Bachelor Degree Project

UNIVERSITY OF SKÖVDE

DESIGN OF FURNITURE FOR SMALL PLACES FOLLOWING INCLUSIVE DESIGN

Bachelor Degree Project in Product Design Engineering
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Certificate of originality

Submitted on December 22nd, 2014 by Talia Serrano Salazar and Lucía Aspizua Sáez to University of Skövde as a Bachelor Degree Project in Integrated Product Development/Product Design Engineering at the School of Engineering Science.
We certify that all material in this Bachelor Degree Project, which is not our own work has been identified and that no material is included for which a degree has previously been conferred on us.

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ABSTRACT

The objective of the project was to develop a furniture set that consists of a multifunctional bed and a cabinet. A pre-study was performed to define the problem area and to set the requirements for the furniture. The pre-study included: studies and discussions at the associated company, literature review within the field, user survey, market search and ergonomics study. When the specification was set and clarified, the concept generation phase was started. Design methods were used to structure and support the design activity. In addition, principles of inclusive design were followed in order to end up with a design that would fit a larger part of the targeted customer group. The generated design concepts were assessed according to fulfilment of set requirements. One final concept was chosen for further development in the following detail design phase. This activity included specifying the design in detail, e.g. related to materials, colours and accessories. The collaboration with the company was essential during the whole project for getting inspiration, feedback and important inputs to the design activity. Hence, the company's opinions were continuously considered along the design process. A prototype was made of the final design and tests were performed to assess the design and to get input for further development.

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1. INTRODUCTION

The need for foldable furniture sets for small bedrooms are assumed to increase in the future since more people (most of all young people) live in small apartments. This project tries to meet this need by the design of a furniture set that offers good comfort and functional features to the user while taking as little space as possible. The overall design, mechanisms and ergonomics are some of the important aspects to consider during the design of such a product. This degree project was conducted in collaboration with Olby Design company in Skövde, Sweden. The company wanted the degree project to contribute to the design of a furniture set that suits compact living circumstances and that fulfils or exceeds customers' desires.

A great deal of popular furniture is from Scandinavia, North America and Europe (Eypórsdóttir, 2011). Scandinavians have a passion for colour and nature. Because of that, there are many companies which work with the same objective (Bendixen and Benktzon, 2013). Olby Design is focused on the timelessness, ingenuity and simplicity of furniture. The basic reason for the development of a furniture set for small places at Olby Design is due to the fact that the company does not offer this kind of furniture today. The company wants to include such a product in their product portfolio. The design challenge is the conflicting condition that the user wants a bedroom with spacious furniture, but at the same time the furniture should occupy minimum of space, especially when the bed is not used for sleeping. Therefore, the furniture should make it possible to hide some of its parts into other parts of the furniture. The design challenge is hence to meet the needs despite the limited space.

1.1 BACKGROUND

There are many reasons for why it is becoming more common to live in small places, also called 'compact living', and the following text highlights some of these reasons.

Some years ago, to live in a big house indicated that one was rich, while to live in a small house signalled a lack of resources. However, this is very different today. Due to the pace of life, many people prefer to live in a small apartment where there is less housework and more time to enjoy life (Reyes-Heroles, 2012).

Nowadays, the space for living has been reduced. Most young people live in small shared flats or in small apartments with their partner. Usually, also older people prefer small flats due to the accessibility that these present and also to the easiness to clean such flats. This means that the functionality must also be possible in small flats in order to offer the same functions that a bigger flat does (Reyes-Heroles, 2012). The desire or necessity to live in city centres due to the availability of cultural life and services, or to the proximity of the workplace, is leading many people to live in city centres. Security and public transportation are also typically more developed (Inmuebles Reales Agencia, 2012).

Another point to consider is the deteriorated economy in some countries which implies that people tend to buy smaller flats and live more compact. Consequently, there are changes in society that calls for the development of furniture that meets the need of this kind of dwelling.

For all these reason the demand of apartments has increased in last years, therefore the apartment constructions have also enlarged (Figure 1.1).

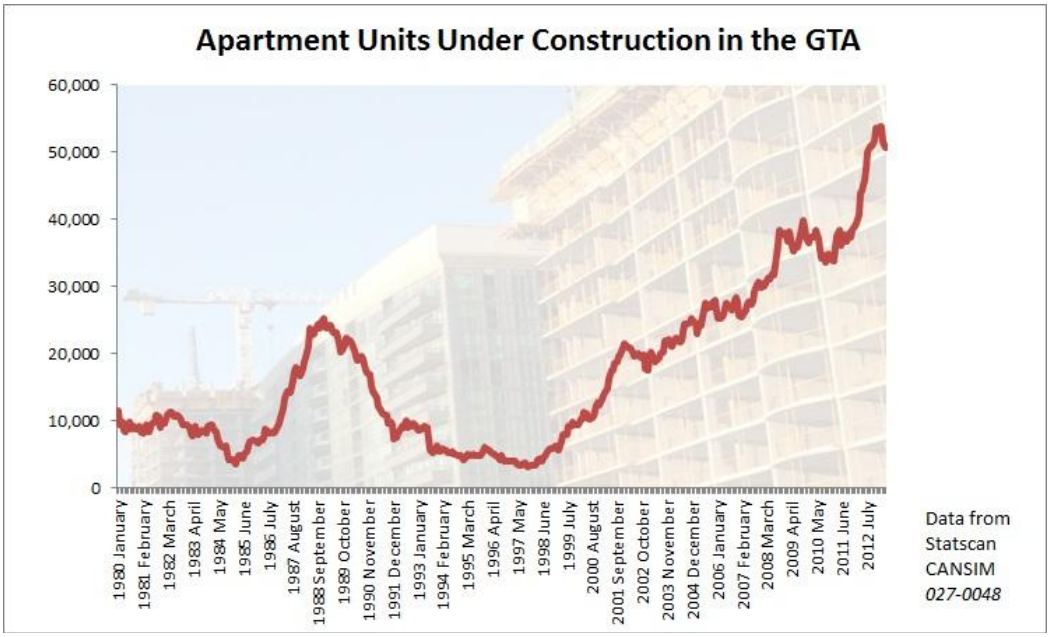


Figure 1.1 Increase in apartments construction (www.smashingreader.com)

1.2 AIMS AND OBJECTIVES

Comfort, order and cleanliness are very important aspects of living, also when living in a small flat. For this reason this project wants to reduce problems related to space that small flats usually have by the design of a furniture set that meet the needs while occupying little space.

The main objective of this project is to develop a furniture set in which the usable space plays an important role. This furniture set will consist of a bed, including a night stand, some shelves and some drawers. The objective is to optimize the use of the space. The other piece of furniture to be developed is a cabinet that also will cover more than one function. These pieces of furniture are aimed to be proper to a large target group, including old and young people, disabled, people of different places around the world with different cultures and capabilities, etc. Hence, the design process will be inspired by the principles of inclusive design, using the Inclusive Design Toolkit (2013).

Bedrooms are not only used for sleeping. Nowadays, bedrooms have more functions. Hence, in small places it is relevant to offer the possibility to, for example, read a book, have breakfast and use the PC. Therefore, these initial objectives were defined in collaboration with Olby Design:

- The furniture will consist of two pieces: one bed and one cabinet. These pieces of furniture have to cover more than one function.
- These pieces of furniture are aimed to be proper to a large target group, to obtain a final product that answers to the goals of Inclusive Design.
- It has to be characterized by exploiting space efficiently, giving sense of spaciousness and acting as an assistance in the users' life.
- The night table, shelves and drawers have to be included in this set of furniture.
- The night table can be hidden whenever it is not used.
- Drawers and shelves should be strategically placed to form symmetry among them.

- The furniture will expand the range of products of the company, affirming Olby Design's original style and quality.
- The design of the pieces of furniture should be performed within maximum four months.
- The furniture shall be compact in size while offering desired functions.

Target market for the product:

- Primary market: Companies which buy lot of pieces of furniture to sell them in their own companies.
- Secondary market: People who look for innovation furniture, who always want to acquire the latest products.

The stakeholders group is composed by designers, Olby Design company, manufacturers, sellers, distributors, customers and users.

1.3 OLBY DESIGN COMPANY

Olby Design was founded in 1980 by the two sisters Kerstin and Tina Olby. Since then, a large collection of contemporary furniture has been produced by hand in their factory located in Skövde, Sweden. Kerstin is the designer and her objective is to create timeless and valuable pieces of furniture. Tina is the head of the factory, and her goal is to produce furniture with high quality.

For thirty years Olby Design Company has focused on simple designs with durable value, following the Nordic furniture tradition, American style and the Arts & Crafts movement. Their aim is to contribute to making everyday life simple and beautiful.

The aim of this project is to design bedroom furniture that is compatible with the characteristics of Olby Design furniture design, though including some variation.

The main material used by Olby Design is wood. Steel, stone, wool, leather and glass are mixed together with wood to manufacture furniture (Olby Design, 2014).

1.4 DESIGN STRATEGY

The project in essence will follow a typical designs process as described by Cross (2008). Hence it will begin with an exploratory phase (pre-study) for investigating the problem area and define the requirements for the product. This is followed by a concept generation phase to find appropriate design solutions that meet identified requirements. The generated concepts will be evaluated in an iterative manner in order to gradually identify the best design solution. The selected conceptual design solution is then further specified in the following detain design phase. All along the design project there will be communication with the company and other stakeholders, e.g. potential end users.

Additionally, the design process will follow the principles of Inclusive Design (Inclusive Design Toolkit, 2013) in order to end up with a design solution that will fit a large range of the users in the targeted user group, e.g. related to nationality, ages, sizes, abilities.

That means that the design must not be designed for the average, but rather a range of different users. It is very important for designers to also focus on the needs of the people who have more difficulties in their life. This is done by understanding users and their different expectations and needs. In this way the designer can address the problems in order to know the responsibilities of the project.

To do the design properly, a continuous communication was essential among the members of the design group, i.e. the students, the company (Olby Design) and the

supervisors. That means that before and after accomplishing major changes in the design, the new proposals were discussed, to ensure a coherent solution.

The company Olby Design was visited in many occasions during the project. The doors were open to ask different questions that appeared along the project and to see the installations and how the company works.

In the different visits, topics were discussed like the measurements of the furniture, the best way to work, the aesthetics to follow etc.

At all times contact was kept either by e-mail or by visiting the factory. Due to the proximity to the factory, most of the time the meetings were held in the factory in order to carry out brainstorming sessions and to see the real facilities or physical products together with the representatives of the company.

2. PRE-STUDY

A pre-study was carried out in order to clarify the problem and to set the requirements and functions that should be introduced into the furniture set.

This step consisted of exploring and making analyses about the problem and also of looking at what is offered by other companies on the market. Figures 2.1 and 2.2 (Inclusive Design Toolkit, 2013) show the question that should be answered in this chapter; what the needs are, always keeping in mind the subsequent steps such as creation and evaluation.

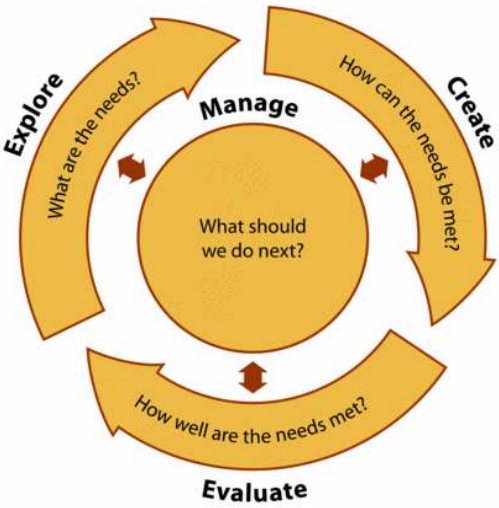


Figure 2.1 Inclusive Design in three steps (www.inclusivedesigntoolkit.com)

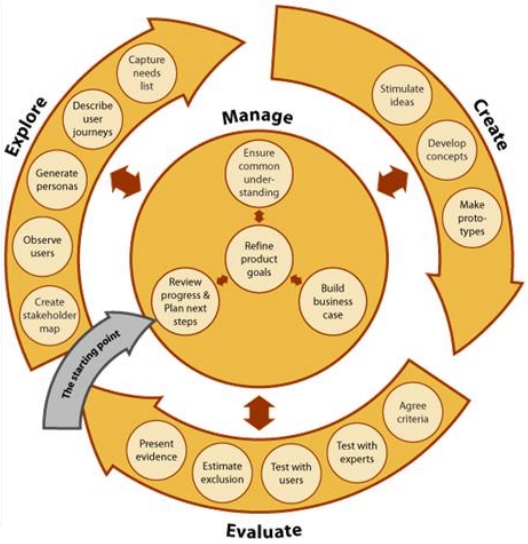


Figure 2.2 Inclusive Design stages (www.inclusivedesigntoolkit.com)

These design activities aim to determine what the problem is and what the solutions are. The Inclusive Design approach is focused on (Inclusive Design Toolkit, 2013):

- Understanding the real diversity of users and the business needs of the company.
- Applying this knowledge to better inform the design decisions during the development process.
- Evaluating prototypes with real users before finishing the development to be able to make improvements.

2.1 INFORMATION GAPS

Before to start working, there is a need to take into account some key points or information gaps, in order to follow an order and to remember important fields. These information gaps were identified and addressed in the pre-study:

- There is a need to define the targeted population for the product.
- Following inclusive design principles, an ergonomic study is needed.
- Other existing solutions and products have to be investigated.
- The exact measurements of the designed and bought-in components must be decided to ensure that everything fits and runs smoothly.
- The connections between the pieces of furniture have to be clarified to obtain a harmonious bedroom set.

- It is important to understand the range of mechanisms that can be used in different parts of the furniture to facilitate desired movements.
- Materials have to be chosen.
- Sketches should be done.

2.2 LITERATURE REVIEW

Inclusive design is not a characteristic of the product; it is a different way to think and work in the design process. The word 'inclusive' means that nobody within the targeted population should be excluded. The goal of inclusive design is to make people feel comfortable and equally accepted (Ates, 2012). The products should be usable and accessible for as many people within the targeted population as possible, leading to reducing needs for a particular design or special adaptation (Cross, 2008). 'To create a good design, it is essential to understand the demands and capabilities of the intended users' (Clarkson et al., 2013).

The problem is that most of the products on the market have been designed for young and healthy people. Then, people with any kind or range of disability often have to add expensive adaptations to make the product fit their conditions and needs. Inclusive design is trying to remove exclusion that occurs because users cannot use products or services. Related to this, Clarkson et al. (2013) state that the product will be better if the amount of users is bigger. The inclusive design approach hence promotes the design of products that fit the whole targeted population. This is commonly done by trying to identify design solutions that would include disabled people, because products designed with these user needs in mind can be used by able people as well, whereas the opposite situation is less likely. The inclusive approach is economic in the long-run in spite of what one may think, because there will be more customers and, therefore, the sales are likely to increase. Adopting a design so that it follows inclusive design principles is often not a costly process, but rather a challenge for the designers to be creative and think in new ways and consider alternative users and ways for interaction. Hence the approach is cost effective in that market segments are expanded (System Concepts, 2011).

