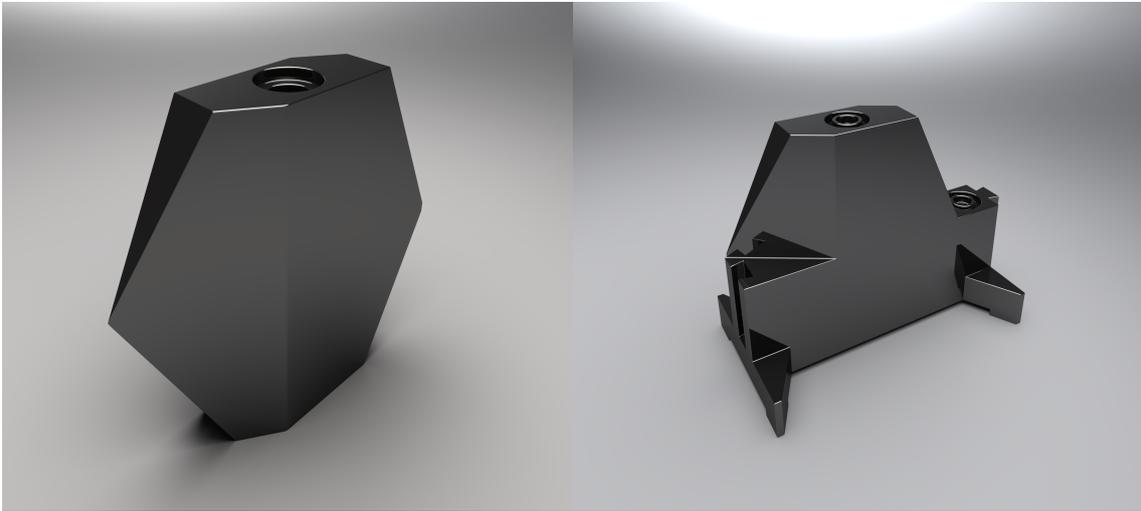


Figure 7.1: Left: Full assembly. Right: Drawing

#### 7.2.1 Aesthetics

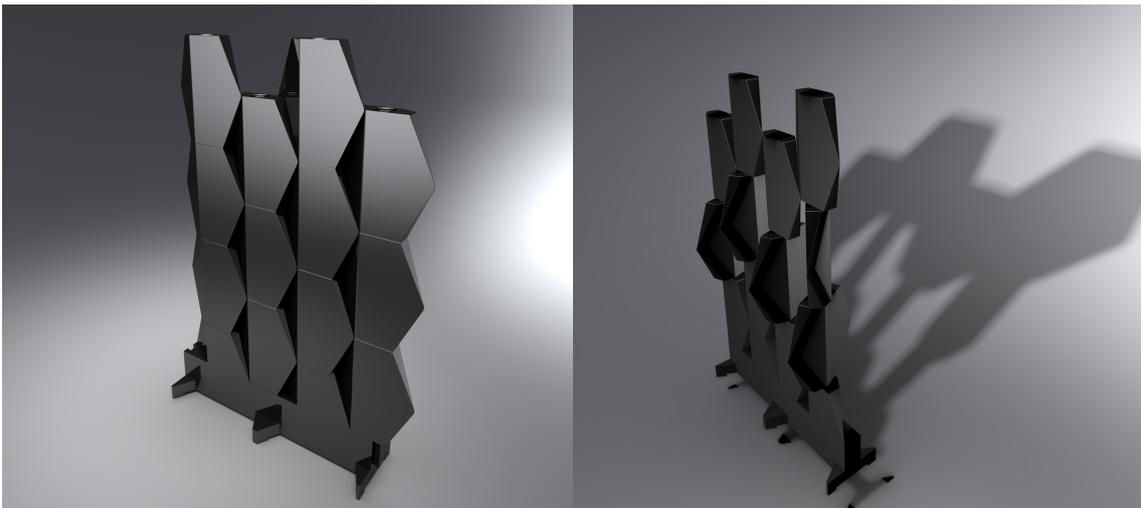
A hexagonal shape for the modules was chosen since it supports the alternating pattern arrangement. Consequently, the base is partially elevated to facilitate the alternating pattern. The modules are slanted on both sides, enabling overlapping

between modules while maintaining lateral positioning for a flat surface. Similarly, the base is designed with partially slanted sides to ensure a consistent and seamless transition between the base and the module, thus enhancing the overall uniformity of the design. See Figure 7.2.



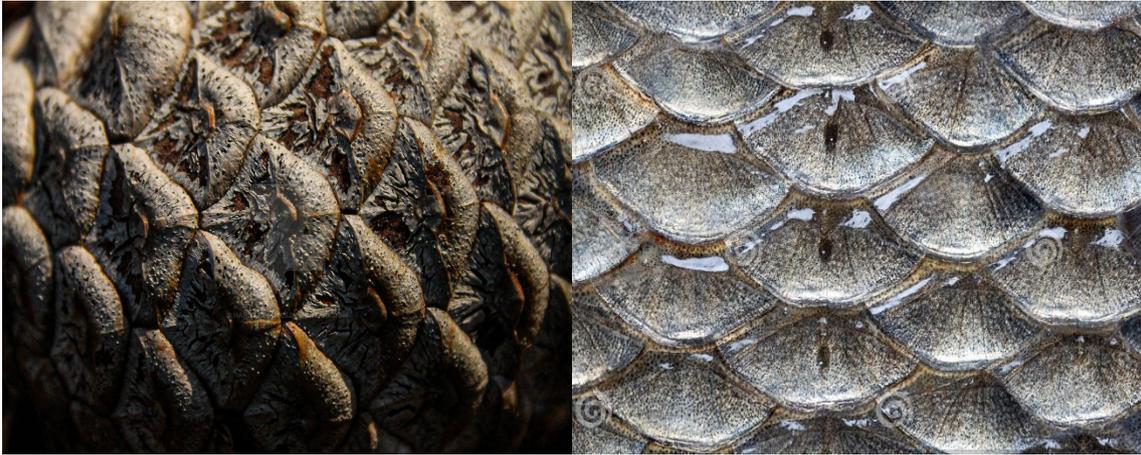
**Figure 7.2:** Left: Module; Right: Base

The alternating pattern arrangement of the concept adds a dynamic aesthetic appeal, which is further emphasized by the modules' ability to rotate. The passage of sunlight through the openings not only allows for lighting and natural lighting, but can also create interesting shadow arrangements, that can vary throughout the day. The ability to rotate could also make small spaces feel less confining, especially comforting for users living in more compact housing. 7.3.



**Figure 7.3:** Left: Assembly; Right: Shadow arrangement of the assembly

The inspiration behind the alternating hexagonal pattern arrangement derives from the principles of biophilic design, specifically from "biomorphic forms and patterns." The design takes inspiration from nature, specifically patterns found in pine cones, fish scales, bee hives, and hexagonal basalt stones. Although not exact replicas, the intention is to induce a sense of familiarity with these natural patterns, thereby creating a biophilic experience. See Figure 7.4 and 7.5.



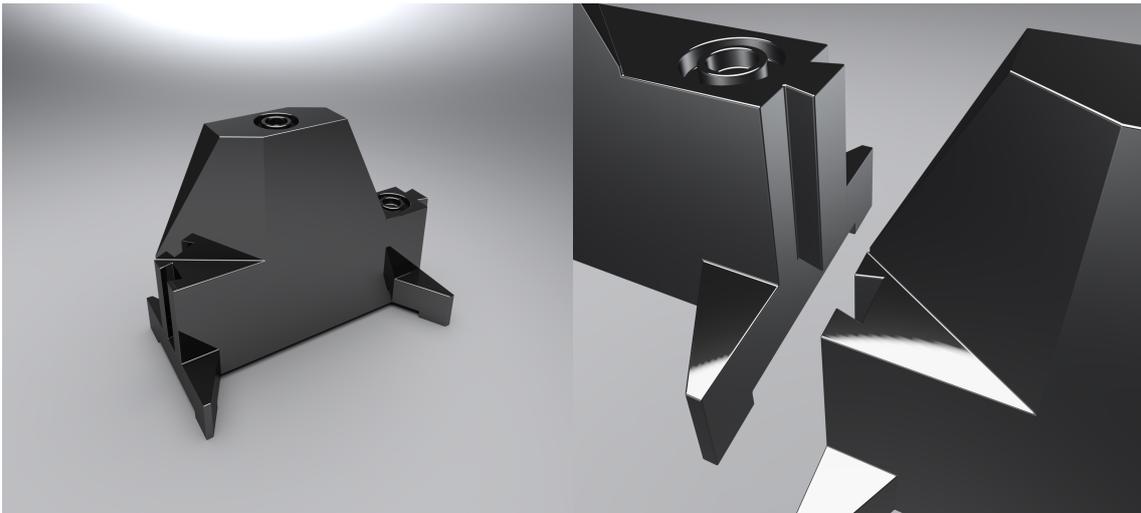
**Figure 7.4:** Left: Pine cone pattern (Endres, 2021); Right: Fish scale pattern (Dreamstime, 2021)



**Figure 7.5:** Left: Hexagonal basalt stone pattern (Henderson, 2019); Right: Honeycomb pattern (tapet.com, 2021)

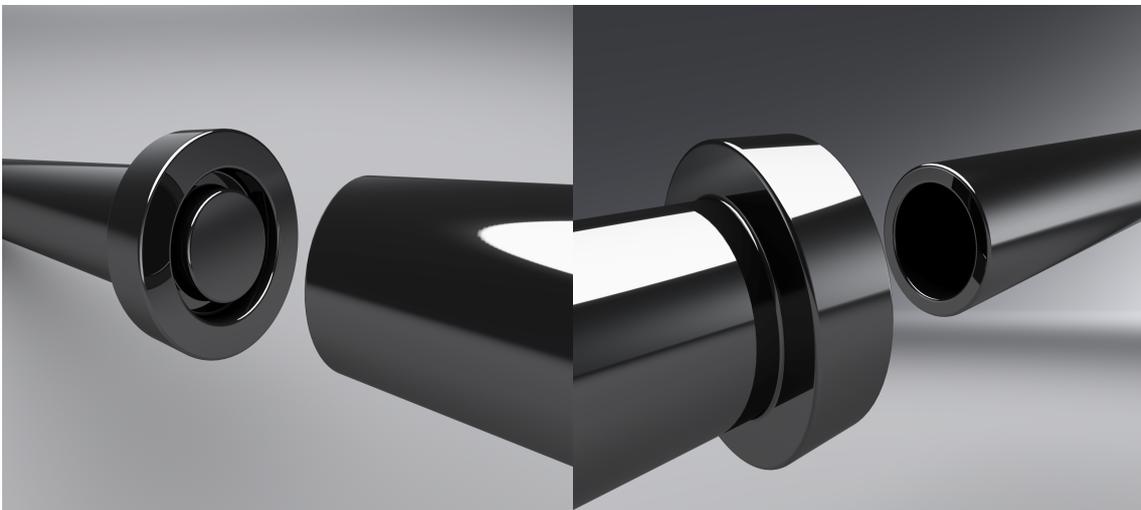
### 7.2.2 Assembly

The base of the structure can be connected using two beams, with one of the attachments being elevated. For lateral construction, the bases are joined by inserting the extruded portion into the opening of the subsequent base. To ensure stability, the base includes four corner feet that are expanded, creating four points of contact. See Figure 7.6.



