

LINKÖPING UNIVERSITY
FACULTY OF SCIENCE AND ENGINEERING

“DESIGN OF A MODULAR AND TRANSPORTABLE PRODUCT”

Bachelor Thesis – Erasmus Exchange

Industrial Design Engineering and Product Development

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Abstract

The objective of the following thesis is to design a piece of furniture for a habitat environment, in particular, a stool that can simultaneously serve as an auxiliary table and facilitate transport and storage, created under the influence of Nordic design.

On the one hand, an analysis of the trends and products already existing in the market will be made. The objective user will be analyzed and later we will make a technical investigation on the ergonomics and the anthropometry to be able to determine the final dimensions of the product.

On the other hand, after analyzing the information, we will propose several alternative solutions, which after different methodologies of selection criteria, will allow us to arrive at a single solution. With this solution, a detailed description of both the product as a whole and its individual components, as well as a production budget will be made.

Keywords: nomad, habitat, side table, stool, small spaces, transportable.

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1 PURPOSE OF THE PROJECT

This project will aim at the design of a collapsible structural module for the living room or the bedroom, which allows performing various functions of auxiliary furniture and can be transportable. As well, the study of its technical development and the analysis of the life cycle of its environmental impacts.

In this way, this proposal aims to offer a product that covers various needs such as seat, support or even space saving. As an auxiliary table, the module should allow tasks such as enjoying an aperitif, serving drinks, board games, using electronic devices or reading magazines. As a stool, you should be able to support a standard adult at a practical and ergonomic height. Above all, the design should allow the module to be collapsible and easily stored in order to free up space to allow it to cover other needs.

2 BACKGROUND

Multifunctional furniture means any product that performs more than one function. Nowadays, these pieces have gained some relevance thanks to that they allow unifying several uses while reducing the required space.

On the one hand, the table is a piece of furniture generally composed of a horizontal board placed at the appropriate height. Among its most common uses is eating, writing, supporting the computer or simply supporting objects. There are different types of tables in the market, those of our interest are known as night tables or tables. There are many examples in Europe, but also in Japan and the area of Arabia by the culture transmitted by the route of the silk. In all these environments we can find the frequent use of supports in the form of a standard table but with a much lower height than were located in the rest areas.

On the other hand, a stool is one of the earliest forms of seat furniture. It will be many similarities to a chair. It consists of a single seat, for one person, on the basis of either three or four legs. The stool is distinguished from chairs by their lack of arms and back. With a simple and basic nature that allows us to find examples of the use of Stools spread all over the world in early times of our history. To this day, Stools are used within the domestic sphere generally as an auxiliary seat and relieved to other functions of secondary character also due to the greater comfort that they are able to offer the chairs.

3 MARKET RESEARCH

3.1 INFLUENCES

One of the main influences for this project has been the idea of designing modular products for small spaces. This tendency to make spaces smaller and smaller has allowed designers to create modular products with more than one function.

Another important influence is the Scandinavian design. The elegance and simplicity of the products that are designed there, the good use of wood and the thought of creating industrial products without forgetting the crafts, are some of the characteristics to emphasize in this movement.

On the other hand, the ecological part has also been an influential factor. In Sweden, they are very aware of the environment, which has led to the creation of a recycling system that converts waste into energy. For this reason, environmentally friendly, and mostly recycled, materials are used in this product.

3.1.1 Dieter Rams "Less but better"

Great inspiration from the products of the German designer Dieter Rams and specifically its 10 basic principles of good design. Its principles have had a lot of influence on the designs of the Apple Company. Simplicity and elegance are the most important features in their designs. His designs constituted the identity of Braun. Its main principle and motto is the famous "Weniger, aber besser" which means "Less but better".

These are the 10 basic principles for a good design:

1. Good design is innovative.
2. Good design makes a product useful.
3. Good design is aesthetic.
4. Good design makes a product understandable.
5. Good design is honest.
6. Good design is discreet.
7. Good design has a long life.
8. Good design is consistent in its details.
9. Good design respects the environment.
10. Good design is design in its minimal expression.

The ideal result is a product of greater purity and simplicity.