Following the principles of inclusive design, the objective is that the product will have the following beneficial characteristics (Inclusive Design Toolkit, 2013):

- Functionality: The features should satisfy the needs and desires of the users (Figure 2.3 and Figure 2.6).
- Usability: The product should be practical, easy to understand and utilize, and it also ought to have a durable material to be able to be used as long as possible (Figure 2.4).
- Sustainability: Balance among the existing resources. Sustainability consists of satisfying the needs of the present generation without sacrificing the ability of future generations to accomplish their own needs. If the lifespan of a product is longer, the quality will be longer as well, and the product will be more sustainable.
- Desirability: The design should be attractive from an aesthetic perspective (Figure 2.5).

- Viability: The product should offer high value to customers and meanwhile offer opportunities in profitability to companies involved in product development, production and marketing.
- Simple and easy to assemble: There must be a balance between the easiness to disassemble and its durability. Furniture that is easy to disassemble is easier to transport and therefore cheaper, but the material should be shockproof.

Figure 2.3 Multifunctional chair (www.pinterest.com)

Figure 2.4 Inclusive wheel (www.carbodydesign.com)

Figure 2.5 Minimalist table design. (www.homemodish.com)

Figure 2.6 Public drinking fountain for different heights.
(www.belson.com)

There is a 'Population Pyramid' reproduced from Hosking et al. (2010) that shows the people difficulties (Figure 2.7). These people difficulties increase when the pyramid rises. Depending on the level of the disability people will have different needs and preferences.

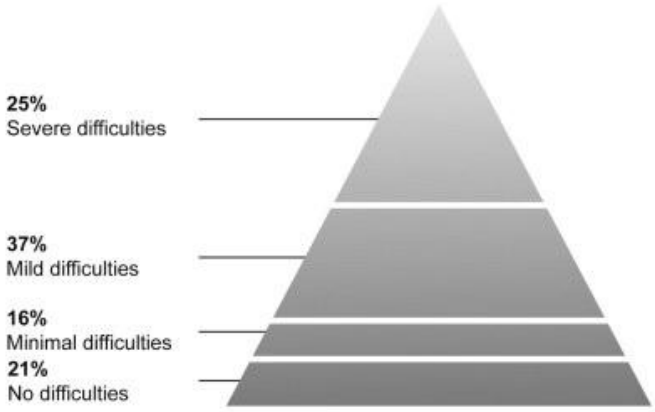


Figure 2.7 Population pyramid difficulties
(Bendixen and Benktzon, 2013)

Inclusive design is centred in the product design, in the obtained profits and in the environmental care, with the target of use the developed product for the whole population, which is compound by people with different percentages of difficulties. It is seen into 'Population Pyramid' (Waller et al., 2013).

Inclusive design process is focused on making a proper design for all kinds of clients, taking into account most of their necessities and pleasures. Because of that, the search for information about customers is very important, including surveys and more profound studies when needed. It is important to ensure the needs at the start of the design process and to have a thorough understanding and then, translate the needs into product design specifications. If this process is not followed, the costs can increase when there are changes in other steps of the process.

Inclusive Design can be an assistance for the user in many ways; for a better use of the planet without damaging it, for leading a healthier life, etc. But people are not mentally prepared to think in this way and people adopt an easier lifestyle. One of these most important wrong ideas is that the best product is the cheapest one. This is not the way for a sustainable life (Fletcher et al., 2014).

There are many examples of inclusive design in real life. One of them is 'Ferrari Enzo' (Figure 2.8). A press article by Benoit et al. (2004) explain how Ferrari changed the door to include more users to more easily enter to these sporty vehicles, especially older or disabled people, the result was a car with inclusive doors.

Figure 2.8 Ferrari Enzo with inclusive doors (www.swotti.com)

An example of inclusive design interface is Nintendo's Super Mario Bros (Ates, 2012). Almost everyone can play this game without difficulties. An inclusive interface is an interface that starts with a few fundamentals and then evolves and adapts to the user. The interface is a basic interface, everything is clear; because all is captured with big letters and basic colours, therefore, most of the people can understand the interface (Figure 2.9).

Figure 2.9 Super Mario Bros Game (www.lib.uchicago.edu)

When iPhone was designed, Steve Jobs used inclusive design in the interface of the phone (Ates, 2012). Most of the time, the hardware buttons (the numbers on a regular mobile phone) are unnecessary. When there is no need to use these buttons, for example when the user is using any of the applications on the phone, the number buttons are

hidden on the iPhone. Hence, the buttons are available only when the user has a reason to use these buttons. To enable this, hardware buttons have been replaced by soft buttons on a screen. When there are too much information in a limited space, it is difficult to understand, when this information only appear when it is necessary, it will be easier to manage it (Figure 2.10).

Figure 2.10 iPhone inclusive ability (www.iphonejd.com)

Besides Inclusive Design, Universal Design and 'Design for All' have similar purposes but different origins and somewhat different focuses.

According to Null (2013), Universal design must have the following characteristics:

- Supportive: Users must not support undue burden in any movement.
- Adaptable: All products should be possible to use for all individuals because user needs are changing.
- Accessible: The environment must change as many people are disabled.
- Safety oriented: The goal is a secure design both from the psychological and physical aspect.

One example of the 'Design for All' concept is Knud Holcher's bus-stop shelter designed for Aarhus City Council (Figure 2.11) that has tactile information to include more users (Bendixen and Benktzon, 2013).

Figure 2.11 Bus stop according to 'Design for All'.
(Bendixen and Benktzon, 2013)

2.3 USER STUDY

Users were observed in order to identify their needs and expectations. Apart from the interviews and the other used methods, observing users is valuable in the design process because some users could either (Ulrich & Eppinger, 2008):

- Have a lack of knowledge of their own behaviour.
- Find it too difficult to imagine solutions.
- Or say what is usually well done or what the interviewer wants to hear.

This means that the observation of people might gather information that cannot be collected by interviews, focus groups or questionnaires.

This observational method was carried out in The Furniture and Light Fair in Stockholm (2014), where there were many bedrooms mounted allowing people to interact with these pieces of furniture. Valuable notes were taken:

- The high beds were decidedly accepted.
- The drawers turned out essential for a large percentage of people.
- The quiet closing mechanisms of the drawers and doors were pleasantly appreciated.

In addition, some other specific techniques were directed in which the users were involved. One of these techniques was individual interviews (Appendix 8), which were conducted according to Beyer & Holtzblatt (1998).

In order to do collect user needs, and investigate possible design solutions, the interview study was carried out to know the opinions of people living in small flats. The age of the interviewed people was between eighteen to sixty years old, divided as 18-30, 31-45 and more than 46. There were at least five members in each group. 45% of the interviewees were male and 55% were female.

An affinity diagram was made of the collected information from the interviews, following a method by Bonacorsi (2008):

- Every single piece of information was written down on a piece of paper.
- These notes were grouped according to the contents.
- These groups were labelled with colour post-it notes, where each colour represented a level of hierarchy.

Finally, the groups were combined with others to get a hierarchy of four levels.
Legend:

- White notes – individual notes.
- Blue notes – summaries of groups of white notes.
- Pink notes – summaries of groups of blue notes.
- Green notes – labels identifying an area of concern indicated by pink notes.

The interviews were done online (using Skype) or in person. Some questionnaires were also collected by email. Following conclusions were drawn:

20% of the interviewees lived or had lived alone in a small apartment and 80% lived with somebody else. In this group of people 60% thought that they will live in a small flat in a near future. 55% of the interviewees possessed folding furniture in their homes, in the kitchen, living room and bedroom in particular. For everyone, order is very important to live, above all in small flats. For this reason, having folding furniture

at home was a great idea for 90% of the interviewed people, and all of them would prefer light colours in this furniture.

The possibility to have the night stand under the bed was a question that 70% answered positively. Having space in the bedroom is important for all the people, since 86% of them said that having some space under the bed to keep things is a good option.

Drawers were preferred instead of shelves, or in some cases both were selected, however, the idea of having only shelves was rejected. A few big drawers had more acceptance than many smaller drawers. Bed, closet and night stand were pointed out as essential pieces to furnish a bedroom.

The interview indicated that the range of age of people who lives in small flats is quite large, from eighteen to sixty years old.

2.4 MARKET RESEARCH

In this chapter, the existing market sectors relevant to this product and its main competitors are studied.

Benchmarking is a rational method that studies the similar existing products to the product which is being developed, or the problems in which these are focused on (Education Portal, 2014). In this step, it is very important to know the competitive products (Figures 2.12 to 2.16). This consists of an external search, which can be very useful to find new solutions.

Figure 2.12 Bed with closet (www.ciiwa.com)

Figure 2.13 Bed with headboard (www.ikea.com)

Figure 2.14 Drawers under bed (www.pinterest.com/)

Figure 2.15 Space under bed (www.derickg.com)

Figure 2.16 Bed Up and Down (www.gizmodo.com)

First of all, it is required to talk about Scandinavian Design since Scandinavian Design is one of the main styles which Olby Design follows. And then, the study of competitors is needed in order to analyse similar products.

2.4.1 SCANDINAVIAN DESIGN

Scandinavian Design was born in the 1950s in the Scandinavian countries: Sweden, Denmark, Norway and Finland. This movement design is characterized by minimalism and functionality. For this reason the Scandinavian Design usually uses simple lines and colours (Figure 2.17 and Figure 2.18). The main revolutionary idea of this movement was the emergence of a democratic design by using low-costs materials and methods for mass production (Figures from 2.19 to 2.22) (Eypórsdóttir, 2011). This style is followed by Olby Design, so the furniture being designed in this project has to meet this Scandinavian Design line.

Figure 2.17 Scandinavian Bedroom light colours (www.home-designing.com)

Figure 2.18 Scandinavian Bedroom with drawers under the bed (www.ihomedecorsideas.com)

Figure 2.19 Scandinavian *Bedroom (www.homemydesign.com)*

Figure 2.20 Scandinavian Living room A (www.freshome.com)

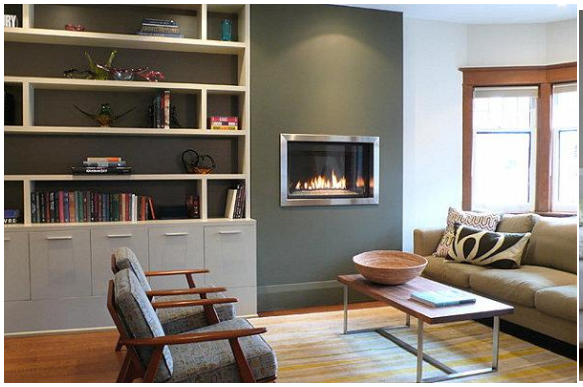


Figure 2.21 Scandinavian Living room B (www.decoist.com)

Figure 2.22 Scandinavian Living room C (www.vangviet.com)

2.4.2 STUDY OF SWEDISH COMPETITORS

A search of the companies that are competitors to Olby Design was required, since it is important for the design team to know what kind of furniture market Olby Design have to compete within. Therefore, market research is useful to design and analyse furniture, as well as the purchasing power of customers, the availability of distributors and consumer profiles. Primary market would be small/medium furniture companies and secondary market would be big furniture companies and hobbyists. Companies that in one way or another were considered valid to investigate further were:

IKEA: IKEA is an international corporation that was born in Sweden but it has its headquarters in Netherlands. This company is dedicated to retail sale of furniture and household and decor items. It has contemporary design and offers relatively low prices. IKEA is one of the main companies in furniture. The company is considered to be the contemporary design icon and it is one of the most innovative. The slogan of the company is the European open-minded, moving away from the supposed closed mentality of American commercial culture (IKEA, 2014).

NORRGAVEL: Norrgavel is a company which sells furniture made for functional form and the environment. Its founder is Nirvan Richter and he believes that furniture should not be too intrusive. His inspiration comes from the peasants in Swedish Dalarna, The Shakers in the US and the Wabi-Sabi in Japan. Norrgavel always works

with natural materials, often from the Swedish woods. They have stores all over Sweden, but the main store is located in Stockholm (Norgavel, 2012).

G.A.D: G.A.D is a company in Gotland that manufactures wood furniture, with limestone and wool. Their philosophy is to make an effort to achieve the highest quality from purchasing to packaging. Rapid consumption is avoided and in its place things good for the body, brain and environment are selected (G.A.D., 2013). The G.A.D style is very similar to the Olby Design style. Olby Design was the pioneer of these designs. On its web page furniture can be seen and it looks similar to Olby Design's.

The above mentioned companies are the ones that are direct competitors to Olby Design. Below, there are some companies that are competitors but on a small scale.

Mio AB: Mio AB was founded in 1962 and is based in Tibro, Sweden. They operate furniture chain. Decorating accessories are offered by the company as well (Mio, 2013).

String Furniture AB: The design is distinctive and minimalist. The designer, Nils Strinning has the reputation as one of the designers who laid the foundations of modern Scandinavian design. Now his designs can be found all over the world. The company is from Malmö (String, 2014).

Tibro Möbelindustri: The Company is located in western shore of Tibro, a city with a long tradition in furniture. They confirm that all the materials are high quality and the furniture too. They can produce everything in the way of manufacture furniture (Tibro Möbelindustri, 2014).

Lundbergs Möbler: Lundbergs manufacture all kind of furniture, but their specialty are tables, chairs and furniture related with storage. The company is located in Tibro, Sweden (Lundbergs Möbler, 2014).

Blå Station: Blå Station is a family company and based in the town Åhus on the Swedish south-east coast. They make furniture with birch and stainless steel. They always meet the demands and desires of the customers and try to innovate. Curiosity is their fuel (Blå Möbler, 2014).

BordBirger: They are well known in the furniture industry and they are associated with high quality and timeless design. In their factory which is located in Småland, the machines are highly developed and the workers know craftsmanship and technical advanced training (BordBirger, 2014).

2.5 ANTHROPOMETRY OF TARGETED USERS

An anthropometric study was needed in this process and the obtained conclusions were used as a guide for this procedure. It is such an important part of the development process, because the designed product must satisfy the user and this is possible only when the user's data are fully known.

The first step of this study consisted in to know who the users are (target population), with this purpose 'Generate Personas' method was accomplished (Inclusive Design Toolkit, 2013). Each person of this target population were different in age, sex, ethnic composition and physical-health characteristics and all of these were within boundary cases. These boundary cases were established based on Germans and South-East Asians, the first group is one of the tallest populations in the world, and the second

one is among the smallest. Besides, the measures according to the largest percentile of Germans and the lowest percentile of Asians were chosen, to ensure a broader diversity range of people within this analysis. Once the problematic parts and the audience are known, the following step is to choose a properly anthropometric database.

The table 2.1 and 2.2 below show these measurements, according to each target group for some concepts like stature, vertical fingertip reach and hip height. These values were important to keep in mind, in order to obtain the proper measures of the piece of furniture. The values were calculated through the PeopleSize (2008), Anthropometry online software (Delft University of Technology, 2004) and some others calculations.