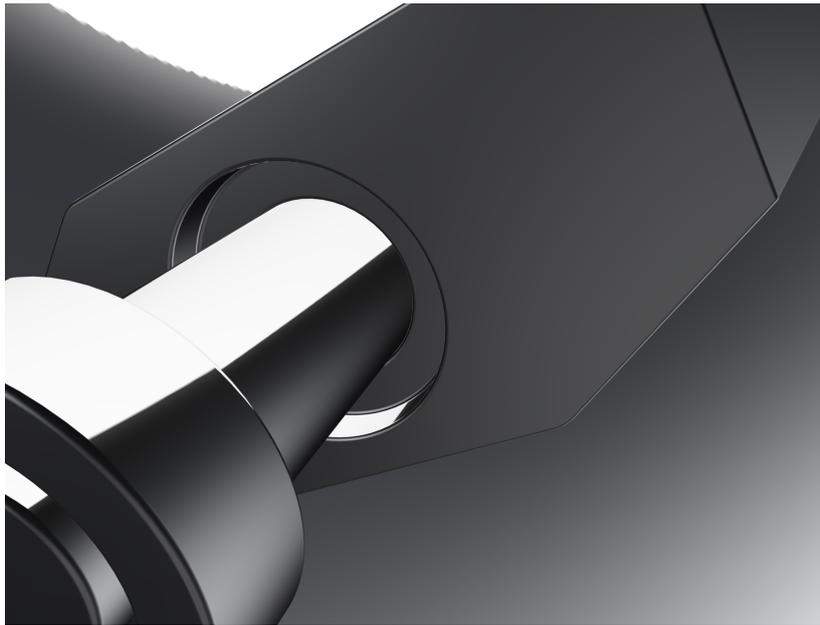
**Figure 7.6:** Left: Base; Right: Base to base attachment

For vertical assembly, beams are attached to the base by inserting the beam into the attachment opening of the base. This vertical construction can be extended laterally by attaching additional beams. The beams themselves are attached by inserting one beam into the bottom opening of another, similar to the base-beam attachment. See Figure 7.7.



**Figure 7.7:** Left: Beam to beam attachment; Right: Beam to beam attachment

The modules are threaded onto the beams through the holes located in the middle of the modules. They are supported by the wider circumference of the beam's base. To prevent gaps between the modules when resting on the beam base, the bottom of the modules is countersunk. This design also allows for smoother rotation of the modules, as the weight of the modules above does not hinder their rotation. See Figure 7.8.



**Figure 7.8:** Beam to module attachment.

To assemble the modules with the beams, the modules are threaded through the beams first before attaching the subsequent beams, taking into account the wider circumference of the beam's bottom. See Figure 7.9.



**Figure 7.9:** Exploded view of the assembly

### 7.2.3 Features

The key feature of the concept revolves around the modules' ability to rotate independently, resulting in openings between them. The rotation feature empowers users to create personalized patterns of openings based on their preferences. The openings serve a dual purpose by allowing both light and sound to pass through. The passage of light can extend sunlight's reach in rooms with limited natural light. Likewise, the passage of sound enables improved verbal communication and enhanced supervision, particularly beneficial for child safety. See Figure 7.10.



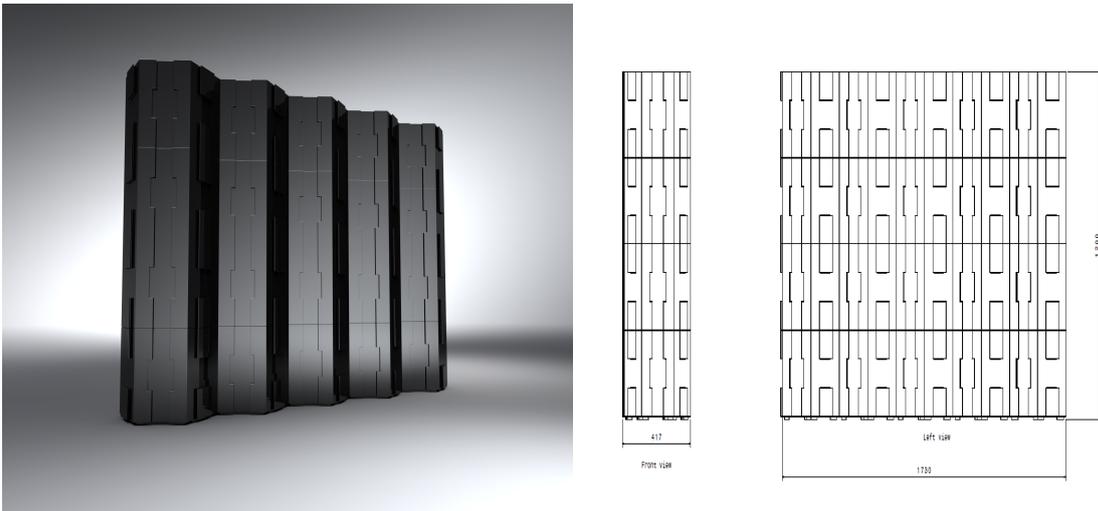
**Figure 7.10:** Assembly with modules turned

The module rotation mechanism is designed to be user-friendly and easily accessible. Returning to the original configuration of the modules is as simple as rotating them back to their original positions.

The concept is a modular system, supporting different modules with different functionalities to be attached, provided they conform to the overall module specifications.

## 7.3 Turning puzzle

The concept Turning puzzle is comprised of two components; module and lid. The sizes of the components are 0.3 m x 0.355 m x 0.4 m and 0.015 m x 0.355 m x 0.4 m respectively. The modules offer flexibility in their arrangement, a possible arrangement is presented in Figure 7.11.



**Figure 7.11:** Left: Assembly; Right: Drawing

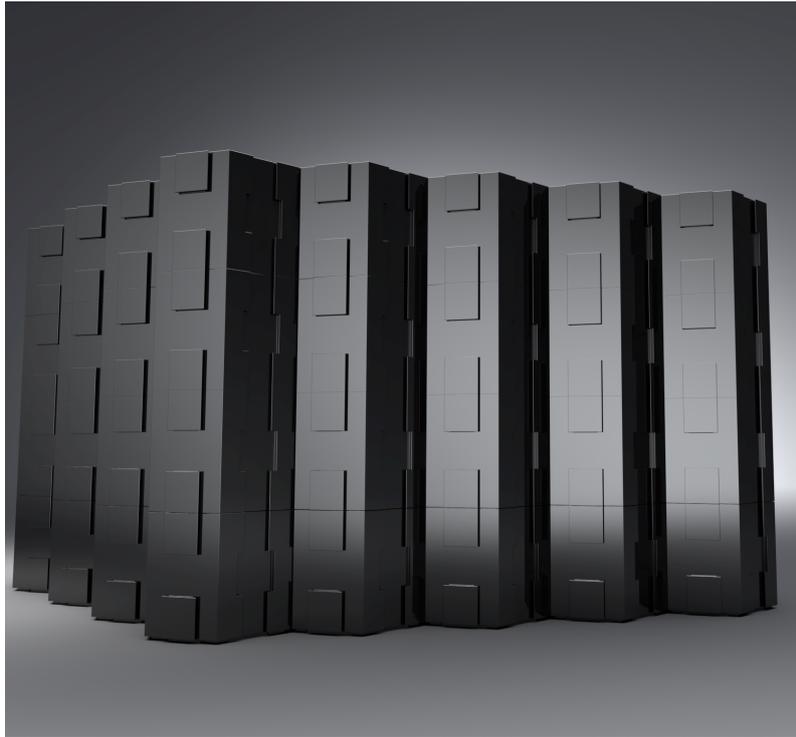
### 7.3.1 Aesthetics

The concept's simple aesthetics make it suitable for various environments. The modules can be kept in a minimalistic style or transformed into more visually interesting aesthetics due to their versatility in shapes and forms. The flexibility not only allows for the desired functional layout but also provides users with the freedom to express their aesthetic preferences. Different aesthetic compositions can be created, as seen in Figure 7.16, which could be ideal for a showroom as a surface for displaying products.

Similar to Vertical, the hexagonal shape of the modules is inspired by natural phenomena. However, when assembled as a room divider with greater height, the hexagonal pattern may not be prominently visible, instead emphasizing the minimalistic aesthetic. On the other hand, when used as a surface, the pattern becomes more apparent, resembling patterns found in nature and providing a biophilic experience. See Figure 7.12

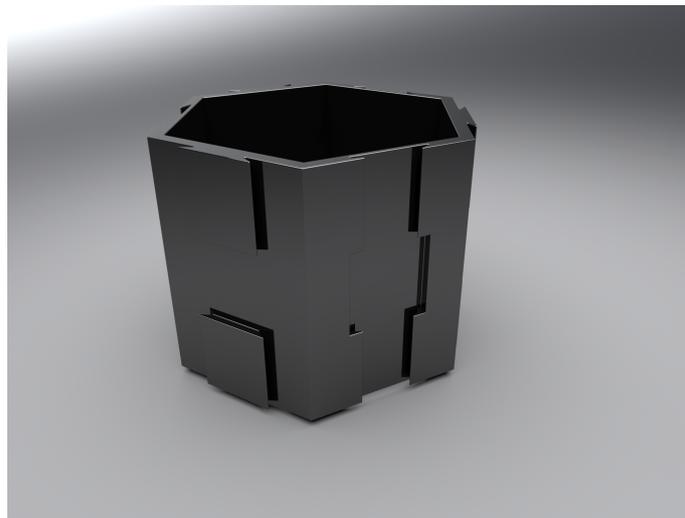
### 7.3.2 Assembly

The concept features a hexagonal design, with each side of the module having an attachment. The lateral attachments alternate between an extruded portion and an opening, where the extruded portion connects to the opening. Since it is hexagonal, it can be attached from all sides simultaneously. The extruded portion is partially



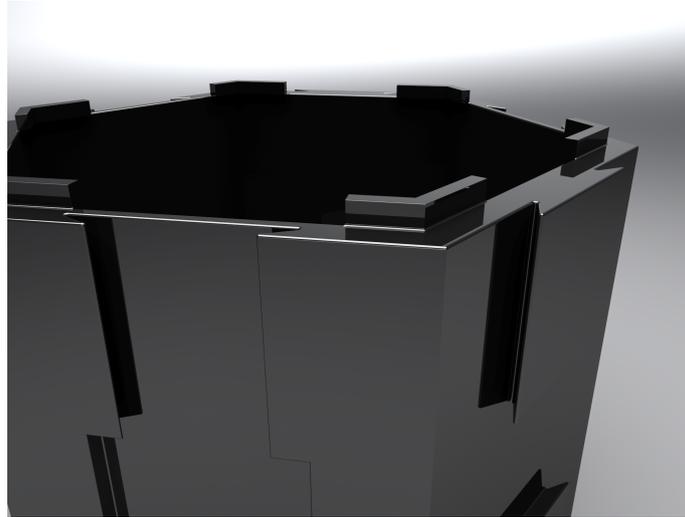
**Figure 7.12:** Assembly

extended along the side of the module, but it is not extruded for the entire length. Instead, it is separated into two parts, with a non-extruded center portion. Similarly, the openings on each side are differentiated, with the center portion having a wider opening. This design enables the modules to be attached without requiring the entire length of the module to be raised. Instead, the lower extruded portion is inserted into the wider opening at the center, while the higher extruded portion remains elevated above the module, or vice versa. See Figure 7.13.



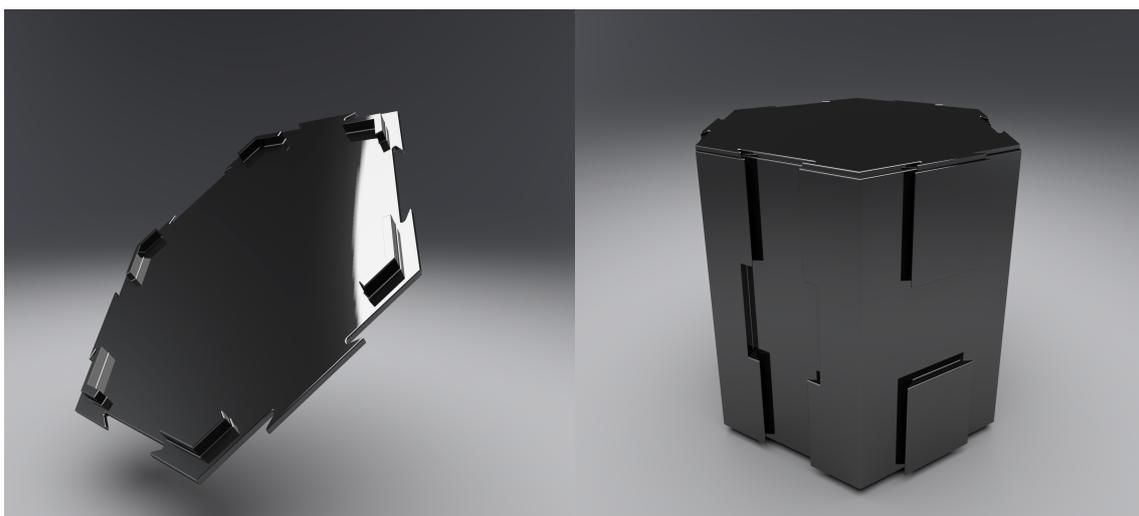
**Figure 7.13:** Module

The vertical attachment serves a dual purpose, functioning as both attachments and as feet for the module. It consists of six protruding surfaces located in the inner corners at the bottom of the module. The protruding surfaces are fitted into the top of the module to be attached. The protruding surfaces at the bottom module act as feet, creating six points of contact. See Figure 7.14.