3.2 TREND ANALYSIS

3.2.1 Design-Led, Space Saving Products

More than half of the world's population lives in cities, and this figure continues to grow (60% of the world's population by 2030), never before in history had so many people living in urban areas. This has led to the creation of increasingly smaller spaces, and according to the Royal Institute of British Architects (RIBA), we now live in smaller houses with only half the space of houses built in 1920.

Many students or young workers, seek to live in the center of the city in the big cities. This means giving up the living space and paying a slightly higher rent, but being in a good area to live. Despite the reduction of space, the design has not been neglected. Small houses are still equipped with design and new ideas such as multifunctional products. In addition, it is given much importance to the storage since rational thinking would be little space little storage. But this is not so because storage spaces are designed that are hidden and do not take up space to live.

There are some benefits that the Space-Saving Products can give to the users, like:

- Stretch your housing budget further: Too often, city dwellers have to trade location for size, or vice versa. In many ways, smart furniture is an investment in extra real estate — one that lets you live where you love without feeling cramped.
- Reduce clutter: Our products are designed for anyone who appreciates minimalism in the home. Enjoy true, open concept living with furniture that folds up when not in use.
- Enjoy greater flexibility: Imagine if your spare room could be a home office one day and a yoga studio the next! Multifunctional furniture makes it easy to change around a room for various purposes, so you can enjoy the freedom and flexibility to always have the space you want when you need it.
- Minimize your impact: Smaller spaces are better for the environment, not to mention cheaper to heat and cool. Too often, people think they need a larger home to live the way they want to. Space-saving furniture proves this isn't true. Our products let you do more with less, minimizing your impact on the environment in the process.

Living in a small space shouldn't have to mean feeling cramped. Multifunctional transforming furniture is a smarter way to live more comfortably in a condo, apartment, townhome, or single family home, or when you frequently have guests. These are designed for sophistication but built for functionality, the transforming furniture is an ideal choice for anyone that needs more space.



The floor plan for one of the micro-apartments at Carmel Place project in Manhattan.

3.2.2 DIY (Do-It-Yourself)

The DIY movement consists basically in the manufacture of products by the user himself or the assembly of products already manufactured (as in the case of IKEA). The low purchasing power of the majority of the population has led to this tendency to reuse materials and recycle products that have been damaged. In addition, companies have started to create products that the user has to assemble on their own, thus reducing the price of products. The reduction of the purchasing power of the majority of the population and the increasing inclination towards the reuse and recycling of the products has stimulated the development of this tendency that is sold off the accessible and affordable materials for the development of its products.

DIY consumers are not just crafty house wives with a Pinterest board. And, DIY consumers don't just do-it-themselves. DIY consumers are savvy, modern shoppers who want a tailored shopping experience. They cover a large demographic and care more about buying unique and quality products than pinching pennies. DIYers are a unique consumer set because they don't neatly fit into one demographic or another. They come from all different age ranges, income levels and geographic locations.

People are being driven to do DIY projects not only for saving money, also because they feel like they can handle the task and just because they enjoy the work. People want to have a positive home improvement experience which means they are willing to pay more for products that will help make this happen. They want their home to feel unique and special. Offering custom options is a great way to get the DIY consumer interested in your product.

The bottom line is that educating and inspiring the DIY Consumer are some of the biggest things you can do to help position your product in the buying process. The desire to personalise your home, and help the environment and help your wallet will continue to drive the growth of the DIY Consumer. The DIY Consumer is here and growing. How could your product convince them to purchase it?

Within this trend, there is a movement that estimates the modification or customization of products or existing components, by the user to adapt them to their own needs. This move is known as Hacking.

Some examples of DIY furniture projects:



Table made with wooden boxes



Tables made with tires

3.2.3 Nordic Design

Architecture and Nordic design are two areas in which the spirit of the north has conquered the entire world. North America and Central Europe are the areas that have been most influenced by minimalism, simplicity, simple but elegant geometry of the Scandinavian design. The Scandinavian motto could be "less is more".

The Nordic design offers slightly autumnal tones like blue, green, brown or grayscale. Neither can the simplicity and brightness of the target be lacking. In addition to the accents colour candy, mustard, ash and softly red, and some cold cakes. As for materials, you will not miss the pure materials rich in natural textures: stone, marble, copper and wood. For furniture, cushions, and carpets: a lot of velvet.

The rustic complement is perfect to accompany this style full of clean and sober lines.