Table 2.1 German data for male and female

Percentile > 99,99		Stature (mm)	Vertical Fingertip reach, sitting (mm)	Hip (Trochanter) height, standing (mm)
German	Female	1720	1407	894
	Male	2100	1509	976

Table 2.1 Asian data for male and female

Percentile < 0,01		Stature (mm)	Vertical Fingertip reach, sitting (mm)	Hip (Trochanter) height, standing (mm)
South East Asia	Female	1475	1195	742
	Male	1572	1278	805

A body is only well positioned when the feet or the highlight of the seat are supported. For the feet, it is essential to have enough space in order to avoid loss of balance, so that is why the piece of furniture ought to be compact (Bridger, 1995).

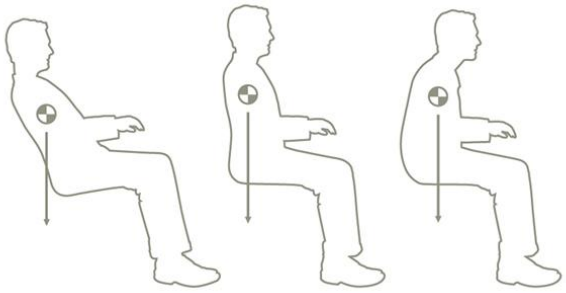


Figure 2.23 Typical seated postures (www.hermanmiller.com)

The user should easily reach the shelves or drawers without suffering any hurt. The study that was previously done has the values for vertical fingertip reach and sitting. These measurements were needed to know the average of the people measures in this position. Headboard or shelves were designed according to this data. The study also includes hip height, standing. This measurement was focused on the handles positioning, which had to be positioned according to these measurements.

2.6 MANUFACTURING

A guided visit over the workshop was necessary for a suitable comprehension of the manufacturing process commonly used.

Firstly, wood is cut in different size boards, by a specialised machine (Figure 2.24). Then, glue is applied on the plywood boards with the help of this machine (Figure 2.25).

Figure 2.24 Cutting machine

Figure 2.25 Machine to glue

After that, the wood laminates (Figure 2.27) are positioned on the edges of the plywood boards in another machine which ensures their adhesion (Figure 2.26).

Figure 2.26 Adhesive machine

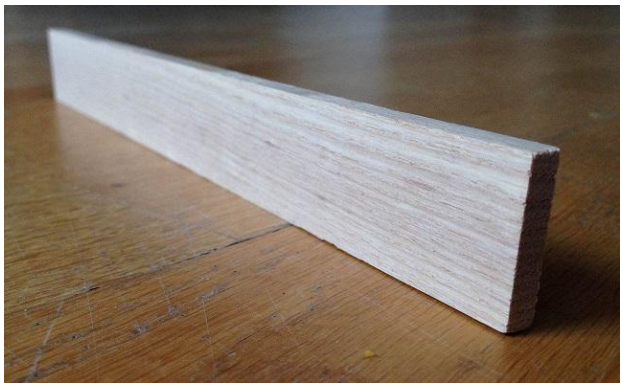


Figure 2.27 Wood laminates

The last step to obtain the Elder plywood, consists in gluing the oak laminate (Figure 2.28) on the top of the previous plywood (Figure 2.29).

Figure 2.28 Machine to glue the oak

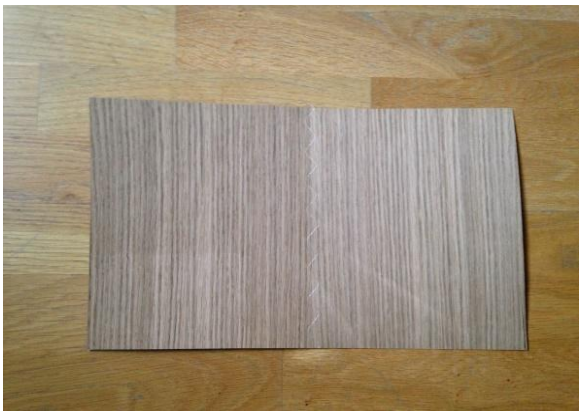


Figure 2.29 Oak laminated

These two machines are used to make needed holes in the different shapes and sizes that are required. The first one is called CNC (Figure 2.30) meanwhile the second one is only able to do holes with different bits due to be a manual tool (Figure 2.31).

Figure 2.30 CNC machine

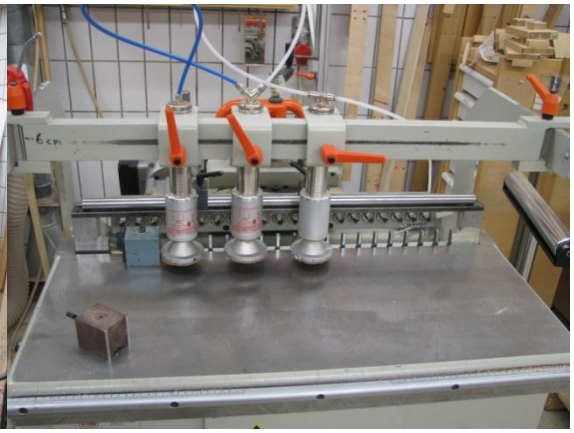


Figure 2.31 Machine to make holes manually

If there is a rounded shape or an unusual form, this machine is able to do different forms in the wood (Figure 2.32).

The next step is about sanding the wood. This machine easily sands the wood and leaves it in a perfect condition (Figure 2.33).

Figure 2.32 Machine to make unusual shapes

Figure 2.33 Sanding machine

Later, the tables will be joined through cylindrical wooden brackets (Figure 2.35). Then, the piece of furniture can be assembled (Figure 2.34).

Figure 2.34 Joined tables through cylindrical wooden brackets

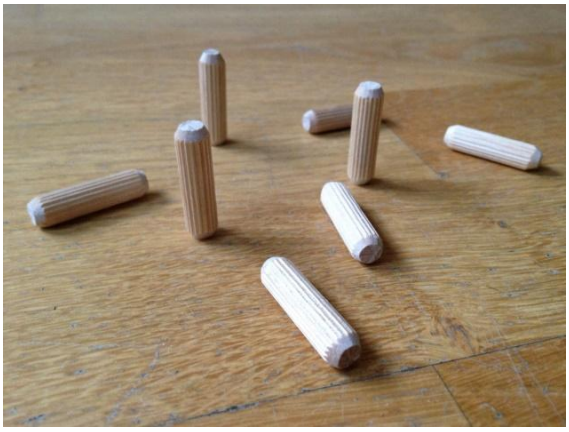


Figure 2.35 Cylindrical wooden brackets

The next step is to mount accessories in the piece of furniture such as drawers, metallic mechanisms, rails, etc. (Figure 2.36) and soon thereafter the piece of furniture is transported to a room, where this will be painted for a better finish (Figure 2.37 and 2.38).

Figure 2.36 Closet with accessories

Figure 2.37 Paint sprays

Figure 2.38 Paint room

If there is any detail made with clothing, this is the step to carry it out. Everything about textiles is carefully made by hand in one of the last steps (Figure 2.39).
Finally, when the whole process has been followed, the piece of furniture is packed and transported (Figure 2.40).

Figure 2.39 Clothing details made by hand

Figure 2.40 Packaging

2.7 RECYCLING AND ENVIRONMENTAL ASPECTS

Recycling is a fundamental aspect in the environment. Wood is a readily recyclable, especially if it is plywood (Tchobanoglous, 1994). At Olby Design, plywood is recycled in some ways. There are some wood pieces that are reused if the wood board is of good quality and big enough. Other smaller wood sections are recycled after crushing them. Then, wood is burned, or is given to farmers for the chickens' breeding.

In the environment field, it is known that manufacturing process can produce pollution. However, wood is the least polluting material when processed. An aluminium beam can produce 227 kg of carbon dioxide, while a wood beam produces only 6 kg. Besides this, wood is the only building material that is 100% renewable. Carbon dioxide is retained during its lifespan, and this is only emitted in small amounts (Barrera, 2010).

3. SPECIFICATIONS AND DEMANDS

Customers have needs, which describe what functions should have the product. Specifications and demands are values and metrics that the product must fulfil. This chapter is divided in three parts: 'Generate personas', 'function analysis' and 'final requirements'.

3.1 GENERATE PERSONAS

This stage is called 'Generate personas' (Inclusive Design Toolkit, 2013). The main aims of this method are:

- To summarise user diversity considering physical, cultural and social contextual factors.
- To simulate a problem situation which the user should try to solve. User problems were seen and tried to be solved by the design team.
- To assist by the evaluation of concepts and ideas.

Personas should be representative of a large group of people of different contextual situations, ages, cultures that are within the age range of the product. Many ideas were generated by observing and analysing the users. After that, some questions were asked to users to know what they were thinking about the task and some notes were taken. The personas table obtained from Inclusive Design Toolkit (2013) was very useful to this investigation (Appendix 5).

In this step it was concluded that people of different ages have different necessities. For example, children usually have problems when they want to reach something of high shelves, i.e. it is a stature related problem. While old people may have problems of vision, hearing and also with their dexterity or the body movements. As it has been observed, most of the people can understand simple technology, usually only people from 70 years old and older have problems to understand it. However in this case, these pieces of furniture will not use difficult technology, therefore everybody should be able to understand the uses of each part of the piece of furniture.

3.2 FUNCTION ANALYSIS

A function analysis was made to thoroughly investigate the main problem areas (Cross, 2008). The main and sub functions of the furniture were then identified and put into a function tree. The top level of the tree represents the main function and the lower levels represent sub-function (See Figure 3.1).

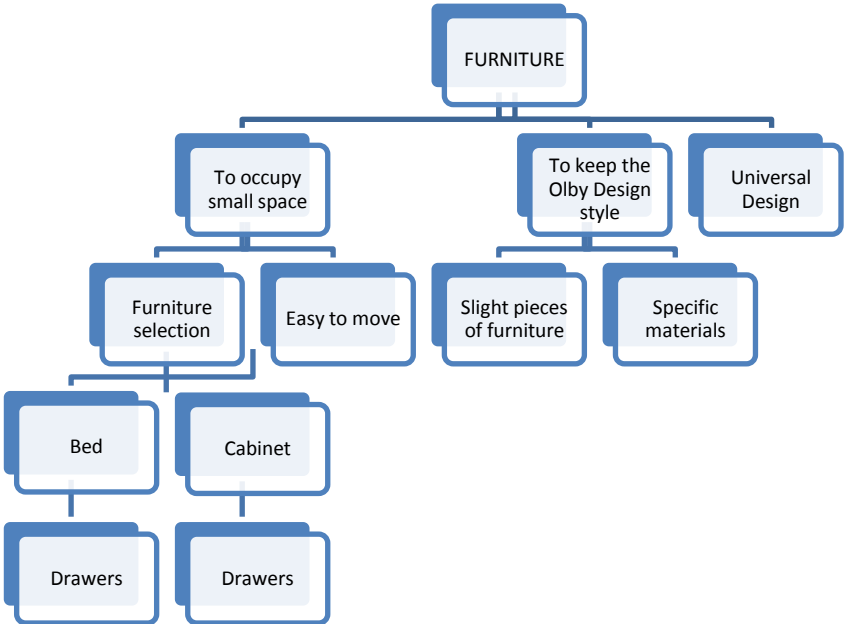


Figure 3.1 Function tree

The function tree explains how the general problem can be divided into sub-problems. It is a good method to clarify concepts and maybe an easier way to look for good solutions. When the pieces of furniture are selected, the search of problems ought to be focused on these, which are; bed and cabinet. And each of these pieces has to be studied. The bed has to bring in some other functions like having drawers. The cabinet ought to have several drawers of different sizes which could be easy to open and close and it could have an integrated TV so it occupies less space. Another main problem that needs to be solved is the importance of obtaining a inclusive product design which will be apt and functional for people from any place in the world, elderly, disabled people, etc.

3.3 FINAL REQUIREMENTS

The last step of the specifications and demands chapter consist in summarising in two tables all the requirements, dividing them into abilities requirements and technical requirements (Table 3.1 and 3.2).

Table 3.1 Final abilities requirements

Bed	More than one function	Closet
		Bed
		Night table
	Night table	Ability to be hidden
	Ease	To use
		To manufacture
	Quality	Stability
		Durability
		Good appearance
Cabinet	More than one function	
	Ease	To use
		To move
		To manufacture
	Different size of drawers	
	Quality	Stability
		Durability
		Good appearance

Table 3.2 Final technical requirements

WISHES (W) / DEMANDS (D)	REQUIREMENT	TECHNICAL FEATURES	ACCEPTABLE VALUE	IDEAL VALUE
D	Bed Measures	Depth	2000 mm	2000 mm
		Height	440 mm	300 mm
		Strength	2000 N	2500 N
D	Cabinet Measures	Depth	268 mm	400 mm
		Height	742 mm	1000 mm
		Space for the TV	680 x 45 mm	680 x 45 mm
D	Headboard Measures	Doors	Big: 800 x 20 mm	800 x 15 mm
			Small: 400 x 20 mm	400 x 15 mm
		Shelves	400 x 220 mm	400 x 220 mm
		Depth	250 mm	300 mm
		Width	1600 mm	1500 mm
		Height	1700 mm	1500 mm
		Strength	250 kg	250 kg
W	Customizable	How many modules?		6
W	Total Size	Length		2250 mm
		Width		1600 mm
		Height		1700 mm
W	Easy to Clean	0º or 90º surfaces		100%
		Polished texture material		100%
D	Costs	Budget in workshop	15000 SEK	< 15000
		Cost in the store	30750 SEK	< 30000
D	Recycling Material	%	50%	100%

4. CONCEPT GENERATION AND SELECTION

After the specifications were defined, the next stage was looking for the solution to solve all the problems, presented in previous chapters. This search of solutions was made following the Inclusive design toolkit, in order to create many ideas, concepts and sketches of them. Then, these concepts were studied, evaluated and compared and, finally, the best ones were selected and separated from the others to be presented to the company. These steps followed a number of specific methods and these will be explained below. Once the company had evaluated these concepts, they presented some other ideas and demands which they required of the final concept. These ideas were noted down by the design group and again some others sketches were outlined and scrutinized.

4. 1 FIRST STAGE

This first stage of Concept Generation consists in the development of the first concepts. The specifications have to be well known to indicate what needs to be searched. For this reason, it was necessary to observe users and generate personas.

Then, some methods were carried out: on the one hand, the rational methods called Check list and Bench Marking and, on the other hand, the first creative method called Brainstorming. After a first selection, some first concepts have been obtained.

Ulrich and Eppinger (2008) described a way to find a wide range of ideas that may solve the customer needs. Every concept ought to be defined by sketches and some explanations. Usually these concepts do not focus on technical details; they are more general. However, these details will appear in the next phase of the process, although, according to Ulrich and Eppinger (2008), every concept has to be quite studied in the first phase in order to reduce time and costs of development. The importance of finally obtaining a 'customer-focused product' is also stressed by Ulrich and Eppinger (2008).

Following the Inclusive Design Method (Inclusive Design Toolkit, 2013), this first stage in the present project is based on the creativity activity. And the question is, How can the needs be met?