**Figure 7.14:** Feet of the module

A lid can be added to the modules to either create a surface or seal the top opening of the module. The lid is attached in the same way as the vertical attachment, where the protruding surfaces of the lid are fitted into the top of the module. See Figure 7.28.

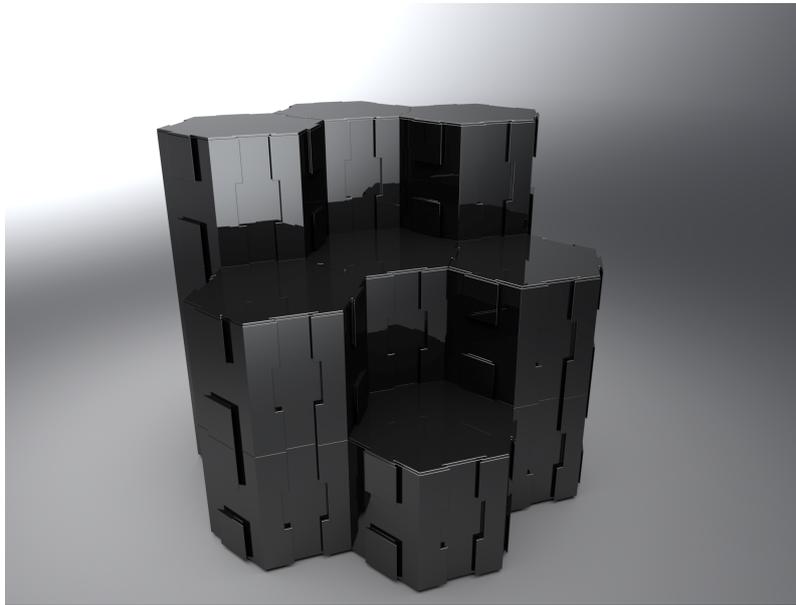


**Figure 7.15:** Left: Lid; Right: Module with lid

### 7.3.3 Features

The concept's simple attachments contribute to an intuitive assembly process. The ability to attach modules from all sides minimizes the likelihood of errors during assembly. Additionally, the lightweight of the module caused by the hollow modules facilitate easier handling and lifting during the assembly process.

The attachments on all sides of the modules enhance the concept's adaptability to various settings. This versatility enables the creation of numerous shapes and forms based on individual preferences. Furthermore, the concept can be transformed into surfaces of different sizes by adding lids, which can be customized to the preferred height, width, and depth. See Figure 7.16.



**Figure 7.16:** Mountain-shaped assembly

## 7.4 Material Selection

The material selection for both concepts was carried out using Ansys Granta EduPack (2023), a comprehensive database that includes information on various materials and their different properties. The material selection process involved screening and evaluating materials based on different criteria. These criteria were gathered from previous research and product specifications, which emphasized sustainability. The material-dependent requirements and desires are:

- Acoustic absorption coefficient over 0.3 at 1000Hz
- Maximum 15 kg per module
- Made of renewable material
- Made of recyclable material
- Made of recycled material
- Minimal age defects

These requirements and desires are used to screen and select materials. Due to the three different desires depending on what type of material should be used, renewable materials are selected for screening, since the desire is weighted higher in comparison, see Section 6.1.3.

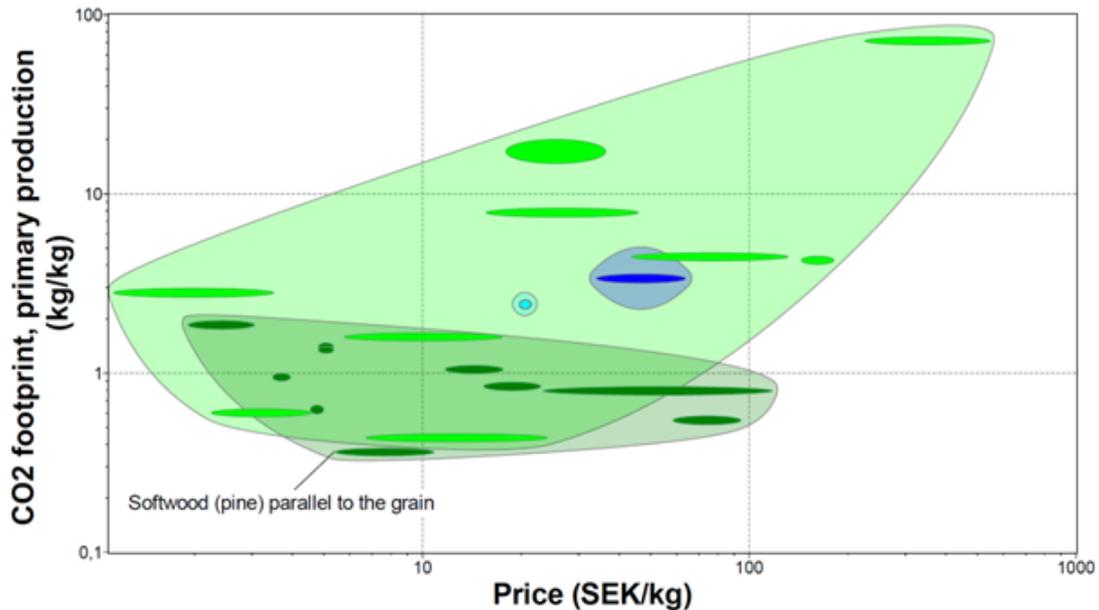
Granta EduPack does not state a materials acoustic absorbing coefficient, instead, materials are graded on a scale, the grades are: very poor, poor, average, good, and very good. The acoustic requirement derives from the acoustic absorption coefficient of plaster, and in Granta is considered to have the rating of average.

The screening process in the Granta EduPack began with an initial list of all possible materials suitable for an interior setting. From this list, a limitation was set to only include renewable materials with average, good, or very good sound absorption.

This screening resulted in 26 materials that met these criteria, these are:

- Bamboo
- Canvas
- Cellulose polymers (CA)
- Cork
- Cotton
- Flax
- Glulam
- Hardboard parallel to board
- Hardboard perpendicular to board
- Hardwood (oak) parallel to the grain
- Hardwood (oak) transverse to the grain
- Hemp
- Jute fiber
- Leather
- Medium density fiberboard parallel to board
- Medium density fiberboard perpendicular to board
- Natural rubber (NR)
- Palm fiber
- Particleboard parallel to board
- Particleboard perpendicular to board
- Plywood parallel to board
- Plywood perpendicular to board
- Silk
- Softwood (pine) parallel to the grain
- Softwood (pine) transverse to the grain
- Wool

Subsequently, the remaining 26 materials were assessed based on the  $CO_2$  footprint from primary production and price. Figure 7.17 displays the ratings of all the materials, with particular attention given to the bottom-left corner, where the cheapest material with the lowest  $CO_2$  footprint from primary production can be found. Softwood (pine) parallel to the grain emerged as the best option in this category, displaying low  $CO_2$  footprint from primary production relative to its price. To



**Figure 7.17:** Material selection with Granta EDU pack

ensure that this material would be suitable for the concepts, an evaluation of manufacturability was also conducted. This assessment revealed that Softwood (pine) parallel to the grain had the highest factor in terms of production with machinability as well as a score of 2 - 3 out of 5 in moldability. The density of the material is on a span with a maximum of  $600\text{kg}/\text{m}^3$ . Among the modules of the concepts, the largest one is the base for the Vertical and has a volume of  $0.008\text{ m}^3$ . Using the selected material, the module's weight is calculated to be 5.8 kg. The weight of 5.8 kg aligns with the specified requirement, Maximum of 15 kg per module. Additional research revealed the material is recyclable as well, also fulfilling the desire "Made of recyclable material" (Davies, 2022). Initially, the research did not provide the necessary strength information for each concept, necessitating a static structural analysis using ANSYS.

## 7.5 Technical Analysis

To assess the feasibility of the chosen material in real-world applications, a static structural analysis was conducted using Ansys Mechanical (2023). The analysis involved simulating the concepts with applied forces to determine their performance. The stress distribution of the concepts was calculated and evaluated based on the material specifications obtained from Granta Edupack, which were then implemented in Ansys.

The analysis was performed on the full-height concepts, measuring 2.7 meters, and the gravitational force was applied with fixed support on the bottom. The results of the concept analysis can be observed in Figures 7.18 and 7.19, showcasing the stress distribution, here the concepts are dark blue which indicates low impact.

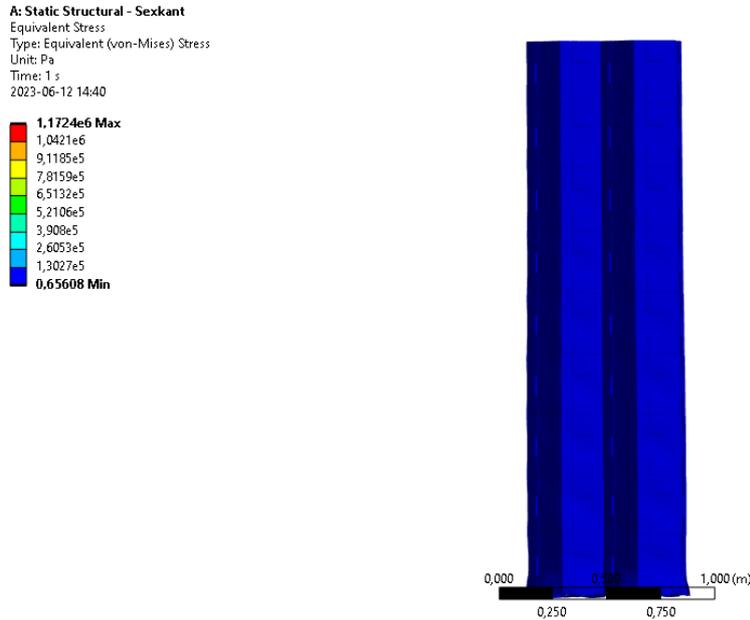


Figure 7.18: Von mises stress distribution on concept *Turning Puzzle*.