4.1.1 GENERATION OF ALTERNATIVE CONCEPTS

The 6-3-5 Method is a creative method which includes brainstorming, this is called Brainwriting (Mind Tools, 2013). This consists in generating a large number of new ideas in a short time. The quantity of ideas is more important than the quality of them but some of these ideas will be developed in a future phase. The technique normally involves a design group of six members and a moderator who has to control the time because, every 5 minutes, each participant has to do a quick sketch of three ideas. The next five minutes, the sketches are passed along to the next member of the group who will add, change or modify them. When the whole group has given input to all ideas, the Brainwriting has finished. It has the advantages that there is no interruption or blocking

during this time; the group is concentrated in the same aim and with all their senses (Ulrich & Eppinger, 2008).

This method was used by this design group. However, since this design group consisted two members, adjustments were necessary. The performance was divided into two different stages with two separate groups. The first group was the design group, who developed sixteen concepts. The second group consisted of three different persons who were randomly selected (Figure 4.1 and 4.2). Nine concepts were generated and a total of twenty-five concepts were analysed and organized in different groups for a better overview (Figure 4.3).

Figure 4.1 Brainwriting method

Figure 4.2 Brainwriting method (2)

This part of the concept generation was very important, because some conclusions and ideas were written. The most important ideas were as follows:

- Most of the bed drawings had something under the bed.
- Headboard had an important function in the bed.
- Different sizes of drawers were drawn.

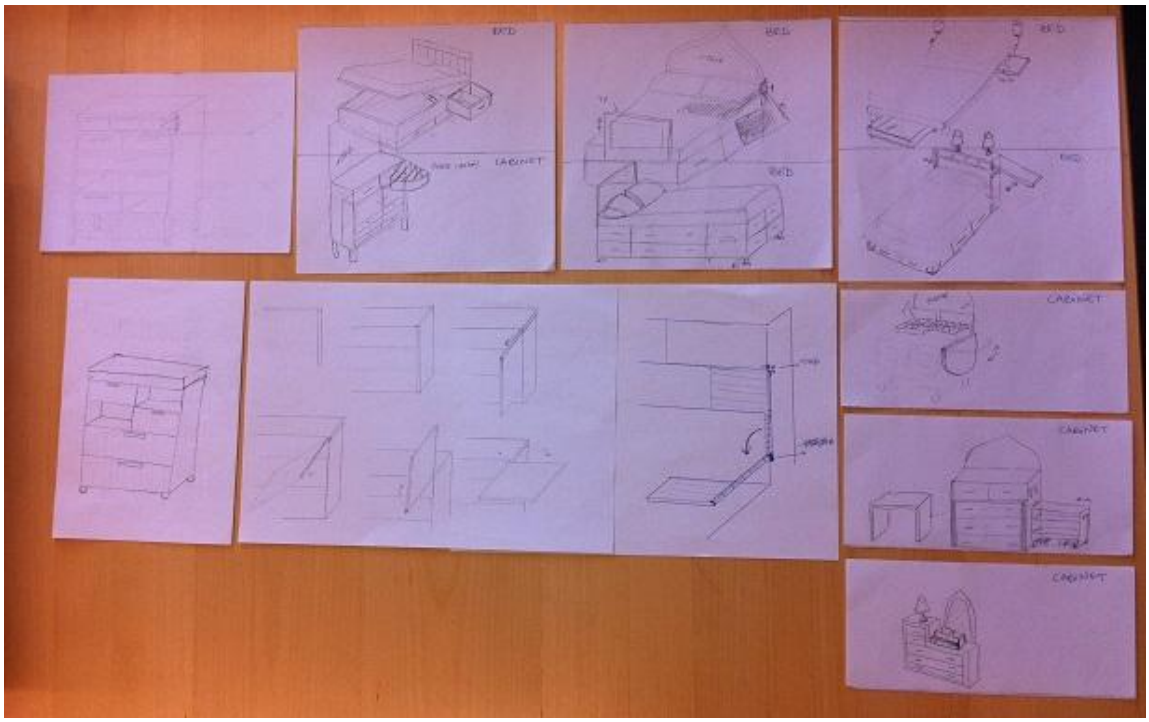


Figure 4.3 Sketches

4.1.2 FIRST SELECTION

Multivoting (Ulrich & Eppinger, 2008) was the method used for the selection of the first concepts. All the concepts were evaluated and ranked by the design group in order to dismiss the least appropriate concepts. Thereby, the number of concepts decreased and the project came slightly closer to the final concept.

4.2 SECOND STAGE

Once the first selection step had been performed, it was needed to go on with the selection process for dismissing some more concepts, updating others and also developing new ones.

4.2.1 'WHY? WHY? WHY?'

This technique consists in a consecutive chain of why? It is like a persistent child and it can help the designers to open their minds, which is very important in the search for solutions. It is necessary to create more concepts and to improve the existing ones. This method was rather helpful to understand what should be done and why (Cross, 2008).

4.2.2 USE RELATED STIMULI

The aim in this stage was looking for stimuli to develop new ideas. As a stimulus, it was good to make a trip to The Furniture and Light Fair in Stockholm. Some pictures and notes were taken and it was beneficial to observe the visitors (Figure 4.4 and 4.5). It was advantageous to see how clients interacted with all kind of pieces of furniture.

Brands such as *ygg&lyng, string, CS Möbelfabrik* and *BordBirger,* among others, presented their products at the fair. The visitors were fascinated about the variety of designs, textures, colours and materials. More information available at: http://www.stockholmdesignweek.com/

Figure 4.4 Furniture Fair exhibitor

Figure 4.5 Furniture Fair exhibitor (2)

4.2.3 EXTERNAL DECISION

As Ulrich and Eppinger (2008) declare, this method aims to ask customers about their favourite concepts or ideas. After the first selection was carried out by the design group, a second selection followed, but this time the decisions were taken by the company. A

study visit was necessary in which the concepts were expounded and the selection was carried out.

The company also provided several ideas, which were accepted as indispensable for the new concepts development.

4.3 THIRD STAGE

In this third stage sketches of the bed and the cabinet are going to be exposed and analysed, which will be aimed to a rear selection.

4.3.1 SELECTION MATRIX

One selection matrix of each piece of furniture was needed to study these concepts (Ulrich & Eppinger, 2011). This consists in introducing in a table, the relation between developed concepts and required features. The selection criteria were chosen based on the company and customers' needs that the team had identified before as final requirements (Chapter 3.3). Then, a reference concept was chosen in order to compare it with all the others concepts (Table 4.1 and 4.3). For evaluating and summarising of this matrix, a legend was established:

- Positive point (+): Better features than the reference concept.
- Zero point (0): Same features.
- Negative point (-): worse features than the reference concept.

Once each feature of each concept was valued, it was proceeded to count marks to define the rank of all the concepts.

CABINET

Cabinet concepts might be seen from figure 4.6 to figure 4.13.

Fourth concept was chosen as reference concept (Figure 4.9), in order to compare the other concepts with it.

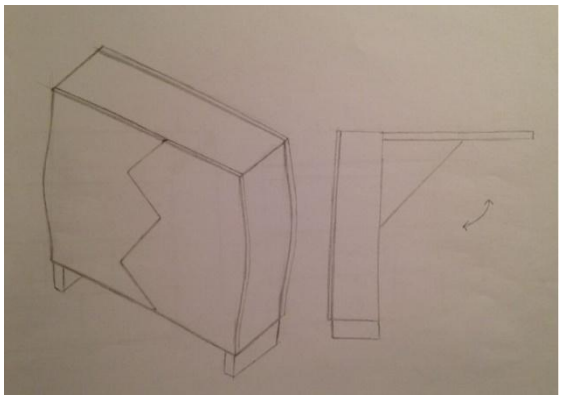


Figure 4.6 Concept 1 Zig-zag

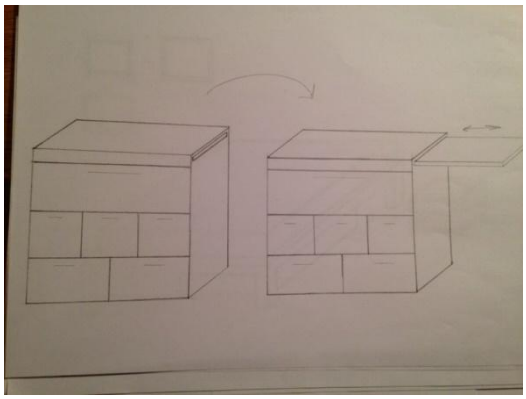


Figure 4.7 Concept 2 Hidden table

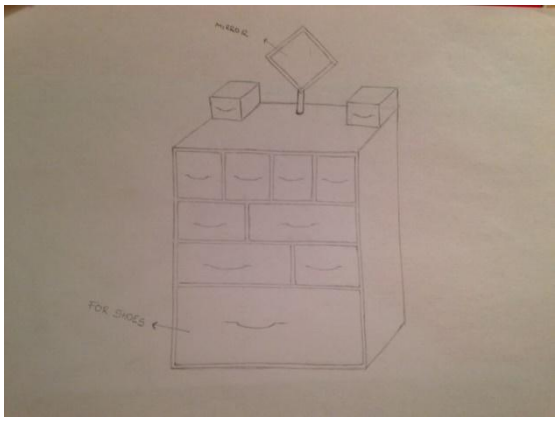


Figure 4.8 Concept 3 Mirror and drawers

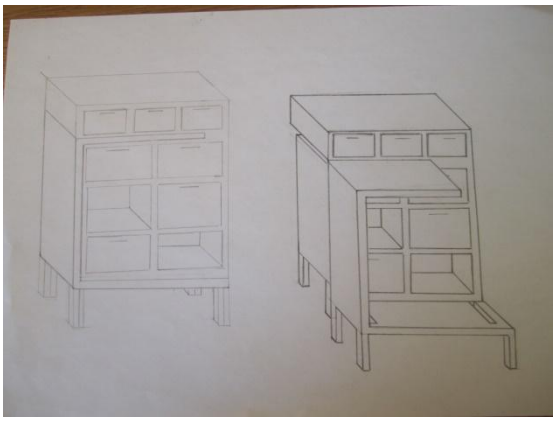


Figure 4.9 Concept 4 Table for bed

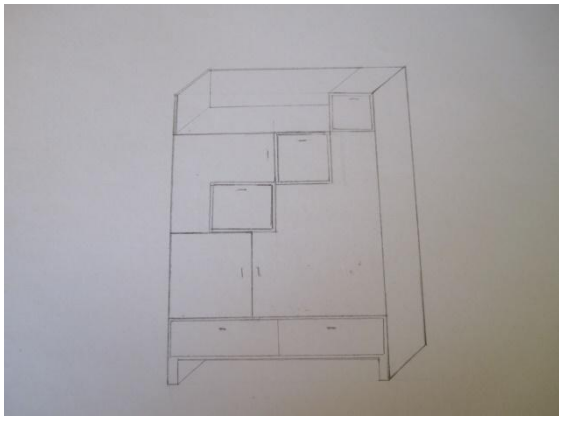


Figure 4.10 Concept 5 Shelves and drawers

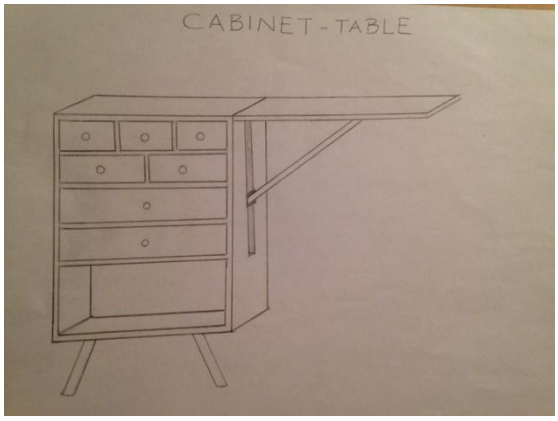


Figure 4.11 Concept 6 Iron table

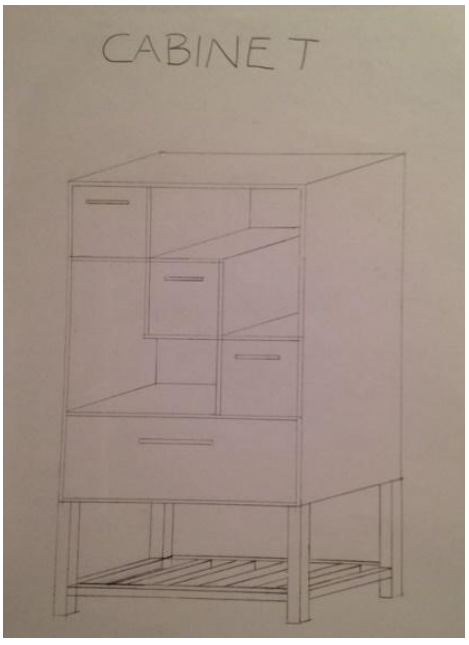


Figure 4.12 Concept 7 Stairs drawers

Figure 4.13 Concept 8 Mirror and table

Table 4.1 Selection matrix for Cabinet Concept

	Concepts							
Selection Criteria	C.1 (Zig - zag)	C.2 (hidden table)	C.3 (mirror and drawers)	C.4 (C table for bed)	C.5 (shelves and drawers)	C.6 (Iron table)	C.7 (Stairs drawers)	C.8 (mirror and table)
Double function	0	0	-	0	-	0	-	+
Accuracy measurements	-	0	0	0	0	0	0	0
Easy to move	0	+	0	0	0	+	0	0
Easy to use	0	+	+	0	+	0	+	0
Different size of drawers	-	0	0	0	0	0	0	0
Easy to manufacture	+	0	+	0	+	0	0	+
Easy readability	0	-	+	0	+	+	+	0
Durability	+	0	+	0	+	-	+	+
Stability	0	-	+	0	+	-	+	-
Net score	0	0	4	0	4	0	3	2
Rank	4	4	1	4	1	4	2	3
Continue	No	No	Yes	No	Yes	No	Combine	Combine

Some ideas were concluded after this selection matrix. Seven concepts were compared with concept four (Table for bed), which had obtained quite a similar rank between the first and the fourth position. The two concepts that can be emphasized are called: mirror and drawers and shelves and drawers, which have had the same voting. This matrix helped to realise that these two concepts were the simplest ones, which did not reach the expectations. This event highlighted the need of reconsidering what had been searched for. It was demanded to see others approaches and other ways to finally achieve the wished concept result. To assist the mind opening process and the arrival of distinct new

ideas, a new search based on observing people and researching on internet was carried out.

A new cabinet concept was developed from a different standpoint. The cabinet was positioned at the feet of the bed aimed to keep a TV inside and to provide drawers and shelves at the same time, thus the TV would be placed in a comfortable location for its watching.

Once the respective data search was done, it was decided to use a mechanism that could move the television up and down. This mechanism would be inside the cabinet and it would be bought from a specialised company, called Häfele.

This cabinet could be attached to the bed or in other case, placed anywhere in the room depending on the clients wishes. Concept nine (Figure 4.14):

Figure 4.14 Final cabinet concept

This ninth concept seemed as a good concept that will cover all requirements and users' needs; nevertheless, the lack of the ergonomic study would not give the certainty of the product success. Therefore, undoubtedly it was returned to the ergonomics study.
Eye heights, sitting are called the values from the hip to the eyes height for a good TV position (Table 4.2).