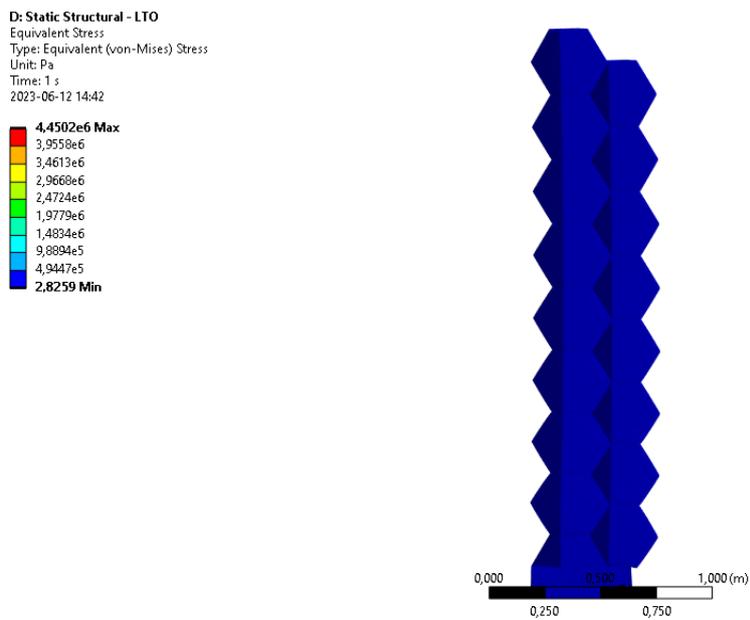
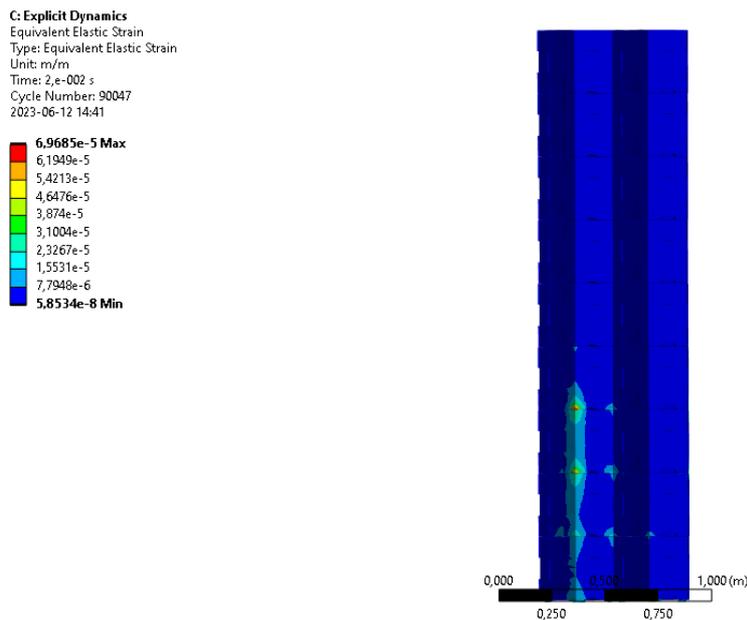


Figure 7.19: Von mises stress distribution on concept *Vertical*.

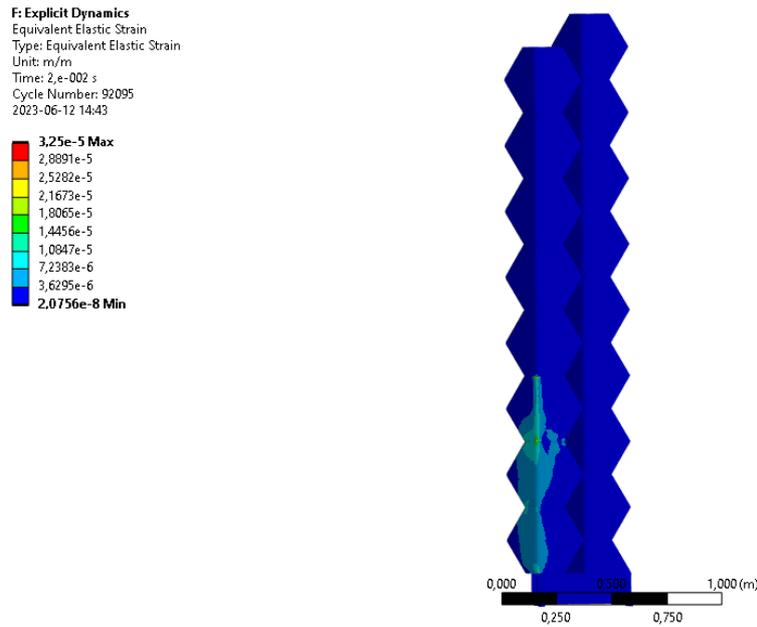
The von Mises stress serves as a reliable indicator for determining when a material will start to yield. It is important to note that as long as the maximum von Mises stress remains below the yield strength of the material, yielding will not occur. The result from the analysis validates both concepts, confirming the material and the construction's applicability.

Once it was established that the material effectively supported both concepts in a standing position, an additional analysis was carried out to evaluate the requirement set in the product specification. This requirement were their ability to withstand a horizontal force of 277N for a temporary amount of time. In order to accomplish this, the simulation settings were the same as in the previous static structural simulation, with addition of an external force applied to the structures, and a explicit dynamics simulation was performed to calculate the elastic strain. Elastic strain refers to the deformation that can be completely recovered once the applied load is removed. The results of this analysis can be observed in Figures 7.20 and 7.21, demonstrating the performance of the concepts under the applied horizontal force. Here the concepts has dark blue color and hints of light green, which is assumed to be low impact.

In summary, based on the static structural analysis and the explicit dynamics analysis, both concepts, when evaluated with the selected material, meet the set requirements and desires established for this project.



**Figure 7.20:** Elastic strain on concept *Turning Puzzle*.



**Figure 7.21:** Elastic strain on concept *Vertical*.

## 7.6 Cost Assessment

To estimate the manufacturing cost, a cost assessment was conducted. This involved specifying the manufacturing processes, creating a bill of materials and estimating the costs associated with the various processes and the material.

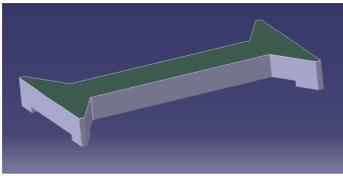
### 7.6.1 Manufacturing

This section presents the manufacturing processes for each component of the two concepts. It provides details on whether and how the components are segmented, the specific manufacturing method used.

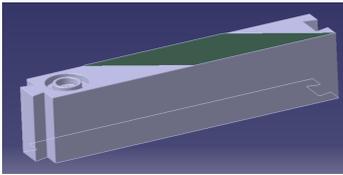
#### 7.6.1.1 Vertical

Base is manufactured in three parts: Feet, bottom portion and top portion. Module is manufactured in one single part. Beam is manufactured in two parts: Top portion and bottom portion. See Figure 7.22 to 7.27.

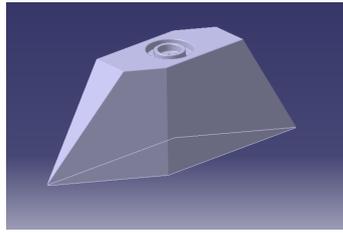
## 7. Detail Design and Analysis



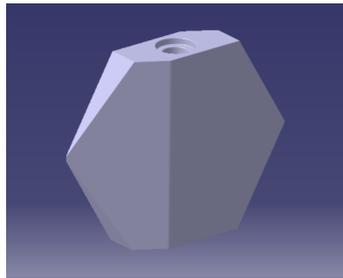
**Figure 7.22:** Feet portion of base



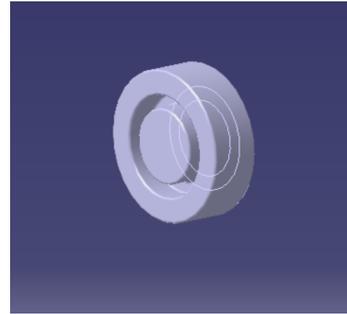
**Figure 7.23:** Bottom portion of base



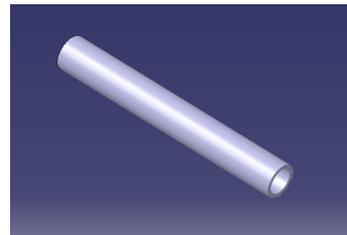
**Figure 7.24:** Top portion of base



**Figure 7.25:** Module



**Figure 7.26:** Top portion of beam



**Figure 7.27:** Bottom portion of beam

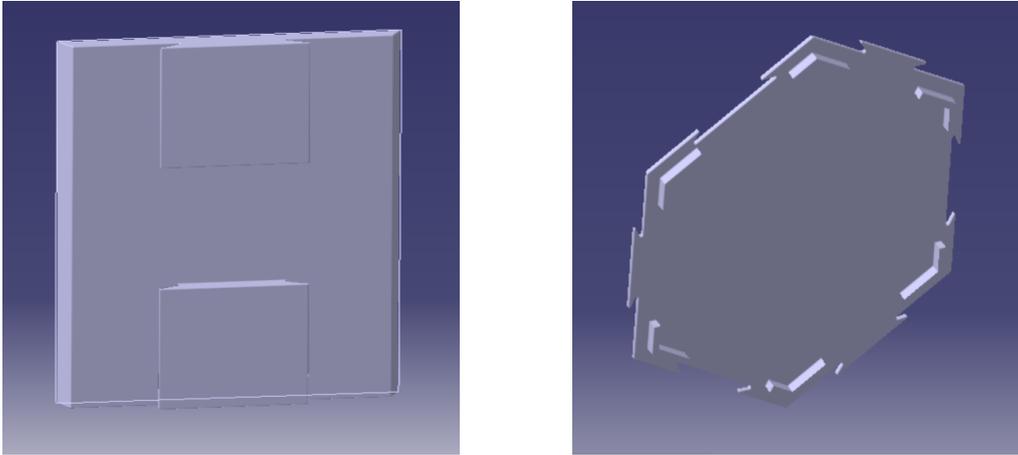
The manufacturing processes and any additional information are provided in Table 7.1.

**Table 7.1:** Manufacturing processes for concept Vertical

Vertical	Base		Module		Beam	
	Manufacturing method	Comment	Manufacturing method	Comment	Manufacturing method	Comment
	Sawing	The material is cut using a saw into specific dimensions for each component part. The sizes for the feet are 430x50x240mm, for the bottom portion are 450x100x80mm, and for the top portion are 340x150x80mm. The cumulative volume of all the parts adds up to 0.01284m <sup>3</sup> .	Sawing	The material is cut using a saw into specific dimensions for each component part. The size is 350x300x80mm. The volume is 0.0084m <sup>3</sup> .	Sawing	The material is cut using a saw into specific dimensions for each component part. The sizes for the bottom portion are 290x40x40mm, and for the top portion are 20x60x60mm. The cumulative volume of all the parts adds up to 0.000536m <sup>3</sup> .
	Planing		Planing		Planing	
	CNC-machining		CNC-machining		CNC-machining	
	Drilling	The two attachment holes are drilled, including the outer circle of the hole.	Drilling	The attachment hole is drilled, including the countersink	Drilling	The two attachment holes are drilled, including the outer circle of the hole.
	Sanding		Sanding		Sanding	
	Glueing	The parts are glued together	Finishing	Wood stains and oil for colour and layer of protection	Glueing	The parts are glued together
	Finishing	Wood stains and oil for colour and layer of protection			Finishing	Wood stains and oil for colour and layer of protection

### 7.6.1.2 Turning puzzle

Module is manufactured in 6 parts: 6 sidewalls. Lid is manufactured in one single part. See Figure 7.28.



**Figure 7.28:** Left: Sidewall of module; Right: Lid

The manufacturing processes and any additional information are provided in Table 7.2.

**Table 7.2:** Manufacturing processes for concept Turning Puzzle

Turning puzzle	<i>Module</i>		<i>Lid</i>	
	Manufacturing method	Comment	Manufacturing method	Comment
	Sawing	The material is cut using a saw into specific dimensions for each component part. The size of the part is 300x200x24mm. The cumulative volume of all 6 parts adds up to 0.00864m <sup>3</sup> .	Sawing	The material is cut using a saw into specific dimensions for each component part. The size is 400x350x15mm. The volume is 0.0021m <sup>3</sup> .
	Planing		Planing	
	CNC-machining		CNC-machining	
	Sanding		Sanding	
	Glueing	The parts are glued together	Glueing	The parts are glued together
	Finishing	Wood stains and oil for colour and layer of protection	Finishing	Wood stains and oil for colour and layer of protection

### 7.6.2 Bill of material and cost assessment

In the cost assessment, the manufacturing methods for the concepts are categorized into two groups: CNC-machining, utilized for complex module shapes, and other processes such as sawing, drilling, sanding, planing, finishing, and glueing. CNC-machining is applied to all component parts, resulting in fixed costs associated with tooling and setup (Ulrich & Eppinger, 2011). The fixed costs for other manufacturing processes are deemed negligible, and thus no fixed costs are assumed.

## 7. Detail Design and Analysis

Variable costs are determined based on the production time per unit in minutes and the labour cost, which was assumed to be consistent across all processes. The labour cost is assumed to be 30 dollar per hour for developed countries (Malmqvist, 2022).

The assumed time required for each manufacturing process is provided in Table 7.3. Furthermore, the production volume is set at 1000 units, which represents the upper limit for low-volume production (Swift & Booker, 2003).

**Table 7.3:** Number of minutes for each process

Manufacturing process	[min/unit]
1. Sawing	5
2. Planing	5
3. CNC-machining	10
4. Drilling	3
5. Glueing	2
6. Sanding	7
7. Staining/finsihing	8

The material properties, including density and cost, are sourced from Granta EDU pack. The values used for the calculations are assumed to be the highest in density and cost, in order to provide an upper-limit estimate. The bill of material and its calculations are shown in Table 7.4.

**Table 7.4:** Bill Of Material

Component:	Material	Material Density [kg/m <sup>3</sup> ]	Volume [m <sup>3</sup> ]	Mass [kg]	Material Cost [SEK/kg]	Material Cost per Unit [SEK/unit]	Production Volume [units]	CNC Setup Cost [SEK]	CNC Tooling Cost [SEK]	CNC Processing Cost [SEK/unit]	Other processing methods used	Other Processing Cost [SEK/unit]	Labor Cost [SEK/min]	Unit Cost [SEK/unit]
A. Vertical														
A1. Base	Pine	600	0,01284	7,704	10,8	83,2032	1000	477,47	159,15	52,83666667	1, 2, 3, 4, 5, 6, 7	158,51	5,283666667	295,1864867
A2. Module	Pine	600	0,0084	5,04	10,8	54,432	1000	477,47	159,15	52,83666667	1, 2, 3, 4, 6, 7	105,6733333	5,283666667	213,57862
A3. Beam	Pine	600	0,000536	0,3216	10,8	3,47328	1000	477,47	159,15	52,83666667	1, 2, 3, 4, 5, 6, 7	158,51	5,283666667	215,4565667
B. Turning Puzzle														
B1. Module	Pine	600	0,0084	5,04	10,8	54,432	1000	477,47	159,15	52,83666667	1, 2, 3, 5, 6, 7	142,659	5,283666667	250,5642867
B2. Lid	Pine	600	0,0021	1,26	10,8	13,608	1000	477,47	159,15	52,83666667	1, 2, 3, 6, 7	132,0916667	5,283666667	199,1729533

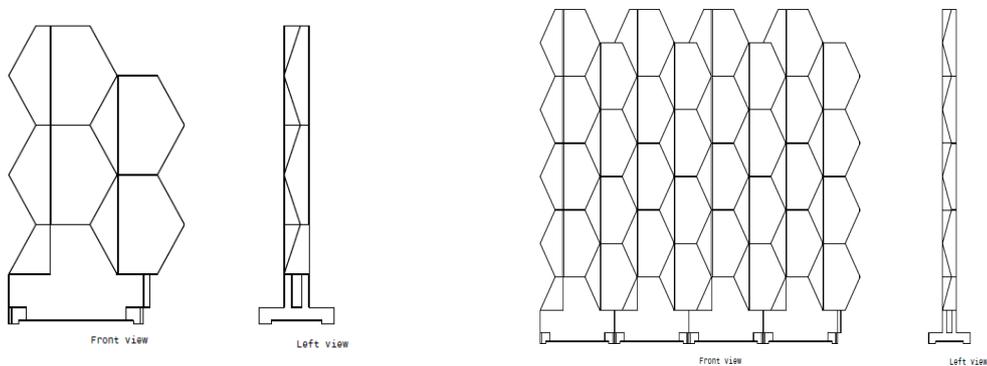
The cost of each component for each concept is shown in Table 7.6.2.

- Vertical
  - Base, 295 SEK
  - Module, 213 SEK
  - Beam, 215 SEK
- Turning Puzzle
  - Module, 250 SEK
  - Lid, 199 SEK

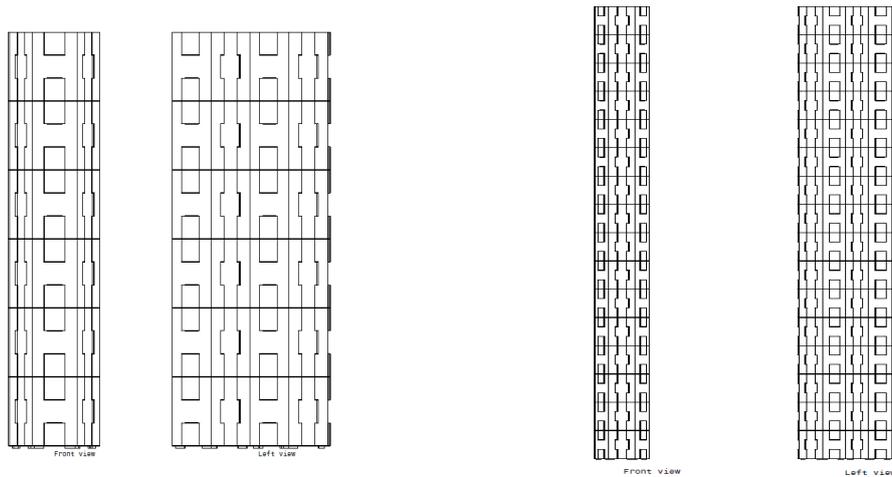
To get a more representative picture of the cost of a whole concept, different combination for each of the two concepts is calculated. The cost, the number of components needed, and the height and width of the concepts are presented in Table 7.5. See Figure 7.29 and 7.30.

**Table 7.5:** Cost estimation of different variations of the concepts

Concept	Components	Height x Width [m]	Cost [SEK]
Vertical	1 Base 4 Modules 4 Beams	0.9 x 0.45	2207
Vertical	4 Bases 28 Modules 28 Beams	2.4 x 1	13154
Turning Puzzle	6 Modules 2 Lids	0.9 x 0.710	1898
Turning Puzzle	16 Modules 2 Lids	2.4 x 0.710	4398



**Figure 7.29:** Left: 1 base, 4 modules; Right: 4 base, 28 modules



**Figure 7.30:** Left: 6 modules, 2 lids. Right: 16 modules, 2 lids

### 7.6.3 Cost assessment discussion

The cost assessment reveals that variable costs are the main cost drivers, whereas material costs represent a relatively small portion, resulting in very similar component costs. Therefore would increasing production volume lead to a decrease in variable costs, resulting in a greater variation among component costs, because of the variation in material costs.

Due to a lack of information, the cost assessment involved numerous assumptions. The costs associated with CNC-machining were estimated based on intricately designed small metal components, rather than larger wood pieces. All components were assumed to have the same lead time for each manufacturing process, disregarding their significant differences. The lead time itself was also assumed without precise data or information. The numerous uncertainties and assumptions made during the cost assessment highlight the need for more information and data to ensure better accuracy.

There is significant potential for improvement in the manufacturing process. The current design of the concepts and the manufacturing approach result in inefficient use of materials, leading to substantial waste. For instance, the vertical module has a scrap percentage of approximately 55%, indicating a significant amount of material being discarded. The complex shape and design of the concepts also contribute to the use of CNC-machining. Simplifying the design could help avoid this dependency and streamline the manufacturing process.

# 8

## Discussion

This chapter explores the project's developments and results, discussing uncertainties, improvements, and insights provided. The chapter is divided into two sections: the results and the development process. The results section examines the outcomes of the project and its significance. The development process section examines the execution of the project.

### 8.1 Results

This section provides a discussion of the results, examining the outcomes and significance of the concepts, manufacturing, materials, testing and aesthetics.

#### 8.1.1 Concepts

The final concepts have successfully met all the requirements and have been chosen as the most promising based on their performance in fulfilling desires. However, it is important to evaluate how well these requirements and desires are fulfilled.

Both concepts can be assembled by a single person, but concerns have been raised regarding their intuitiveness. The ease of assembly has not been verified, such as through user testing, and it remains unclear if the assembly process is tiresome and challenging. Conducting a further investigation into the assembly process would allow for design changes aimed at improving the overall assembly experience.

While both concepts fulfill the requirement for a customizable exterior, the solution is not fully optimized. Both the concepts feature modules, and through the change of modules the exterior could be customizable. Various solutions have been considered, including the use of attachable exterior panels, which would simplify the customization process. However, implementing this solution would add complexity to an already quite complex concept, for example potentially making manufacturing more difficult, and was decided not to be implemented.

The concept Turning Puzzle fulfills the desire to change form and shape, offering an adaptable room divider that can be assembled in various arrangements. This enhances its value through customizable abilities, with the ability to be assembled in all directions and be positioned in a variety of ways. For instance, it can be assembled as a mountain shape, serving as shelves or as an addition to other use

settings such as expos. This flexibility sets it apart in the market competition. The Vertical concept offers the ability to change its form through the use of modules. Additionally, the rotational modules fulfill the desire to allow light to pass through, as emphasized in the interview study. This not only provides customization options for users but also introduces a unique functionality rarely observed in room dividers.

The requirement "Intuitive relocation" has been explored to a limited extent. The different solutions proposed for relocation have proven challenging to implement. The realization during the concept development of how simple solutions is preferred, both in terms of manufacturing and aesthetics, has resulted in the simple solution of using separable components to facilitate relocation. Since the solution may not be the best for relocation, it is worth reflecting upon whether implementing solutions to improve the intuitiveness of relocation is worth the potential added complexity.

The desire for compactness was highly sought after, but finding a viable way to achieve it has been difficult. When attempting to incorporate compactness, it had a negative impact on other attributes and was therefore decided to not be implemented. Once again, the trade-off between added complexity and fulfilling the desire needs to be considered.

Feet were installed on the concepts to better accommodate different surfaces and increase stability. However, the effectiveness of these feet and the potential benefits of alternative methods have not been investigated. Conducting stability analyses and conducting more thorough research on how to achieve better stability and prevent them from losing balance would be beneficial.

### 8.1.2 Manufacturing

This project focused primarily on exploring concepts and ideas rather than creating a finalized product for production. As a result, exact cost and manufacturing requirements or goals were not established. A basic cost assessment was conducted. However, limited knowledge in this area led to rough assumptions being made when choosing the manufacturing type and estimating associated costs. Consequently, the cost assessment is uncertain and could vary when implemented in reality. Therefore, more research is needed to estimate a more detailed manufacturing process as well as the cost of it. The manufacturing process may change if additional knowledge is obtained, impacting both the cost and design. In this project, the designs do not prioritize manufacturability, but it is an important aspect to consider in the future, for example in this instance the tolerances for the attachments are assumed to be tight and could be an obstacle when manufacturing.

### 8.1.3 Material

The material selection was determined and assessed to be feasible and aligned with the product specifications. However, further research is still required to test the material's applicability for the intended functionalities, which has not been conducted

in this project. It is important to establish whether the chosen material is suitable for real-life use. Additionally, evaluating the aesthetic properties of the material is of interest. The project's research has indicated that neutral colors and natural materials are expected to enhance well-being and be preferred. However, these findings have not been validated through testing.

The material selection was conducted using the Granta EDU pack, which provides access to a comprehensive database of materials with tested properties. However, it is worth noting that exploring novel materials becomes interesting when developing a product with a strong emphasis on sustainability. The research indicates a growing trend to find more sustainable materials or upcycled materials. These novel materials offer potential advantages such as being more environmentally friendly and offering a wider range of colors without the need for additional pigment. While these materials were initially considered, Granta EDU packs lack of information regarding qualities such as strength, price, and larger scale manufacturing led to a decision to not utilize them for the concepts at this stage. The novel material has the potential to be implemented, but how needs to be explored further.

#### **8.1.4 Testing**

The project's initial plan was to develop small prototypes for the concepts. However, due to time constraints, this could not be achieved. Conducting further investigations would require prototypes to evaluate the attachment and assess the stability of the concepts. While simulations have been performed on the structure and validated in the project, real-life testing would provide valuable insights and allow testing of the concepts in different arrangements to assess all possible scenarios. In this project, the simulations focused on the force of gravity and the structure's weight, with an additional simulation applying a force as stated in the requirements. More simulations with forces of varying directions and extents are needed to ensure the concepts' stability under different conditions, for example how much force can be applied to the room divider without losing balance.