Table 4.2 Anthropometric aspects about TV distance

		Eye height, sitting (mm)	
		Value	SD
German	Female	759	34
	Male	811,5	36,3
South East Asia	Female	700	24
	Male	730	30

In order to have a good vision from the bed to the TV, according to a Spanish webpage called cuidatuvista.com, the minimum distance to watch TV is 2 m when the TV has 32". In this case, the TV can have a maximum of 37". The ideal position of the body to watch the TV is perpendicular to the TV screen and it is recommendable to have a TV that can spin round to establish the best position.

This last concept, concept nine, was selected as the best cabinet option, which would meet the customer's needs.

BED

Bed concepts are shown in Figure 4.15 to Figure 4.19.

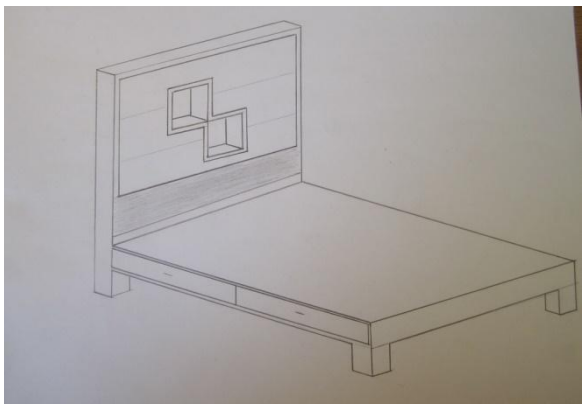


Figure 4.15 Concept A headboard-shelves

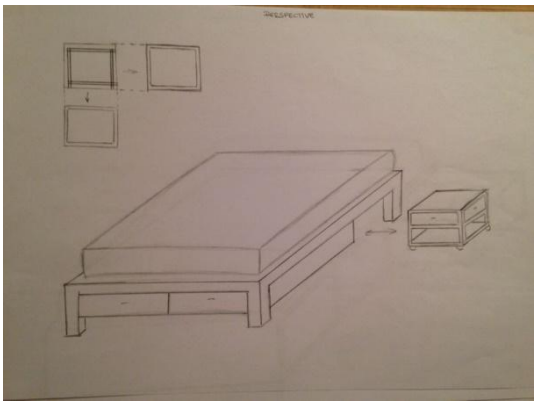


Figure 4.16 Concept B Front-drawers

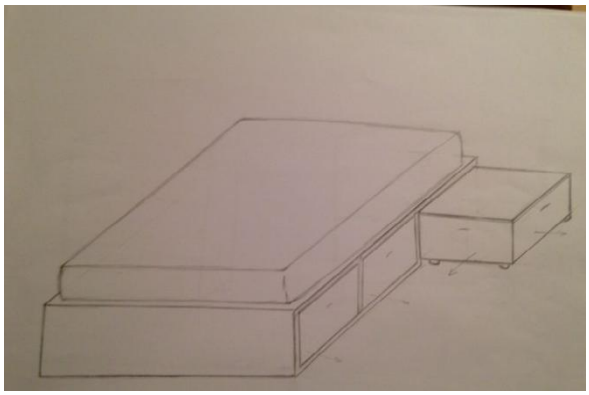


Figure 4.17 Concept C Drawers on the floor

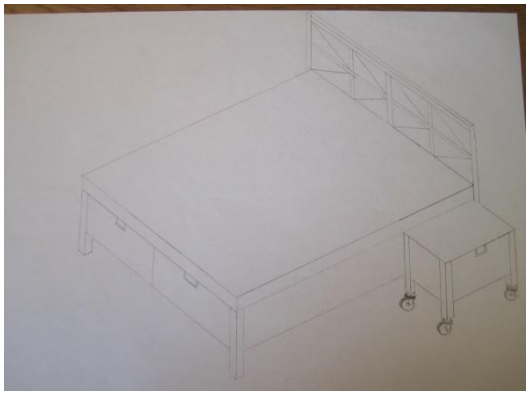


Figure 4.18 Concept D Slide night table

In this case, the reference concept was a concept taken of a previous search. This concept was denominated concept Zero.

Figure 4.19 (Concept ZERO)
(www.derickg.com)

Table 4.3 Selection matrix for Bed Concept

Selection Criteria	C.A (headboard-shelves)	C.B (front-drawers)	Concept Zero	C.C (Drawers on the floor)	C.D (slide night table)
Double function	+	+	0	0	+
Night table	+	+	0	+	+
Stability night table	+	+	0	+	0
Accuracy measurements	-	-	0	0	0
Easy to use	+	+	0	+	+
Different size of drawers	+	+	0	0	+
Shelves/ Drawers accessibility	+	+	0	+	+
Space exploitation	-	-	0	0	-
Easy to manufacture	0	-	0	0	-
Easy readability	+	0	0	+	+
Durability	-	-	0	0	-
Stability	-	-	0	0	-
Net score	3	1	0	5	2
Rank	2	4	5	1	3
Continue	Combine	No	No	Combine	No

In the previous matrix (Table 4.3), five bed concepts were shown, with the goal of choosing the most suitable one. After, three of these concepts were deleted; this meant that there were only two promising concepts left. This fact drove to the proposal of combining these concepts to obtain one, which would be different to the rest, instead of choosing one of these two.

Besides this selection process, the concepts were introduced to the company in order to receive their comments and suggestions:

- The existence of wheels under the night table was dismissed.
- The drawers in the headboard were emphasized as a good choice to take advantage of more space.
- The drawers set directly on the floor made the whole bed seem too robust or stocky. However, the use of this space was flattered. For this reason it was needed to look for some solution which would cover both requirements.

Once the previous data was clarified, new sketches were needed, combining the old sketches and the new information.

This new concept provides a useful headboard which has shelves and one shoe rack in each side. The night table consisted in a simple board, which could be hidden sliding it inside of the bed. On the other hand, the drawers under the bed did not occupy the whole space yet. Concept E (Figure 4.20).

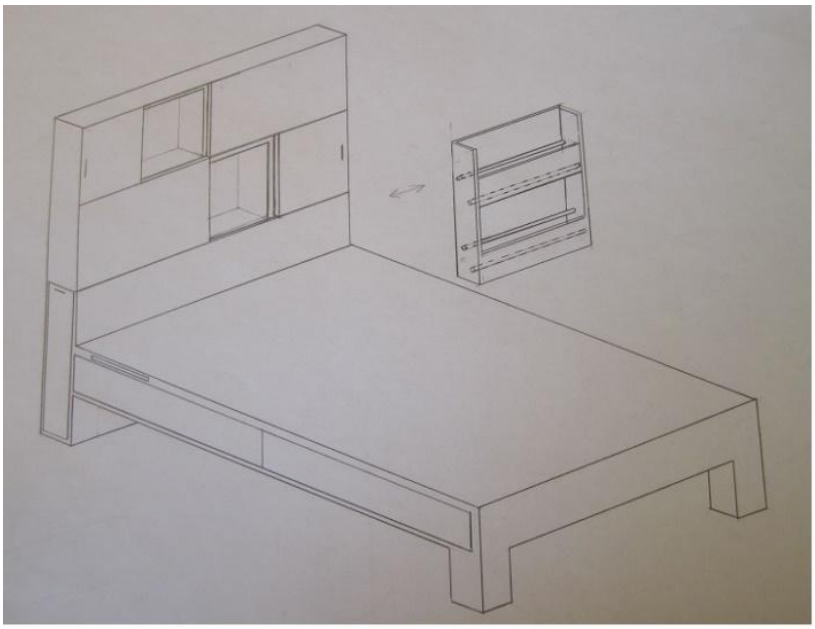


Figure 4.20 Concept E Result of the Bed Matrix

4.3.2 POSITIVE, NEGATIVE INTERESTING

PNI was carried out as an evaluation process, which consisted of classify the positive, interesting and negative parts of each concept (Table 4.4 and 4.5) (Hildebolt, 2010).

CABINET

Table 4.4 Positive, interesting and negative cabinet concepts

CONCEPTS	POSITIVE	INTERESTING	NEGATIVE
C.9	Possibility of keeping the television inside. Shelves and drawers.	Different possible locations in the room.	Big part of the cabinet is occupied by the television.

This last concept nine was selected as the best cabinet option, which would reach the customer's needs.

BED

Table 4.5 Positive, interesting and negative bed concepts

CONCEPTS	POSITIVE	INTERESTING	NEGATIVE
C.A	The possibility of the headboard use.	The incorporation of the night table inside the bed. The idea of some square shape on the headboard.	Wasted space under the bed.
C.B	Drawers of different sizes.	Night table with shelf and drawer. Drawers in other different direction.	Wasted space under the bed.
C.C	Good use of the whole space under the bed.	The night table is linked to the drawer	The double direction of the drawers' rails would be more difficult to manufacture.
C.D	Good handles. It will be necessary of test.	Drawers of different sizes.	Wasted space under the bed.
C.E	Headboard: shelves, slide doors. Use of headboard bottom.	Problem with the shoe rack.	The drawers under the bed are too big.

In the fifth concept, one problem has been mentioned, which is going to be explained.

It was thought that a shoe rack would be a quite useful piece of furniture. However, a cultural difference was not expected. This cultural difference was that Spanish people are used to keep their shoes in their own bedroom; on the other hand Swedish people usually take their shoes in the house entrance. For this reason the shoe rack was removed because of the main aim of this project of getting an inclusive design, which would be a proper piece of furniture for all countries.

4.3.3 EXTERNAL DECISIONS

Another visit to the company was required to present the latest concepts. Several notes were taken, which would be taken into account.

Drawers would have to occupy the whole space under the bed, as well as the robust appearance would be avoided, if the drawers were dark colour painted. This way the drawers would be placed on the floor and the colour difference would give it a softer appearance.

Because of the shoe rack unexpected problem, other possible solutions were sketched (Figure 4.21). This concept combines a part of shoe rack, which can be used for shoes from others seasons, and a shelf part.

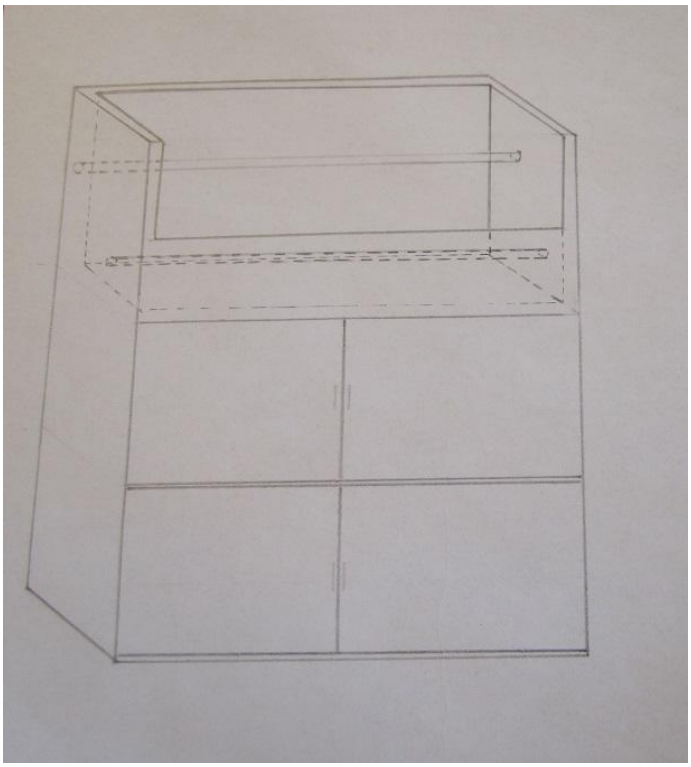


Figure 4.21 Shoe rack, first solution

Notwithstanding, finally the concept shown in Figure 4.22 was selected as a part of the final bed concept, which is made up of four shelves. These could be used for shoes owing to the proper measures for shoes or could be used as normal shelves.

Figure 4.22 Final closet concept

4.4 FOURTH STAGE

Once the final concepts were chosen, these were made as a physical prototype and were thoroughly tested. In this chapter it was still possible and necessary to make changes to improve the product and its continuous update.

4.4.1 PROTOTYPE

A prototype can be really useful to test and see the real product. In this case, the product is simulated as a physical prototype. The prototype is used to get an idea of how the product will be physically. It is needed to validate the functionality of the product. Prototype is done to improve the product and reduce costs before manufacturing it.

The prototype was made by Anni Mykkänen, a girl who was doing her internship in interior design. It took two weeks to see the prototype done. During these two weeks, there were some problems of measurements and there were a lot of changes in the aesthetics of the product, but the product always improved (Figure 4.23 and 4.24).

Figure 4.23 Prototype finished (1)

Figure 4.24 Prototype perspective (2)

4.4.2 TEST WITH USERS

There were many ways to do a test with users. Three methods have been chosen according to the ergonomic needs of the product. These are 'prototype testing', 'Jack software' and 'testing with handles'.

Prototype testing

Testing a prototype with users was very useful to analyse how effective and easy to understand and use the developed concept was. There were some points where this step was focused on:

- Time to look at these pieces of furniture.
- Time to use the product (efficiency and effectiveness).
- Difficulty of its use.
- Comments and suggestions of the users.

This part of the process had to be early carried out because these kinds of tests brought some other problems to light, which had to be solved. For this reason this was a cyclic process and the concept product had always been updated during the process. In this case, during the prototype manufacture process, several details were changed. The prototype had a type of handles that were changed after testing it with users, who thought that these new ones were easier to manipulate. However, a good prototype testing would require a real scale prototype, which could not be made because of the too high economic cost.

VIRTUAL FITTING TRIAL

Another method for testing the final concept was by using the Jack software, which helps to simulate the interaction between the product and users in a real and equal scale for both. Once the 3D model was exported from the PTC CREO, the following activity resided in creating several corresponding mannequins of the selected measures. Four mannequins were created, two men and two women. The approach was the following; the models would measure according to the average of the tallest and shortest women population value, and the same activity would be repeated with men.

The tallest population of men and women are from Netherlands and their average of height is 1655 millimetres for women and 1770,5 millimetres for men, by the other hand, the shortest population of men and women are from South East Asia (Interbasket.net, 2009), the average of height is 1530 millimetres for women and 1630 millimetres for men (Figure 4.25).

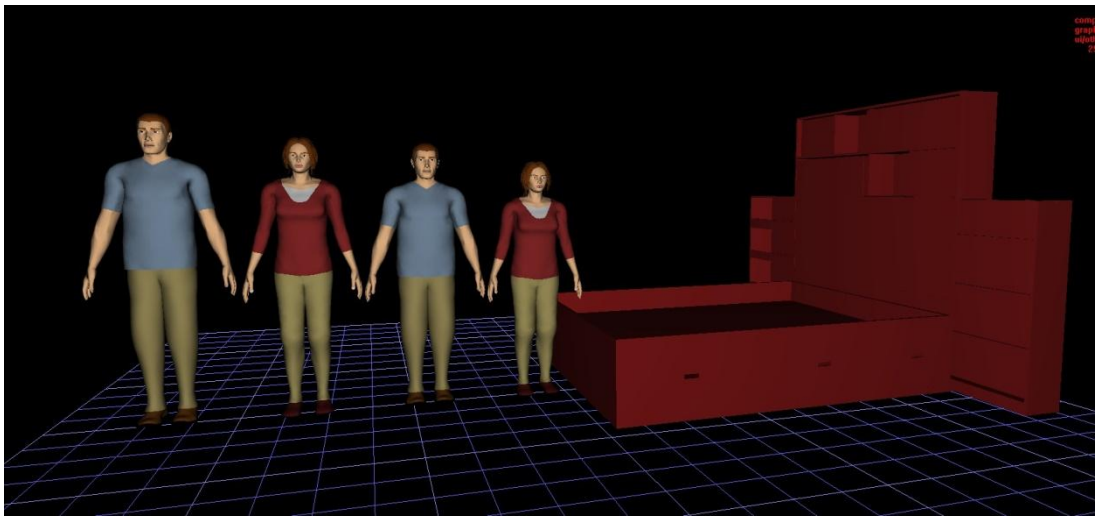


Figure 4.25 Mannequins of different measures

Therefore, if the study indicates that the product is proper for these models, the product will be proper for the whole existing population among them, which is very important to reach the aim of an inclusive design. Then, the Lower Back analysis was carried out for each model in each scene (Jack software).

Two different scenes were analysed (Figures 4.26 and 4.31):

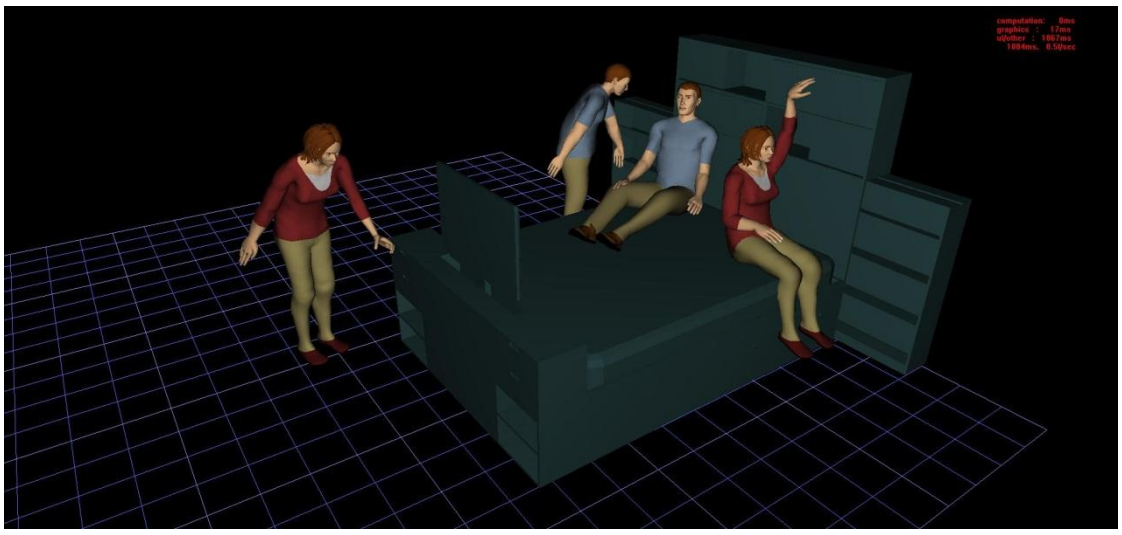


Figure 4.26 Mannequins in different positions (Scene 1)

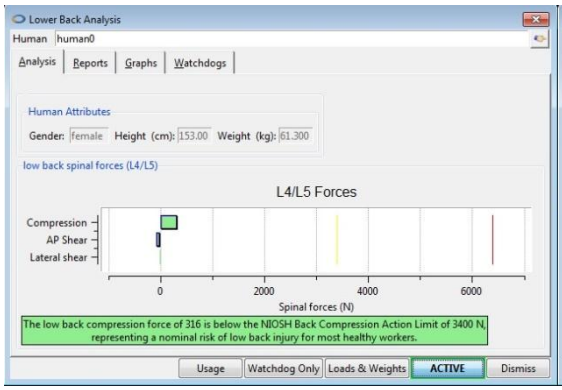


Figure 4.27 Asian female Lower Back Analysis (1)

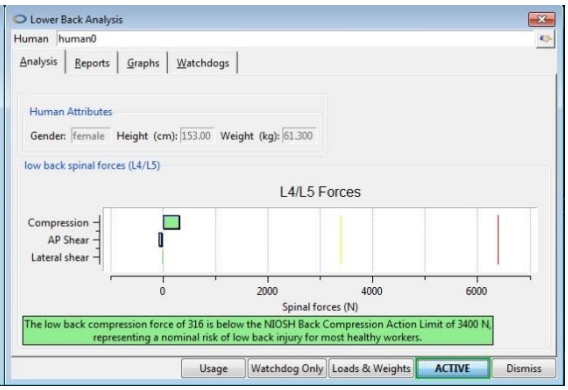


Figure 4.28 German female Lower Back Analysis (1)

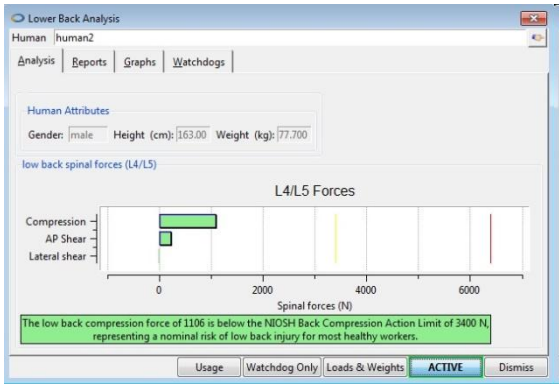


Figure 4.29 Asian Male Lower Back Analysis (1)

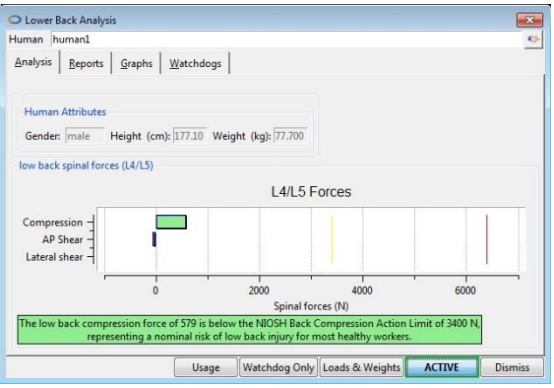


Figure 4.30 German Male Lower Back Analysis (1)

The lower back analysis is performed and all the results are favourable (Figures from 4.27 to 4.30). Therefore, it is continued with study of the next scene.

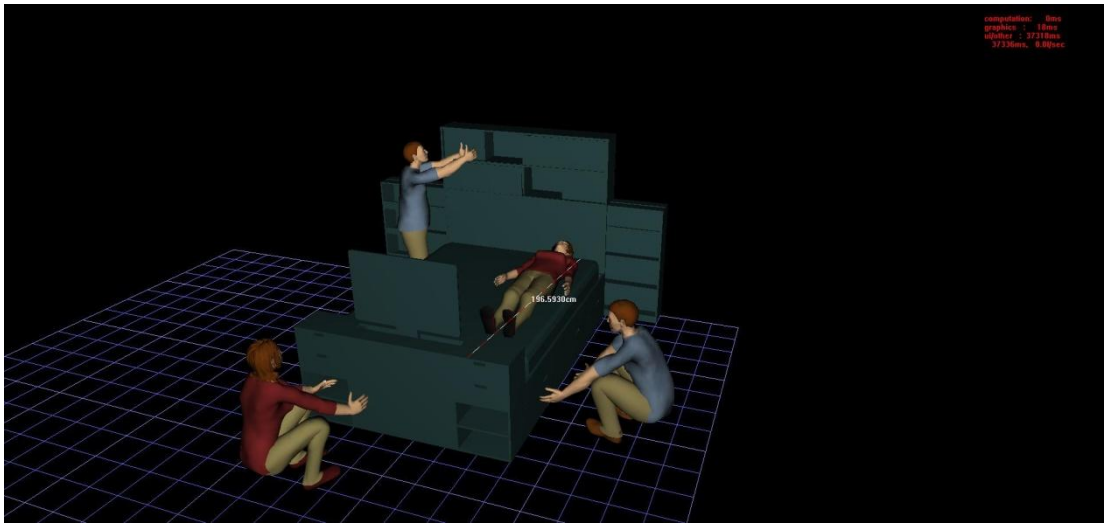


Figure 4.31 Mannequins in different positions (Scene 2)

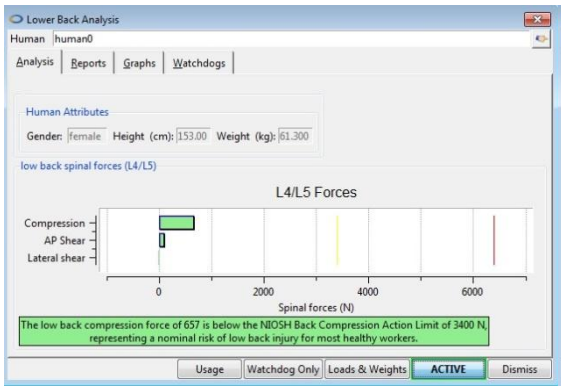


Figure 4.32 Asian female Lower Back Analysis (2)

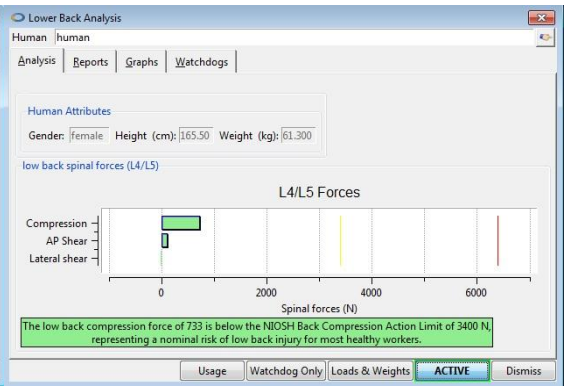


Figure 4.33 German female Lower Back Analysis (2)

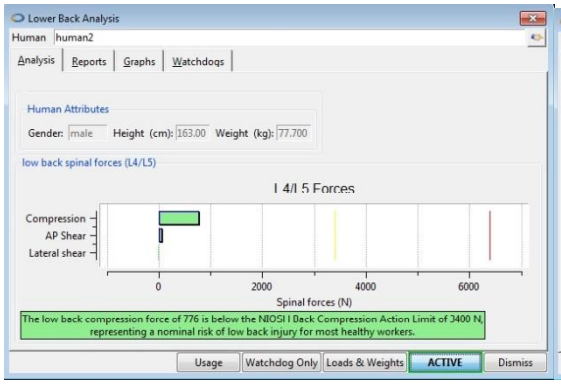


Figure 4.34 Asian Male Lower Back Analysis (2)

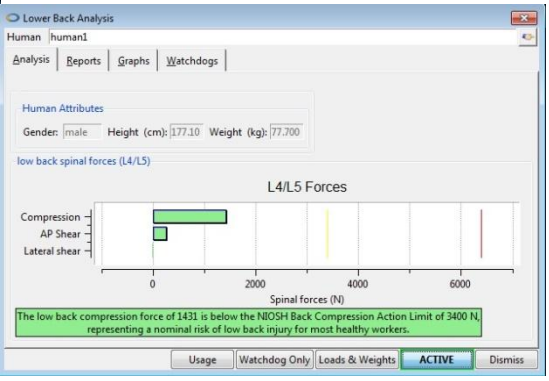


Figure 4.35 German Male Lower Back Analysis (2)

Once the main postures are analysed and the positive results are proven, so it can be concluded that according to this virtual study, this piece of furniture is not detrimental for the human body movements (Figures from 4.32 to 4.35).

TESTING OF HANDLES

This test was part of the ergonomic study. The test consisted to find the right size for handles in the closet placed in the headboard. First, several handles at various heights were placed in a wall (950 mm, 1000 mm, 1050 mm, 1100 mm). Then, the test was explained, which took about two minutes. Ten people of different stature evaluated the test (Table 4.6). Then, the heights of people were written down. It was asked what of the presented handles were better, and 100% of the people answered that the handle with the hole seemed more comfortable. Finally, the chosen handle height by the most votes was one meter (Figures from 4.36 to 4.38).

Table 4.6 Handles Test

	STATURE (mm)	HANDLE HEIGHT (mm)	HANDLE SHAPE (mm)
PERSON 1	1720	1050	Hole
PERSON 2	1660	1100	Hole
PERSON 3	1770	1000	Hole
PERSON 4	1640	1050	Hole
PERSON 5	1810	1000	Hole
PERSON 6	1630	1000	Hole
PERSON 7	1870	1100	Hole
PERSON 8	1830	1000	Hole
PERSON 9	1700	1000	Hole
PERSON 10	1890	1100	Hole

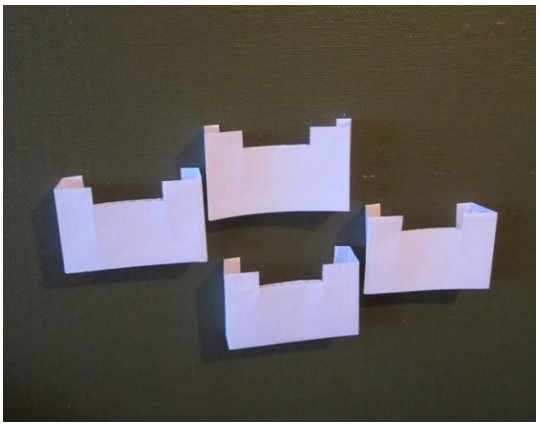


Figure 4.36 Handles in different heights

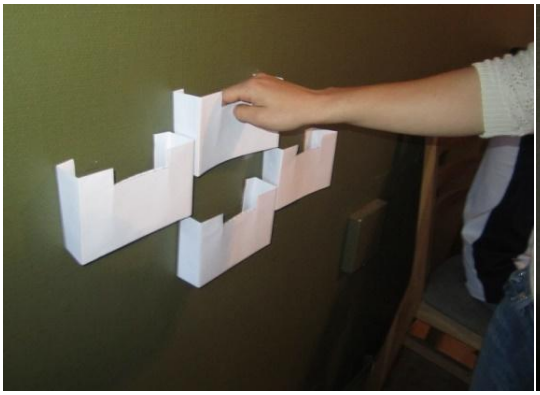


Figure 4.37 Testing handles (1)

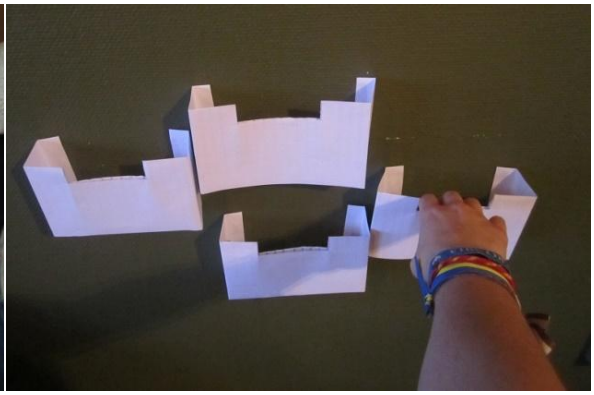


Figure 4.38 Testing handles (2)

4.5 DETAIL DESIGN

Since the furniture's shape and structure have been defined, other details were also established. Some of these details were materials, colours and textures that would be used; the prototype, which was manufactured; accessories, which were introduced; other components involved in this furniture set and its costs.