#### **8.1.5 Aesthetics**

The vertical concept draws its primary aesthetic inspiration from biophilic design, while the turning puzzle concept is primarily inspired by minimalism.

In the vertical concept, the biophilic design elements are recognized through its visual hexagonal shape. Its shape, alternating pattern and ability to rotate creates a distinct visual, differentiating aesthetically from the competitors. However, it can be questioned whether the use of shapes and pattern alone is sufficient to create a biophilic experience. Additional biophilic elements could be implemented, although their influence might be limited depending on the size of the concept. Instead, the concept could serve as an extension of a biophilic environment, contributing to the overall biophilic experience, rather than the concept itself inducing it.

The turning puzzle concept's minimalistic design may be considered aesthetically plain or even dull. Its lack of visual elements might not be suitable if the product is intended to be a decorative piece. However, if it's desired that the concept blends seamlessly with the surroundings, resembling a regular wall, the minimalistic approach can be seen as beneficial.

Color plays a significant role in aesthetics. The selection of colors should consider design trends, biophilic design principles, and their suitability for interior designs in Sweden. It was determined from Chapter 3, that less saturated, neutral, and natural colors are preferred. Therefore, while it was possible to apply a color over the chosen material of wood, it was ultimately decided not to do since the natural color of the wood itself was deemed desirable.

An important aspect of the study regarding aesthetics was that the room divider should integrate with the overall design of the apartment in terms of aesthetics. However, this aspect poses a challenge as it is subjective and varies from person to person, depending on their lifestyle and preference. It is worth noting that the study involved only a small number of individuals, which may tilt the findings towards their preferences. This introduces an element of uncertainty regarding the product's appeal to every user. The two concepts proposed offer a spectrum of possibilities due to their modular design, but validation from a diverse segment of users is yet to be established. For instance, inhabitants of larger apartments and houses might have entirely different perspectives on what they consider important. If the product should be produced on a larger scale, further evaluation and discussion of these points with a more diverse market segment are needed to expand the user segment.

## 8.2 Development Process

The development process could have been more effectively optimized within the time frame of the project.

Insufficient project demarcation contributed to a broad scope that could not be accomplished within the project timeline. This resulted in exploration across multiple areas of interest, but to a limited extent by a lack of time to achieve comprehensive knowledge in each area. For instance, the focus on novel materials for material selection created difficulties in finding their exact properties and suitability for implementation, due to limited information. A more targeted material investigation, with internal testing for aesthetic and structural suitability, or pre-selected materials would have been preferable.

Furthermore, the project's scope, aiming to develop a sustainable, modular, adaptable room divider for apartments, created significant challenges in examining all three focus elements due to the time limit. It would have been beneficial to explicitly state how these are investigated and fulfilled, and establish a prioritized order of the focus elements. For example, a focus on the adaptability to apartments would have benefited from more in-depth interviews with designers and users, more research on

housing trends, and the creation of prototypes for user feedback on aesthetics and functionality. Unfortunately, only a partial investigation was conducted regarding apartment adaptability, resulting in sub-optimal outcomes for that specific aspect.



# 9

## Conclusion

The project involved the development process of constructing a modular, adaptable, and sustainable room divider. The project's result consisted of two alternative concepts with these features, the concept Vertical and the concept Turning Puzzle.

The concepts are designed with modular parts, and the components can be easily assembled in different arrangements. This flexibility allows for customization for different user preferences. The concepts' flexibility and designs are unique, the turning puzzle in its ability to be arranged in various arrangements due to its versatility in attachments, and the Vertical in its ability to rotate modules, allowing the creation of various patterns of openings. Moreover, its modularity, and the choice of a material that is both renewable and recyclable further improve the sustainability aspects of these concepts. In addition, the stated research questions are answered.

R1: What and how are the user's housing circumstances?

After analysing the market segments, three types of users were deemed suitable for the project, which comprised co-living users in apartments. Through interviews conducted with representatives from each type, a common agreement emerged despite their varying circumstances: while they were generally satisfied with their current housing situations, there was a desire for either increased space or improved utilization of their existing space.

R2: What are the user's preferences in regard to a room divider?

Their preferences indicate a desire for a room divider that is user-friendly and adaptable, allowing for easy assembly and the ability to be compacted. The desire for easy assembly extends beyond the initial setup and includes the convenience of changing modules as needed.

Various functionalities and capabilities such as acoustic properties, light facilitation, and storage capabilities are highly valued, for the room divider to serve as a functional feature that can enhance the living space by providing additional benefits beyond its primary purpose.

Aesthetics are an important consideration, with the user desiring a room divider that aligns with their personal preferences and complements the overall style of their home. This includes both the initial aesthetic appeal and the ability to change the

room divider's appearance in accordance with their change of preferences. External research suggests that incorporating natural materials and colors, along with elements from biophilic design principles or minimalism, can help achieve an aesthetic that aligns with current and future interior design trends.

R3: How can a room divider's modular system adapt to the user's preferences?

A room divider with a modular system and attachment can be arranged in various configurations which enhances the divider's flexibility, such as the ability to change size, form and shape according to the user's preference. The simplicity of replacing modules enables the possibility of implementing more modules with different features, resulting in better customization options for the user.

R4: How can a room divider with a modular system achieve improvements in sustainability?

Modularity offers several advantages, including an extended product life cycle. The modularity allows for easy component changes which simplifies repairs since the components are independent and can be easily separated. Furthermore, modularity simplifies recycling at the end of the product's life cycle as the components can be easily separated, even if they are made from different materials.

R5: What novel materials could be applicable for the product to improve sustainability?

Further investigation of novel materials could result in a material change of the concepts to increase sustainability. The investigation focused on upcycled and renewable materials, which showed great potential. The development efforts of the novel materials were considered promising, as there are efforts to further improve their properties, applications, and manufacturability. The renewable materials, such as mycelium and cork, have good properties as well as great sustainability. Of particular interest are upcycled materials that utilize waste, such as fallen leaves or seaweed from local shores, as they not only contribute to sustainability but also align with biophilic design principles by potentially incorporating local waste material, creating a sense of familiarity and connection to the local environment.

In summary, the developed concepts exhibit a high potential to become functional products that meet user requirements. However, there is room for further improvement to enhance the concepts.

# 10

## Recommendations

In this chapter future recommendations for continued development of the product are listed. It includes both recommendations specifically for each of the concepts and general recommendations on suggestions on how to continue forward, if the concepts are decided to be further investigated.

- Design for manufacturing should be given more thorough consideration. In the case of the concept Turning Puzzle, its lateral attachment, contribute significantly to the complexity of manufacturing. The shape should therefore be reconsidered to simplify the manufacturing process while still maintaining their attachment capabilities. The Vertical concept poses manufacturing challenges due to its complex shapes and intricate angles in both the modules and the base. It is therefore necessary to reevaluate the design and make adjustments that align more effectively with the manufacturing processes.
- While the implementation of novel materials with high sustainability show promise, their logistics and suitability in terms of properties should be further explored and tested.
- Further investigation is necessary to ensure the stability of the concepts, such as designs of how to improve stability without compromising other abilities.
- Aesthetic considerations should continue to be investigated to ensure that the biophilic elements of the concepts are effectively incorporated. The design patterns mentioned, such as non-visual connections to nature, should be further explored to determine if their application enhances the biophilic experience enough to be implemented.
- The modules for the concepts should continue to be developed with diverse functions that could enhance the concepts multi-functionality. For instance, modules with built-in rotating hooks can leverage the existing rotation feature in the vertical concept.
- Photo-realistic and material-accurate renderings should be created to be able to more precisely evaluate the aesthetics of the concepts. Furthermore, placing the concept renderings in an appropriate environment would be able to provide more context for the concepts' aesthetic alignment.

## 10. Recommendations

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- Prototyping should be carried out to enable practical assessments that validate the feasibility of the actual product. An initial low-cost prototyping could be performed, for example, 3D printing a scaled-down version to assess its assembly and aesthetics. Thereafter, full-scale prototyping could be performed to assess and verify tests in more detail. Recommendations of which test and assessment that should be conducted are:
  - Stability Testing
  - Assembly and Disassembly
  - Aesthetic Evaluation
  - Material and Durability Testing

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# A

## Appendix - Patent List

Searchword:	Patent:	Description:	Patent Number:	Reference:
Room divider	P1	Acoustically Absorbing Room Divider	US9765516B2	<a href="https://patents.google.com/patent/US9765516B2/en?q=room+divider&amp;pg=room+divider">https://patents.google.com/patent/US9765516B2/en?q=room+divider&amp;pg=room+divider</a>
	P2	Room Divider with UV Sterilization Device	ES2826049T3	<a href="https://patents.google.com/patent/ES2826049T3/en?q=room+divider&amp;pg=room+divider">https://patents.google.com/patent/ES2826049T3/en?q=room+divider&amp;pg=room+divider</a>
	P3	Room Divider	US4559750A	<a href="https://worldwide.espacenet.com/patent/search/family/024240396/publication/US4559750A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/024240396/publication/US4559750A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P4	Room Divider	CA1309226C	<a href="https://worldwide.espacenet.com/patent/search/family/004183624/publication/CA1309226C?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/004183624/publication/CA1309226C?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P5	Room Divider	US2015176273A1	<a href="https://worldwide.espacenet.com/patent/search/family/049223489/publication/US2015176273A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/049223489/publication/US2015176273A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P6	Room Divider	US4161850A	<a href="https://worldwide.espacenet.com/patent/search/family/025628945/publication/US4161850A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/025628945/publication/US4161850A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P7	Fasteners - Portable Room Divider)	US5417021A	<a href="https://worldwide.espacenet.com/patent/search/family/022506950/publication/US5417021A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/022506950/publication/US5417021A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P8	Room Divider With Shelf	CA2059000A1	<a href="https://worldwide.espacenet.com/patent/search/family/026990133/publication/CA2059000A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/026990133/publication/CA2059000A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P9	Fasteners	GB2290846A	<a href="https://worldwide.espacenet.com/patent/search/family/026305168/publication/GB2290846A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/026305168/publication/GB2290846A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P10	Fasteners	GB2404207A	<a href="https://worldwide.espacenet.com/patent/search/family/009918584/publication/GB2404207A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/009918584/publication/GB2404207A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P11	Room Divider	SE1851615A1	<a href="https://worldwide.espacenet.com/patent/search/family/079972844/publication/SE1851615A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/079972844/publication/SE1851615A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P12	Modular Room Divider	US3871435A	<a href="https://worldwide.espacenet.com/patent/search/family/026828269/publication/US3871435A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/026828269/publication/US3871435A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P13	Freestanding Room Divider	US6598649B1	<a href="https://worldwide.espacenet.com/patent/search/family/027608992/publication/US6598649B1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/027608992/publication/US6598649B1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P14	Room Divider System	GB2520279A	<a href="https://worldwide.espacenet.com/patent/search/family/049818574/publication/GB2520279A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/049818574/publication/GB2520279A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P15	Height Extension	GB2290806A	<a href="https://worldwide.espacenet.com/patent/search/family/027267264/publication/GB2290806A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/027267264/publication/GB2290806A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P16	Fasteners	US2003163967A1	<a href="https://worldwide.espacenet.com/patent/search/family/026243362/publication/US2003163967A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/026243362/publication/US2003163967A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P17	Room Divider Flexible	DE3704905A1	<a href="https://worldwide.espacenet.com/patent/search/family/006321114/publication/DE3704905A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/006321114/publication/DE3704905A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P18	Room Divider Mobile	GB2518804A	<a href="https://worldwide.espacenet.com/patent/search/family/048914624/publication/GB2518804A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/048914624/publication/GB2518804A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P19	Fasteners - Electronic	GB2059183A	<a href="https://worldwide.espacenet.com/patent/search/family/021150889/publication/GB2059183A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/021150889/publication/GB2059183A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P20	Room Divider From Roof	GB2558434A	<a href="https://worldwide.espacenet.com/patent/search/family/051842853/publication/GB2558434A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/051842853/publication/GB2558434A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P21	Room Divider	US2021047830A1	<a href="https://worldwide.espacenet.com/patent/search/family/074566689/publication/US2021047830A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/074566689/publication/US2021047830A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P22	Room Divider - Legs	US4121645A	<a href="https://worldwide.espacenet.com/patent/search/family/025162460/publication/US4121645A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/025162460/publication/US4121645A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P23	Fasteners	US4457117A	<a href="https://worldwide.espacenet.com/patent/search/family/023491614/publication/US4457117A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/023491614/publication/US4457117A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P24	Room Divider	US2017196380A1	<a href="https://worldwide.espacenet.com/patent/search/family/059275195/publication/US2017196380A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/059275195/publication/US2017196380A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P25	Room Divider	GB2400867A	<a href="https://worldwide.espacenet.com/patent/search/family/009957224/publication/GB2400867A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/009957224/publication/GB2400867A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P26	Room Divider Functions	WO201012038A2	<a href="https://worldwide.espacenet.com/patent/search/family/044627540/publication/WO201012038A2?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/044627540/publication/WO201012038A2?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P27	Room Divider	GB1356092A	<a href="https://worldwide.espacenet.com/patent/search/family/010178607/publication/GB1356092A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/010178607/publication/GB1356092A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P28	Modular Room	US6243993B1	<a href="https://worldwide.espacenet.com/patent/search/family/023014095/publication/US6243993B1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/023014095/publication/US6243993B1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P29	Room Divider	US2003171818A1	<a href="https://worldwide.espacenet.com/patent/search/family/029421512/publication/US2003171818A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/029421512/publication/US2003171818A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P30	Room Divider	US2007175597A1	<a href="https://worldwide.espacenet.com/patent/search/family/038320869/publication/US2007175597A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/038320869/publication/US2007175597A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P31	Room Divider - Environmental Control	US4351475A	<a href="https://worldwide.espacenet.com/patent/search/family/022586112/publication/US4351475A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/022586112/publication/US4351475A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P32	Room Divider + Fasteners	US2999568A	<a href="https://worldwide.espacenet.com/patent/search/family/021862446/publication/US2999568A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/021862446/publication/US2999568A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P33	Room Divider	AU599184B2	<a href="https://worldwide.espacenet.com/patent/search/family/025640131/publication/AU599184B2?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/025640131/publication/AU599184B2?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P34	Room Divider + Shelves	US4581858A	<a href="https://worldwide.espacenet.com/patent/search/family/024652223/publication/US4581858A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/024652223/publication/US4581858A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P35	Room Divider	DE3533880A1	<a href="https://worldwide.espacenet.com/patent/search/family/006281694/publication/DE3533880A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/006281694/publication/DE3533880A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P36	Fasteners	WO0190501A1	<a href="https://worldwide.espacenet.com/patent/search/family/026058291/publication/WO0190501A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/026058291/publication/WO0190501A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P37	Room Divider	US2005223665A1	<a href="https://worldwide.espacenet.com/patent/search/family/035059115/publication/US2005223665A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/035059115/publication/US2005223665A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P38	Room Divider Storage	US2005231079A1	<a href="https://worldwide.espacenet.com/patent/search/family/035095578/publication/US2005231079A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/035095578/publication/US2005231079A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P39	Fasteners	CA1310163C	<a href="https://worldwide.espacenet.com/patent/search/family/004183672/publication/CA1310163C?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/004183672/publication/CA1310163C?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P40	Room Divider	EP0098061A2	<a href="https://worldwide.espacenet.com/patent/search/family/023522426/publication/EP0098061A2?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/023522426/publication/EP0098061A2?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P41	Room Divider	JP55693948A	<a href="https://worldwide.espacenet.com/patent/search/family/015924917/publication/JP55693948A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/015924917/publication/JP55693948A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P42	Fasteners	JP2004027057A	<a href="https://worldwide.espacenet.com/patent/search/family/031181822/publication/JP2004027057A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/031181822/publication/JP2004027057A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P43	Room Divider	US3788378A	<a href="https://worldwide.espacenet.com/patent/search/family/022589736/publication/US3788378A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/022589736/publication/US3788378A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P44	Room Divider	FR2844686A1	<a href="https://worldwide.espacenet.com/patent/search/family/031970956/publication/FR2844686A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/031970956/publication/FR2844686A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P45	Room Divider - Electronic	DE10106651C1	<a href="https://worldwide.espacenet.com/patent/search/family/007673890/publication/DE10106651C1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/007673890/publication/DE10106651C1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P46	Room Divider	US2012318467A1	<a href="https://worldwide.espacenet.com/patent/search/family/047352745/publication/US2012318467A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/047352745/publication/US2012318467A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P47	Fasteners	US9968212B1	<a href="https://worldwide.espacenet.com/patent/search/family/062090459/publication/US9968212B1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/062090459/publication/US9968212B1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P48	Room Divider	DE19545271A1	<a href="https://worldwide.espacenet.com/patent/search/family/007779194/publication/DE19545271A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/007779194/publication/DE19545271A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P49	Room Divider	DE202004000779U1	<a href="https://worldwide.espacenet.com/patent/search/family/032103724/publication/DE202004000779U1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/032103724/publication/DE202004000779U1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P50	Room Divider	FR2775309A1	<a href="https://worldwide.espacenet.com/patent/search/family/009523350/publication/FR2775309A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/009523350/publication/FR2775309A1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P51	Room Divider	ES1073511U	<a href="https://worldwide.espacenet.com/patent/search/family/043414139/publication/ES1073511U?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/043414139/publication/ES1073511U?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P52	Room Divider	CA683129A	<a href="https://worldwide.espacenet.com/patent/search/family/035984216/publication/CA683129A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/035984216/publication/CA683129A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P53	Room Divider	GB1393945A	<a href="https://worldwide.espacenet.com/patent/search/family/004090323/publication/GB1393945A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/004090323/publication/GB1393945A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P54	Room Divider	US8505246B1	<a href="https://worldwide.espacenet.com/patent/search/family/048916503/publication/US8505246B1?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/048916503/publication/US8505246B1?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P55	Room Divider	US5592794A	<a href="https://worldwide.espacenet.com/patent/search/family/024019248/publication/US5592794A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/024019248/publication/US5592794A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P56	Room Divider	US4360991A	<a href="https://worldwide.espacenet.com/patent/search/family/022681433/publication/US4360991A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/022681433/publication/US4360991A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P57	Room Divider	US5394658A	<a href="https://worldwide.espacenet.com/patent/search/family/026920538/publication/US5394658A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/026920538/publication/US5394658A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>
	P58	Fasteners	US3895670A	<a href="https://worldwide.espacenet.com/patent/search/family/026909498/publication/US3895670A?q=room%20divider&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/026909498/publication/US3895670A?q=room%20divider&amp;queryLang=en%3Ade%3Afr</a>

## A. Appendix - Patent List

Temporary Wall	P59	Temporary Wall	JP2001317140A	<a href="https://worldwide.espacenet.com/patent/search/family/018646574/publication/JP2001317140A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/018646574/publication/JP2001317140A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P60	Temporary Wall	JP2018016996A	<a href="https://worldwide.espacenet.com/patent/search/family/061075120/publication/JP2018016996A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/061075120/publication/JP2018016996A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P61	Temporary Wall	JP2000320151A	<a href="https://worldwide.espacenet.com/patent/search/family/014965823/publication/JP2000320151A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/014965823/publication/JP2000320151A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P62	Fasteners	CN211647443U	<a href="https://worldwide.espacenet.com/patent/search/family/072690660/publication/CN211647443U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/072690660/publication/CN211647443U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P63	Temporary Wall - Soundproof	KR10201738081	<a href="https://worldwide.espacenet.com/patent/search/family/065562260/publication/KR10201738081?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/065562260/publication/KR10201738081?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P64	Temporary Wall - Waterproof	CN215714995U	<a href="https://worldwide.espacenet.com/patent/search/family/079897154/publication/CN215714995U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/079897154/publication/CN215714995U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P65	Temporary Wall	KR102199847B1	<a href="https://worldwide.espacenet.com/patent/search/family/074126655/publication/KR102199847B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/074126655/publication/KR102199847B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P66	Temporary Wall	CN214886127U	<a href="https://worldwide.espacenet.com/patent/search/family/078891134/publication/CN214886127U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/078891134/publication/CN214886127U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P67	Temporary Wall	CN109113206A	<a href="https://worldwide.espacenet.com/patent/search/family/064822178/publication/CN109113206A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/064822178/publication/CN109113206A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P68	Temporary Wall	KR102343617B1	<a href="https://worldwide.espacenet.com/patent/search/family/079178068/publication/KR102343617B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/079178068/publication/KR102343617B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P69	Fasteners	US972059A	<a href="https://worldwide.espacenet.com/patent/search/family/003040443/publication/US972059A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/003040443/publication/US972059A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P70	Temporary Wall	US3480069A	<a href="https://worldwide.espacenet.com/patent/search/family/024920340/publication/US3480069A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/024920340/publication/US3480069A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P71	Temporary Wall - Windproof + Noise Cancelling	CN215670311U	<a href="https://worldwide.espacenet.com/patent/search/family/07983009/publication/CN215670311U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/07983009/publication/CN215670311U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P72	Fasteners	JP2016164341A	<a href="https://worldwide.espacenet.com/patent/search/family/056876535/publication/JP2016164341A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/056876535/publication/JP2016164341A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P73	Temporary Wall	KR20210146572A	<a href="https://worldwide.espacenet.com/patent/search/family/078936227/publication/KR20210146572A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/078936227/publication/KR20210146572A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P74	Temporary Wall	CN212201581U	<a href="https://worldwide.espacenet.com/patent/search/family/073806294/publication/CN212201581U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/073806294/publication/CN212201581U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P75	Fasteners	CN215054189U	<a href="https://worldwide.espacenet.com/patent/search/family/079250141/publication/CN215054189U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/079250141/publication/CN215054189U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P76	Temporary Wall - Soundproof	KR20120113329A	<a href="https://worldwide.espacenet.com/patent/search/family/047282897/publication/KR20120113329A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/047282897/publication/KR20120113329A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P77	Fasteners	JP5397222A	<a href="https://worldwide.espacenet.com/patent/search/family/01174292/publication/JP5397222A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/01174292/publication/JP5397222A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P78	Temporary Wall	CN216364550U	<a href="https://worldwide.espacenet.com/patent/search/family/081246187/publication/CN216364550U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/081246187/publication/CN216364550U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P79	Fasteners	KR102144434B1	<a href="https://worldwide.espacenet.com/patent/search/family/072043504/publication/KR102144434B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/072043504/publication/KR102144434B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P80	Temporary Wall	US10731339B2	<a href="https://worldwide.espacenet.com/patent/search/family/059222906/publication/US10731339B2?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/059222906/publication/US10731339B2?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P81	Temporary Wall	US105019338B2	<a href="https://worldwide.espacenet.com/patent/search/family/064400296/publication/US105019338B2?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/064400296/publication/US105019338B2?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P82	Fasteners	JPH05222822A	<a href="https://worldwide.espacenet.com/patent/search/family/013164487/publication/JPH05222822A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/013164487/publication/JPH05222822A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P83	Fasteners	CN210013446U	<a href="https://worldwide.espacenet.com/patent/search/family/069312706/publication/CN210013446U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/069312706/publication/CN210013446U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P84	Temporary Wall	NZ550223A	<a href="https://worldwide.espacenet.com/patent/search/family/032088637/publication/NZ550223A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/032088637/publication/NZ550223A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P85	Fasteners	US2012324821A1	<a href="https://worldwide.espacenet.com/patent/search/family/053367748/publication/US2012324821A1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/053367748/publication/US2012324821A1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P86	Temporary Wall	US2012255253A1	<a href="https://worldwide.espacenet.com/patent/search/family/046320022/publication/US2012255253A1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/046320022/publication/US2012255253A1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P87	Fasteners	KR20190073054A	<a href="https://worldwide.espacenet.com/patent/search/family/067105225/publication/KR20190073054A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/067105225/publication/KR20190073054A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P88	Temporary Wall	JP2022060869A	<a href="https://worldwide.espacenet.com/patent/search/family/081125327/publication/JP2022060869A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/081125327/publication/JP2022060869A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P89	Temporary Wall	CN216665124U	<a href="https://worldwide.espacenet.com/patent/search/family/081797978/publication/CN216665124U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/081797978/publication/CN216665124U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P90	Temporary Wall	US2008209827A1	<a href="https://worldwide.espacenet.com/patent/search/family/039732109/publication/US2008209827A1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/039732109/publication/US2008209827A1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P91	Temporary Wall	CN210685572U	<a href="https://worldwide.espacenet.com/patent/search/family/070883488/publication/CN210685572U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/070883488/publication/CN210685572U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P92	Temporary Wall	CN202706664U	<a href="https://worldwide.espacenet.com/patent/search/family/047586977/publication/CN202706664U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/047586977/publication/CN202706664U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P93	Temporary Wall	CN21273745U	<a href="https://worldwide.espacenet.com/patent/search/family/075065931/publication/CN21273745U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/075065931/publication/CN21273745U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P94	Temporary Wall	US8904724B1	<a href="https://worldwide.espacenet.com/patent/search/family/052001536/publication/US8904724B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/052001536/publication/US8904724B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P95	Fasteners	US3786607A	<a href="https://worldwide.espacenet.com/patent/search/family/005808592/publication/US3786607A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/005808592/publication/US3786607A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P96	Fasteners	JP2001059300A	<a href="https://worldwide.espacenet.com/patent/search/family/017028875/publication/JP2001059300A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/017028875/publication/JP2001059300A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P97	Temporary Wall	KR101336732B1	<a href="https://worldwide.espacenet.com/patent/search/family/049987225/publication/KR101336732B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/049987225/publication/KR101336732B1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P98	Temporary Wall	JP2022122536A	<a href="https://worldwide.espacenet.com/patent/search/family/082939626/publication/JP2022122536A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/082939626/publication/JP2022122536A?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P99	Temporary Wall	CN210622474U	<a href="https://worldwide.espacenet.com/patent/search/family/070760329/publication/CN210622474U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/070760329/publication/CN210622474U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P100	Temporary Wall	CN214403014U	<a href="https://worldwide.espacenet.com/patent/search/family/078048218/publication/CN214403014U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/078048218/publication/CN214403014U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P101	Temporary Wall	CN214006782U	<a href="https://worldwide.espacenet.com/patent/search/family/072296637/publication/CN214006782U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/072296637/publication/CN214006782U?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	P102	Temporary Wall	US2022178139A1	<a href="https://worldwide.espacenet.com/patent/search/family/081849813/publication/US2022178139A1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr">https://worldwide.espacenet.com/patent/search/family/081849813/publication/US2022178139A1?q=temporary%20wall&amp;queryLang=en%3Ade%3Afr</a>	
	Sound Absorbing	P103	Sound Absorbing Panel	US3858676A	<a href="https://worldwide.espacenet.com/patent/search/family/026985309/publication/US3858676A?q=sound%20absorbing%20panel">https://worldwide.espacenet.com/patent/search/family/026985309/publication/US3858676A?q=sound%20absorbing%20panel</a>
		P104	Sound Absorbing Panel	WO0157328A2	<a href="https://worldwide.espacenet.com/patent/search/family/009885012/publication/WO0157328A2?q=sound%20absorbing%20panel">https://worldwide.espacenet.com/patent/search/family/009885012/publication/WO0157328A2?q=sound%20absorbing%20panel</a>