4.5.1 MATERIALS, COLOURS AND TEXTURES

The chosen material to manufacture these pieces of furniture is one of the materials that the company usually uses. It is called Elder Plywood (Figure 4.39) and described below.

In the sector of furniture and doors manufacturing this material is very commonly used. A lot of finishing touches are allowed to this product. Boards of fibres and particles form this Elder Plywood, its two sides are covered with natural or compound wood. The products that are derived of the wood contribute to keep and to improve forests, therefore it helps to the environment care.

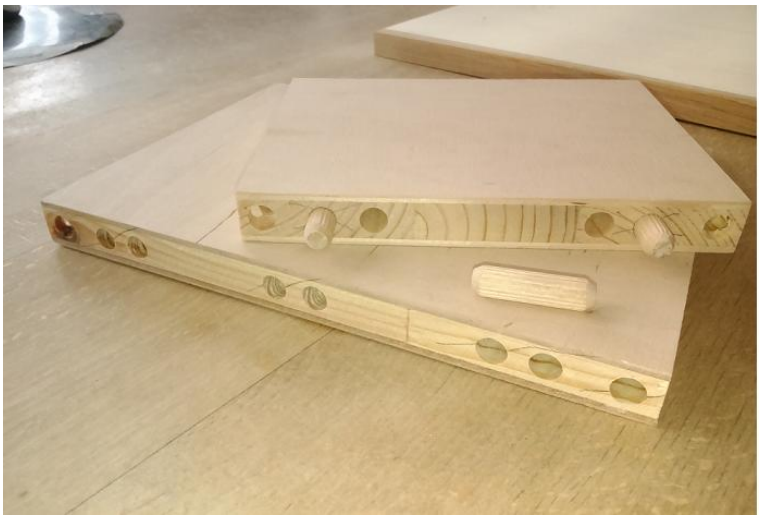


Figure 4.39 Elder Plywood

Another material used in this product is black wool (Figure 4.40). The wool, that the company uses, comes from Swedish suppliers and the sheep are organically reared (Olby Design, 2014).

Figure 4.40 Wool

4.5.2 ACCESSORIES

This kind of piece of furniture needs some accessories to complete the required functions.

Sometimes, due to the minimum space, the measures of the room can be small enough and perhaps the cabinet does not fit. In this case, there is another ending for the bed. It consists in a board of these measurements: 1060 x 460 x 20 mm (Figure 4.41).

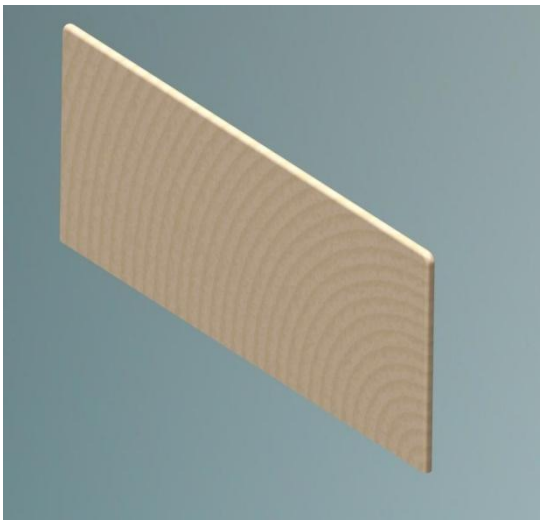


Figure 4.41 Board

4.5.3 COMPONENTS SELECTION

The support of the TV is a component that the piece of furniture has (Figures from 4.42 to 4.44). This support was found in Häfele Company (Häfele, 2013). Olby Design uses a lot of components from this company. The support can turn 210 degrees in case that the user would like to watch TV in another place.

Figure 4.42 Support in the cabinet (www.hafele.com)

Figure 4.43 Support (www.hafele.com)

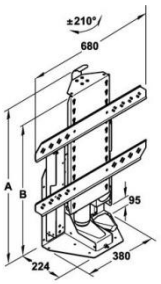
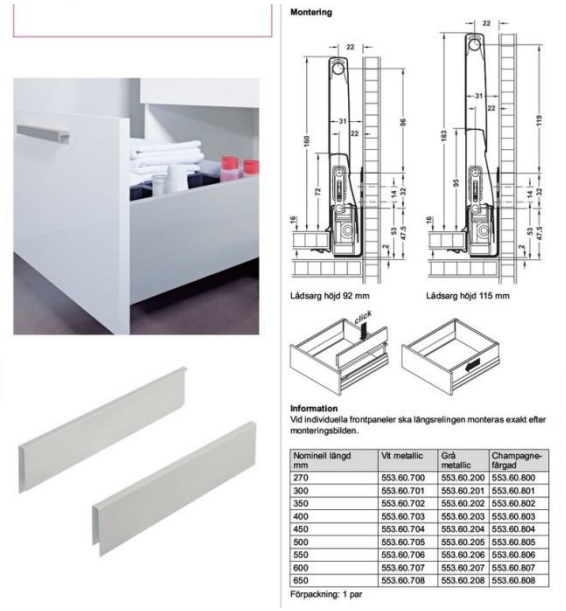


Figure 4.44 Support drawings (www.hafele.com)

The rails of the drawers are from Häfele as well. This kind of rails are designed with the aim of providing longevity to the drawers (Figure 4.45). This means that the rails have a system that when the drawer is closing itself, at the end there is a harder force for closing the drawer slower.



Nominell längd mm	Vit metallic	Grå metallic	Champagne-färgad
270	553.60.700	553.60.200	553.60.800
300	553.60.701	553.60.201	553.60.801
350	553.60.702	553.60.202	553.60.802
400	553.60.703	553.60.203	553.60.803
450	553.60.704	553.60.204	553.60.804
500	553.60.705	553.60.205	553.60.805
550	553.60.706	553.60.206	553.60.806
600	553.60.707	553.60.207	553.60.807
650	553.60.708	553.60.208	553.60.808

Figure 4.45 Rails of the drawers (www.hafele.com)

There are some other kinds of rails, like the rails of the closet in the headboard (Figures from 4.46 to 4.48). Häfele has these rails.

Figure 4.46 Rails (www.hafele.com)

Figure 4.47 Pull out closet runners (www.hafele.com)

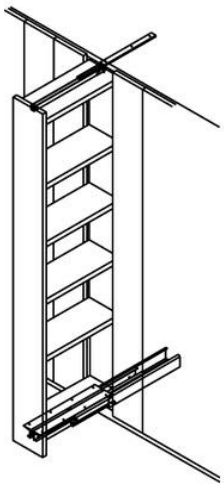


Figure 4.48 Drawings of rails (www.hafele.com)

In the headboard, the doors need a system to support them. Häfele has hinges that are able to support the doors.

The same mechanism is used at the top of the cabinet, where the TV is hidden (Figure 4.49).

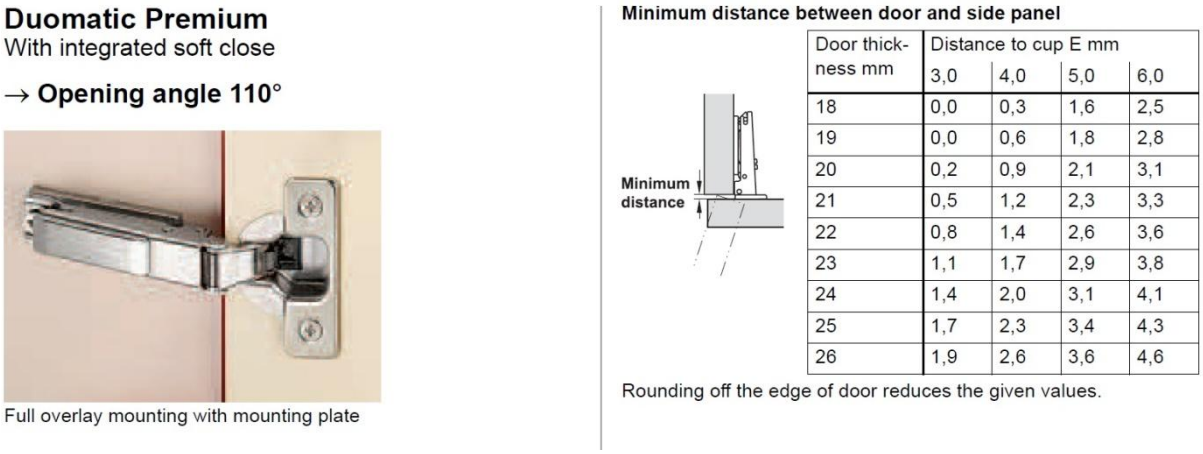


Figure 4.49 Hinges (www.hafele.com)

The sliding doors in the headboard need a mechanism to slide. There is one simple mechanism that Häfele has, that is very easy to understand and very easy to assemble (Figure 4.50 and 4.51).

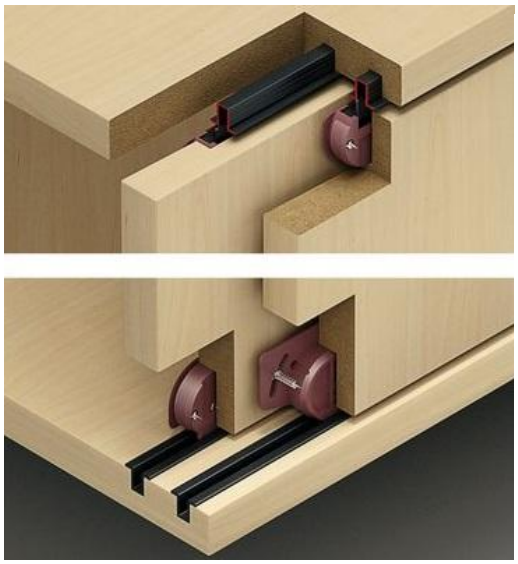


Figure 4.50 Mechanisms of sliding doors (www.hafele.com)

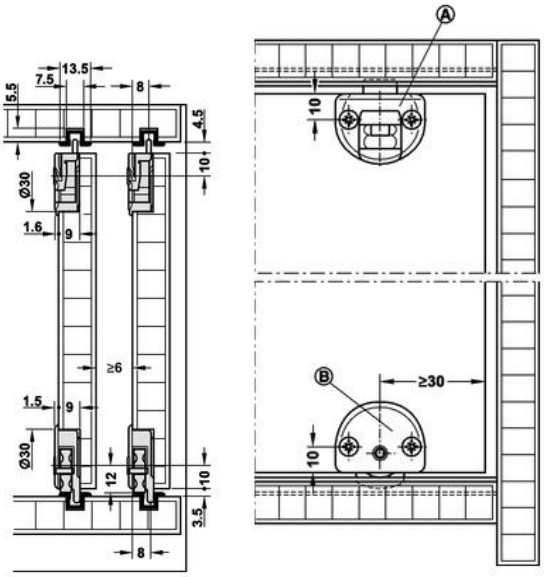


Figure 4.51 Drawings of the mechanism (www.hafele.com)

4.5.4 COSTS

According to the company, the costs of the product are high. Wood used in the piece of furniture is expensive, and the treatment is hard. Wood has to go through several steps to obtain it, and this makes the product more expensive. After a meeting with the company, the fixed costs were valued around 15000 SEK, and the variable costs with a 105% of profit, were around 30000 SEK.

5.RESULTS

5.1 MODELLING IN PTC CREO

PTC Creo Parametric was used to make the 3D model. Different pieces of the furniture were made and later these were assembled. When materials and textures were applied on it, Renders were carried out (Figure 5.1 to 5.4). What took longer was the achievement of more realistic renders. Materials and textures were used, and this was difficult to achieve.

During the whole process many ideas had been developed and analysed. Nevertheless, in this chapter only the final chosen concept is going to be exposed.

This piece of furniture consist of three parts; headboard, double bed and cabinet. The headboard measures a height of 1680 millimetres from the floor, and a width of 250 millimetres. The underside of the headboard is compound of two closet with four shelves each one, which can slide out through the rail. The top of the headboard is made up of two shelves. Each shelf has one sliding door and one door of hinge. The sliding door can slide all over the front even covering the hinge doors. This implies that the headboard can offer several appearances. These doors could also be painted with different colours. The outside part of the headboard, which is in contact with the bed, is lined with wool, for more comfort.

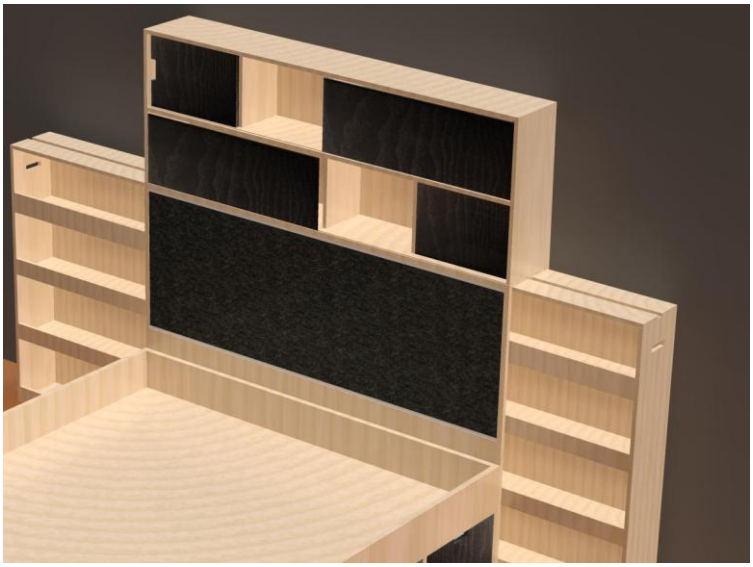


Figure 5.1Headboard A

Figure 5.2 Closet in the headboard

Figure 5.3 Headboard with closets

Figure 5.4 Headboard perspective

The bed part has a gap to put the mattress in, however half of the mattress sticks out. Three drawers are under the mattress, the smallest one is located in the side close to the headboard. In addition, this drawer offers the night table function. The night table consists in a sliding board that is hold by rails. This board covers the middle of the drawer, to allow the drawer opening. The drawers are dark painted to reduce the robust appearance (Figure 5.5 to 5.9).