# B

## Appendix - Morphological Matrix

Morphological Matrix				
Solutions: →				
↓ Functions:				
Composition	Base structure + module + panel	Base structure + module	Module + panel	Module
<b>Base Enhance Structure</b>	Netwire with blocks that can turned for fastening	Toileroll vertical displacement	The Ladder	Telescopic frame both vertical and horizontal
<b>Module Enhance Structure</b>	Cross structure	Horizontal structure	Vertical structure	Square structure
<b>Panel attachment</b>	Click	Slide (Horizontal & Vertical)	Flaps	Key
<b>General</b>				
<b>Adapt Height</b>	Bottle - cap	Plugs	Hook	Lego
<b>Adapt Width</b>	Slide-in	Hasp	Velcro	Puzzle
<b>Enhance Balance</b>	Curved shape structure	Legs on top and/or bottom	Wide feet	Adhesive
<b>Customize Exterior</b>	Click	Slide (Horizontal & Vertical)	Flaps	Key
<b>Reduce Noise</b>	Sound absorbing material	Air cavities	Insulation	No gaps
<b>Allow Mobility</b>	Slide modules	Retractable wheels	Balloon	Slidable cushions
<b>Allow Compactability</b>	Foldable	Wall and structure separated	Roll up	Smaller pieces/Sections
<b>Allow Additional Functions</b>	Transparency Window	Storage	Shelves	Hangers
<b>Change shape</b>	Triangles	Arch	Legs	Frame structure based
<b>Change form</b>	Hinge	Bottle cap	Offset	Attachment on all sides (x and y direction)

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Morphological Matrix									
Horizontal toiletroll	Hanging on horizontal frame	Clamps attached to horizontal frame	Connect 4						
Solid	Triangle Structure								
Jam in	Shell	Screw	Pole	Ramp v^A	Velcro	Adhesive			
Accordion	Shoobox	Telescope	Fold out	Feets	Attachment on all sides	fastening in different angles	Shell	Side in	
Rail	Hook	Bottle - Cap	Telescope						
Magnets	Vaccum (pressure device)	Small Air Gap	Secure wrap	telescopic arm - pressed against ceiling and/ or wall					
Jam in	Shell	Screw	Pole	Ramp v^A	Velcro	Adhesive			
Caterpillar band	Handles	Magnet attachment	Vacuum pump attachment	Foldable	Shower drape	Tileable			
Retractable (fit into each other)	Easy to demount	Push together (wallstack inspired)							
Ventilation	Tunnel between room	Chair/Bench	Electricity outlet						
Accordion	Changeable angle	Click (90 degrees)							



Figure C.2: Moodboard: Family

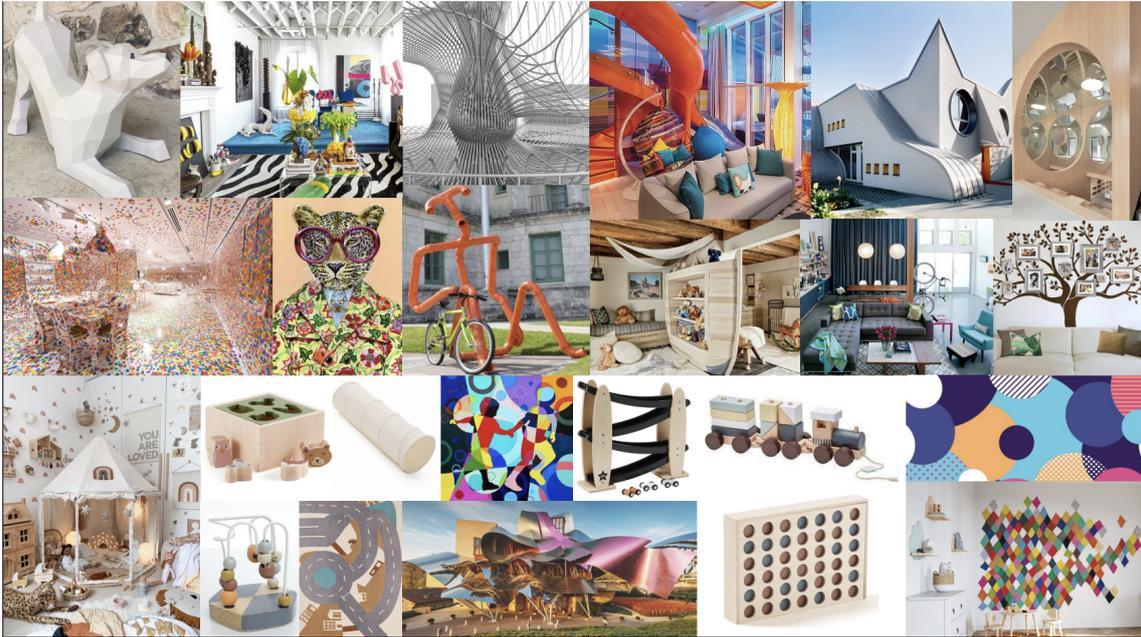
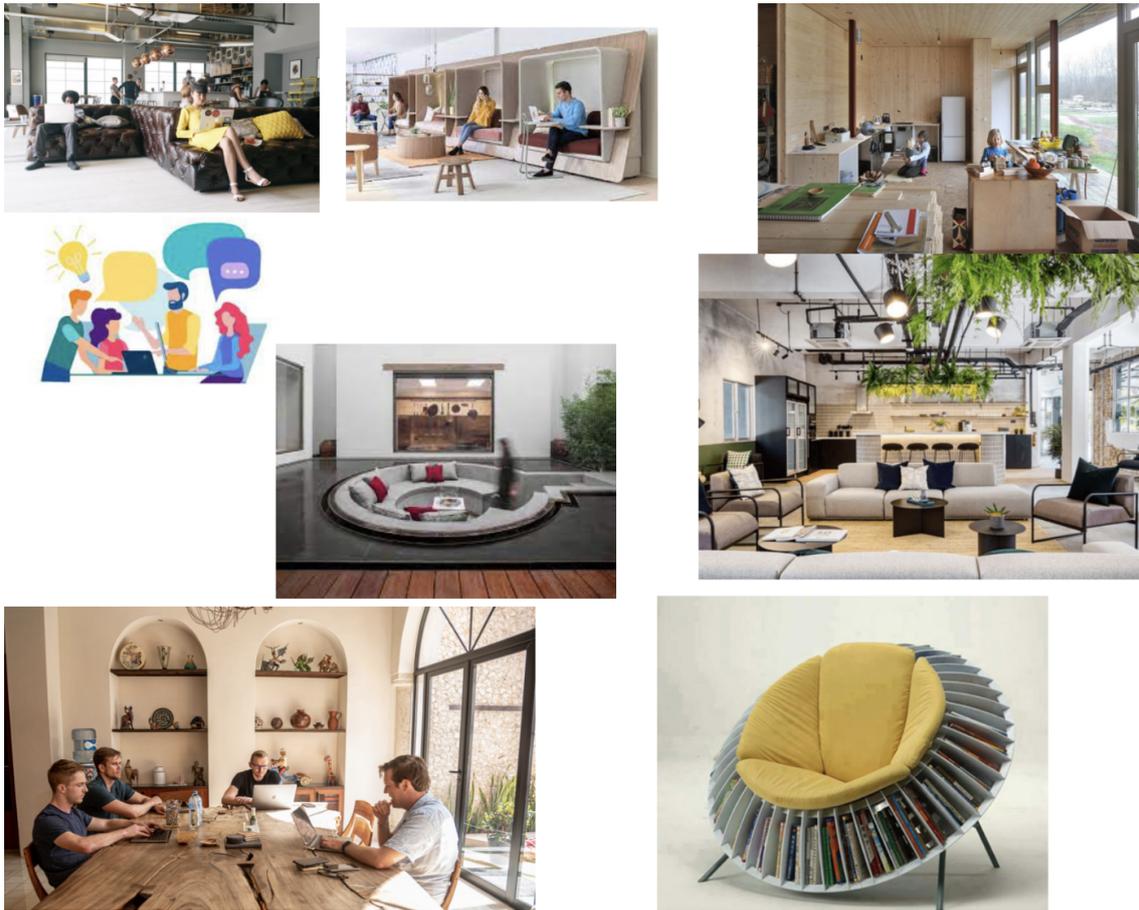


Figure C.3: Moodboard: Biophilia



Figure C.4: Moodboard: Co-living



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