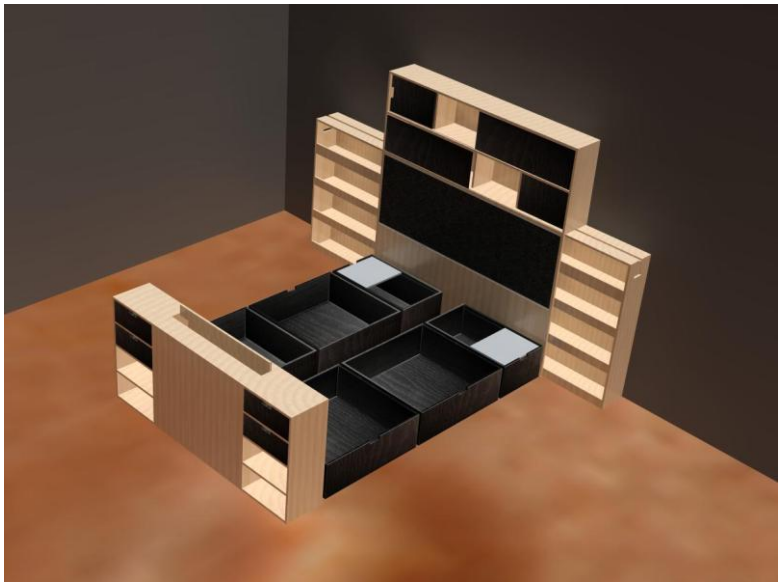


Figure 5.5 Internal view

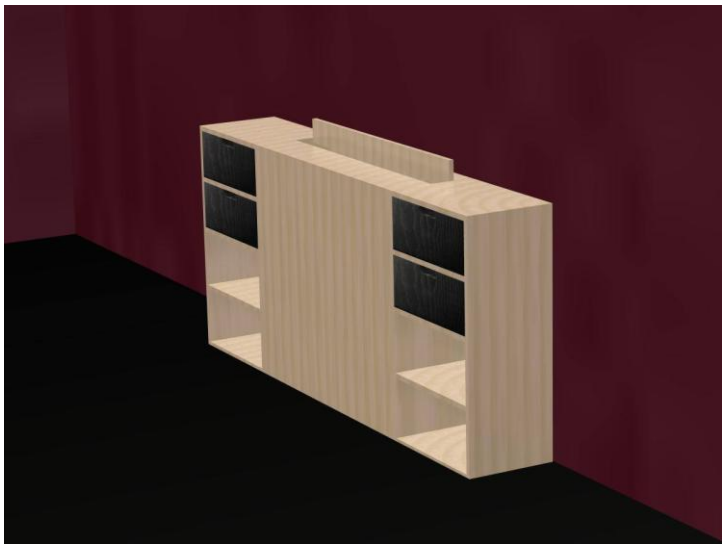


Figure 5.6 Side cabinet view

Figure 5.7 Perspective view

Figure 5.8 Stand table-drawer

The cabinet measures a height of 730 millimetres and a depth of 270 millimetres. In the middle of the top, there is a gap whereby the television is moved. Four drawers and four shelves form the cabinet.

Figure 5.9 Piece of furniture with TV

6. DISCUSSION

From the beginning of the design process, the aim of developing several pieces of furniture was very explicit, although during the whole prolongation of the process, the first idea of furniture had undergone many changes, which were consecutively updated.

Several studies were accomplished; first of all observation of people occurred and a survey was very effective to clarify ideas and conclusions. However, the survey was conducted to a population under sixty years old, this exclusion was not wished, but unfortunately this task resulted too complicated. Besides, an anthopometry study was executed, which demonstrated that this piece of furniture would not cause any damages to the user.

The drawers under the bed used to be deeper in the first sketches; nevertheless the rails put on fit for shorter ones. There was the possibility of ordering special rails, but it would have raised the price. Then, the decision was to make the drawers shorter.

The piece of furniture was made into five modules; shelves, closet, two modules bed and cabinet. These five modules would be easier to transport and introduce in a house. In addition, the sale of this product includes all the elements so that the user could join the modules together. Another facet to stand out is the possibility of the cabinet of being located attached to the bed or close to the wall. The reason of making the bed in two parts was because this way, the bed would be easier to transport and also more stable, considering that there would be two boards in the middle of the bed, which would act as a solid structure.

Olby Design showed us the operation of machinery and all the care they put into each piece. The visits were useful to know about the working world, and so many things were seen closer.

In the last visits the prototype and the material samples were collected, as well as other theoretical information needed. The prototype was done by a girl called Anni who was doing her internship in Olby Design. This was in a scale of 1/5, what has some advantages and disadvantages. On the one hand, a smaller prototype was very useful to transport, it means that the prototype was showed to different people and their opinions were listened. The prototype could also be exposed on the presentation day for a better audience understanding and for showing how the furniture really works. Moreover the process of manufacturing obliges to think about several details that were not thought before. A real scale prototype would be much more expensive as well. On the other hand, if the prototype is smaller than the real one, people cannot interact so well. The tests would be better with a real scale prototype.

Besides, several theoretical and practical methods were applied during the whole process. These methods helped to accomplish each stage of the project and to obtain the final product.

As a conclusion, if the process would not have followed the principles of inclusive design, this product might not be suitable for the most target population. However, since inclusive design has been applied, we can confirm that it is serviceable and appropriate for the most population.

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APPENDIX

APPENDIX 1: Review progress & Plan next steps

Who performed the review and plan?	The design group
What materials were used?	Survey, questions, observation
When did the review and plan take place?	It is one of the first steps, together with the search literature.

		Review progress	
Overall activity	**Design output**	**What have we got?**	**Is it good enough?** (if yes, give evidence)
Manage	Product goals	Furniture set for small spaces	Yes, because some pieces of furniture could cover all users' needs
	Project plan	Search data, required needs, concepts development, concepts analysis, results	Yes, because it is a linear process that should be continuously updated
	Business case	The company needs to expand its products range	Yes, because the company profits will be extended
	Shared understanding across stakeholders	Stakeholders meetings in order to have a good understanding each week	Yes, because problems will be solved easier

		Review progress	
Overall activity	**Design output**	**What have we got?**	**Is it good enough?** (if yes, give evidence)
Explore	**Understanding who all the stakeholders are**	Stakeholders are clearly identified	
	Understanding user types, needs, aspirations and goals	Important stage to perform	
	Summary descriptions of users e.g. personas	Different needs of different ages and capabilities	Yes, because these target groups include all types of people
	Breakdown of the tasks users perform to achieve goals	The checklist, that has been followed during the process	Yes, because it is a useful and theoretical method
	Documented list of user and stakeholders needs	Requirement needs of users and stakeholders	Yes, because all of them are going to interact with the product
Create	**Documented ideas**	A profound search was performed	
	Concept sheets	Some methods were performed to obtain concept sheets	Yes, because a lot of new concepts were developed
	Physical/virtual models of concepts	PTC Creo 2.0 models and a physical prototype	Yes, because these models will be enough to test the final product and make some changes if it is necessary before the product is manufactured
Evaluate	**Assessment criteria**	Evaluation methods were needed to choose concepts	Yes, because it was useful
	Results from testing concepts against criteria	Concepts and criteria, both are necessary	Yes, because it is a complete way to evaluate

APPENDIX 2: Refine product goals

Who refined the product goals?	The company, the design group, the users
What materials were used?	Interviews, meetings, observing users, generate personas
When did the refinement of product goals take place?	It was the first step of the whole process

State the problem
Nowadays, the small places are the most common place to live, due to the economy, or the fast style of life. The company does not manufacture this kind of furniture.

Outline the big issues
No space to keep the clothes, books and household stuff.

Summarise the solution
A furniture set that includes all the functions that are needed for people who live there

APPENDIX 3: Build business case

Who built the business case?	Olby Design
What materials were used?	By Olby Design webpage, its catalogue and in the store
When did building the business case take place?	Since its origins, because this company always uses the same business case

Which factors will impact the business case for the stakeholders?	**Will the factor result in increased or decreased costs or revenue?**
Quality	Increase costs
Price	
Aesthetics	
Exclusivity	Increase costs
Confidence	
Durability	Increase costs
Handmade furniture	
Cheap accessories	

APPENDIX 4: Observe users

Why were these observations performed? – What did you want to learn? – How was the study planned to help you learn this?	To observe users is really important to see what problems they have with the product and what would they need. Some visits to some apartments were needed and it helped to see different ways to organize a bedroom and what the users wanted to have.

APPENDIX 5: Generate personas

Who generated the personas?	The design group
What information was used?	Data taken of the interviews, final requirements of the company, data taken of the ergonomic study
When did generating the personas take place?	Personas was generated during the stage of observing users

Stakeholder - Talia Serrano (24 years old), Lucía Aspizua (23 years old)

Organisation	Talia Serrano and Lucía Aspizua
Job title	student
Job description	Design of bedroom furniture set for small places
Motivation	To make finally a good concept
Impact	To expand the range of products of the company

Persona - Juana (83 years old)/ Pedro (51 years old)/ Laura (52 years old)/ Laura (19 years old)/ Rafa (1 year old)

Work	Pensioner / Civil servant/ Nurse/ Student/ No work
Family & support network	
Medical	Arthrosis, Parkinson's disease/ Cholesterol/ healthy/ healthy/ healthy
Technology experience	Non-existent/ Good/ Good/ Very good/ Non-existent
Hobbies & leisure	To take care of her grandchild and to watch TV/ To play football and to read/ To play tennis and to travel/ To write and to practice sports/ To play and to sleep

	Ability description	**Assistive aids**
Vision	Bad/ Bad/ Bad/ Good/ Good	Glasses/ Glasses/ Glasses
Hearing	Bad/ Good/ Good/ Good/ Good	Hearing aid
Thinking	Good/ Good/ Good/ Good/ Good	
Reach & dexterity	Medium/ Good/ Good/ Good/ Medium	
Mobility	Bad/ Good/ Good/ Good/ Medium	Walking stick

APPENDIX 6: Develop concepts

How were concepts developed?	Theoretical and practical methods
Who was involved?	Company, Supervisors, Design group, Users, Manufacturers
When did the development of concepts take place?	When requirements and needs were clarified

APPENDIX 7: Make prototypes

Who made the prototypes?	Olby Design company
Why were the prototypes made?	For perceiving the product with higher realism and realising which parts work and which ones do not.
What materials were used?	MDF, Wool, Glue, Staples, Velcro
When did making prototypes take place?	When the concept selection was finishing.

APPENDIX 8: Interviews

Questions:

Age
Male or Female
Living in a small flat?
Alone or with somebody?
Will you live in a small flat?
Alone or with somebody?
Do you have more than one dwelling?
Is it a flat or a study?
Do you have folding furniture?
In which part of the house?
Are order and space important to you?
Do you think folding furniture is useful for the order?
Dark colors or light colors?
Would you like the idea of hiding the night table under the bed?
Interested about having space in spite of the room?
Would you like to have some space under the bed?
Shelf or drawer?
Big and few drawers or small and many drawers?
Measure that you need for a closet?
Three furniture that you think are necessary in a bedroom
What is the age range of people living in your residential area?

Answers from 18 to 30 years old:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
23	25	27	25	24	27	23	23	20	28	27	23	29	26	22	22
M	F	F	M	F	M	F	F	F	M	M	M	M	F	F	M
YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
SB	SB	SB	SB	SB	ALONE	SB	SB	ALONE	SB	SB	SB	ALONE	SB	SB	SB
YES	NO	YES	YES	YES	NO	YES	YES	NO	NO	YES	YES	YES	YES	NO	YES
SB	SB	SB	SB	SB		SB	ALONE	SB	SB	SB	ALONE	SB	SB	SB	SB
NO	NO	NO	NO	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES	NO	NO
								NO					APARTMENT		
NO	NO	NO	YES	YES	YES	NO	YES	YES	YES	YES	NO	NO	NO	NO	YES
			BEDROOM	KITCHEN/BED	LIVING		BEDROOM	LIVING/BEDR	KITCHEN/LIV	BEDROOM LIVING					KITCHEN/BED
YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES
LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT
YES	NO	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	NO	NO	NO	YES
						YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
					YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES
					BOTH	BOTH	DRAWERS	DRAWERS	BOTH	DRAWERS	SHELF	DRAWERS	DRAWERS	DRAWERS	DRAWERS
SMALL UP BI	SMALL	BIG	SMALL	BIG	BOTH	BOTH	BIG	BIG	BOTH	SMALL	SMALL	BIG	SMALL	BOTH	SMALL
					2 X 1m	2 X1m	2 X 2m	2,5 X 1,4 m	DEPENDS OF	ASLONGASPO	1X1 m	ASBIGASPOS	2BODIES	2x2m	1,5x1,5 m
BED NIGHT T	BED CLOSET T	BED CLOSET	BED TABLE AF	BED CLOSET	BED CLOSET T	BED TABLE CL	CLOSET BED	BED NIGHT T	CLOSET NIGH	BED CABINET	BED CLOSET	BED CLOSET T	CLOSET BED	BED NIGHT T	BED NIGHT TA
		20/30			24/50		30/60	18/50	80/10	25/80	20/40	AROUND 60	0/80	18/30	18/30

Answers from 31 to 45 years old:

17	18	19	20	21	22	23
32	32	33	44	34	42	35
F	F	F	M	F	F	M
YES	YES	YES	YES	YES	YES	YES
ALONE	SB	SB	SB	ALONE	SB	SB
NO	NO	NO	YES	YES	YES	YES
SB	SB	SB	SB	SB	SB	SB
NO	NO	NO	NO	NO	YES	NO
					STUDY	
YES	YES	YES	NO	YES	NO	YES
BEDROOM	LIVING	LIVING BEDROOM		LIVING ROOM		KITCHEN
YES	YES	YES	YES	YES	YES	YES
YES	YES	YES	NO	YES	YES	YES
LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT	LIGHT
YES	YES	YES	NO	YES	YES	YES
YES	YES	YES	NO	YES	YES	YES
YES		YES	NO	YES	YES	NO
BOTH		BOTH	DRAWERS	DRAWERS	BOTH	BOTH
BIG/MIDDLE	SMALL	BIG	BIG	BIG	BOTH	BIG
2 X 1.5m		ALL WALL	DON'T KNOV	2 x 1 m	2 x 1,5m	2 x 2m
	CLOSET BED	CABINET NIG	CABINET BE	BED NIGHT T	BED NIGHT T	BED CLOSET S
30/35	30/50	70/10	40/60	40/80	30/50	30 /60

Answers from people above 46 years old:

24	25	26	27	28	29	30
51	53	55	70	56	61	52
F	M	F	F	M	F	M
YES	YES	YES	YES	YES	YES	YES
SB	SB	SB	SB	SB	SB	SB
YES	YES	YES	YES	YES	YES	YES
SB	SB	SB	SB	SB	SB	SB
NO	NO	YES	NO	NO	NO	NO
		FLAT				
YES	YES	YES	NO	YES	YES	YES
BEDROOM	BEDROOM	KITCHEN		BEDROOM	BATHROOM	BEDROOM
YES	YES	YES	YES	YES	YES	YES
YES	YES	YES	YES	YES	YES	YES
LIGHT	LIGHT	LIGHT	DARK	LIGHT	LIGHT	LIGHT
YES	YES	YES	YES	YES	YES	YES
YES	NO	NO	YES	YES	NO	YES
YES	YES	YES	YES	YES	YES	YES
BOTH	DRAWERS	DRAWERS	SHELVES	BOTH	DRAWERS	BOTH
BIG	BIG	BOTH	BOTH	BOTH	SMALL	BOTH
2 x 2 m	2 x 2 m	2 x 1,5m	2 x 1m	2 x 1 m	2 x 2 m	2 x 2m
BED NIGHT T	BED NIGHT T	BED CABINET	BED CLOSET	BED CLOSET	BED CABINET	BED CLOSET
40/70	40/70	40/80	30/70	20/60	40/70	20/60