3.2.4 Sustainable design

Absolutely installed between current and future trends, this line makes us aware of the use of recycled or recyclable materials and simple and clean production processes. This trend is currently expressed in the development of new bio-degradable materials and the optimization of production processes to reduce as much as possible from emissions to material debris.

Ecodesign, which in turn is closely linked to sustainable design, is the design that considers actions oriented to the environmental improvement of the product or service in all stages of its lifecycle, from its creation in the conceptual stage, to its Treatment as waste.

There are numerous and diverse motivations and reasons that can promote the use of ecodesign tool: competitive advantage, environmental marketing, differentiation, added value, cost reduction, among others; But above all the reduction of environmental impact in all stages of the product or service life cycle.

3.2.5 Nomadism

The movement called "nomadism", which nowadays occurs in the new generations arises thanks to the technological advances and the facilities of geographic mobility, multilingualism and labor and educational opportunities abroad. After the economic crisis of 2008, the purchasing power of the population began to be very low. Statistical data shows that in America a move is made with an average of 2 or 3 years.

Similarly, a large number of people have begun to live in smaller spaces, because they look for furniture products that are versatile, easy to store or stackable, as well as inexpensive. Because of this, there are movements that are a trend like DIY (Do-It-Yourself).

3.2.6 *Natural materials*

The trends of interior design are again oriented toward the use of natural materials such as wood. The new organic and fresh styles are mainly focused on designs for the home.

The rustic wood in furniture and accessories is being used more and more to get a homely and more intimate space. The industrial, cold and clinical styles are starting, giving way to more comfortable and relaxing spaces. Wood brings an atmosphere and a natural environment, compensating for any excessive use of whites and greys.

Based on current trends, the wood design seeks to create a rugged appearance, evoking feelings of calm and open air. Designers are looking to Nature for inspiration.

3.3 MARKET PRODUCT ANALYSIS

Product: Edie Stool	Designed by: David Steiner & Joni Steiner
	
Dimensions: 150 x 285 mm (Radius x H)	Price: 454 SEK (47,5796€)
Characteristics: <ul style="list-style-type: none"> - This child's stool doubles up as a bed-side table. - It has prototyped the use of Lego-style friction fastenings - It's made from quality, FSC-certified Baltic plywood. - The Edie Stool is designed to be manufactured by a network of independent makers all around the world. - Light and transportable. 	

Product: Stool 60	Designed by: Alvar Aalto
	
Dimensions: 440 x 380 x 380 mm (HxWxL)	Price: 1.868,47 SEK (196€)
<p>Characteristics:</p> <ul style="list-style-type: none"> - It represents the quintessential functionalist furniture design - It's made of Birchwood. - It's also manufactured in a four-leg version, E60. - The simplicity of the design of this stool, now considered a classic, is based on three curved legs and a round seat. - Light, transportable and stackable. - The IKEA design of this stool (FROSTA STOOL) costs only 99 SEK (10€) 	

Product: Stool Y6	Designed by: Alvar Aalto
<div style="display: flex; justify-content: space-around;">   </div>	
Dimensions: 440 x 410 x 410 mm (HxWxL)	Price: 7200,75 SEK (755€)
<p>Characteristics:</p> <ul style="list-style-type: none"> - By splitting the L-Leg in a longitudinal direction and then re-joining the leg, he created a completely new Y-Leg shape. - It's made of Birch wood for the legs and Linen webbing for the seat. - Natural fabric mixed with wood make this stool a collector product. - Light, transportable and stackable. 	

Product: Rotational Stools	Designed by: Anne Filson & Gary Rohrbacher
	
Dimensions: 381 x 241 x 241 mm (HxWxL)	Price: 758 SEK (79,5€)
Characteristics: <ul style="list-style-type: none">- They function equally well as low stools or as side tables - individually, in pairs, or in aggregate.- It's made of Plywood- Handy when you need a step up or a quick seat.- Light and transportable.	

Product: Wedge Table	Designed by: Andreas Kowalewski
	
Dimensions: 450 x 410 x 410 mm (HxWxL)	Price: 2.857,88 SEK (299€)
Characteristics: <ul style="list-style-type: none">- The three interlocking legs generate a solid structure and define the table's characteristic aesthetics.- It's made of Beech Plywood- It does not occupy storage space.- You can use and save it.- Light, removable and transportable.	

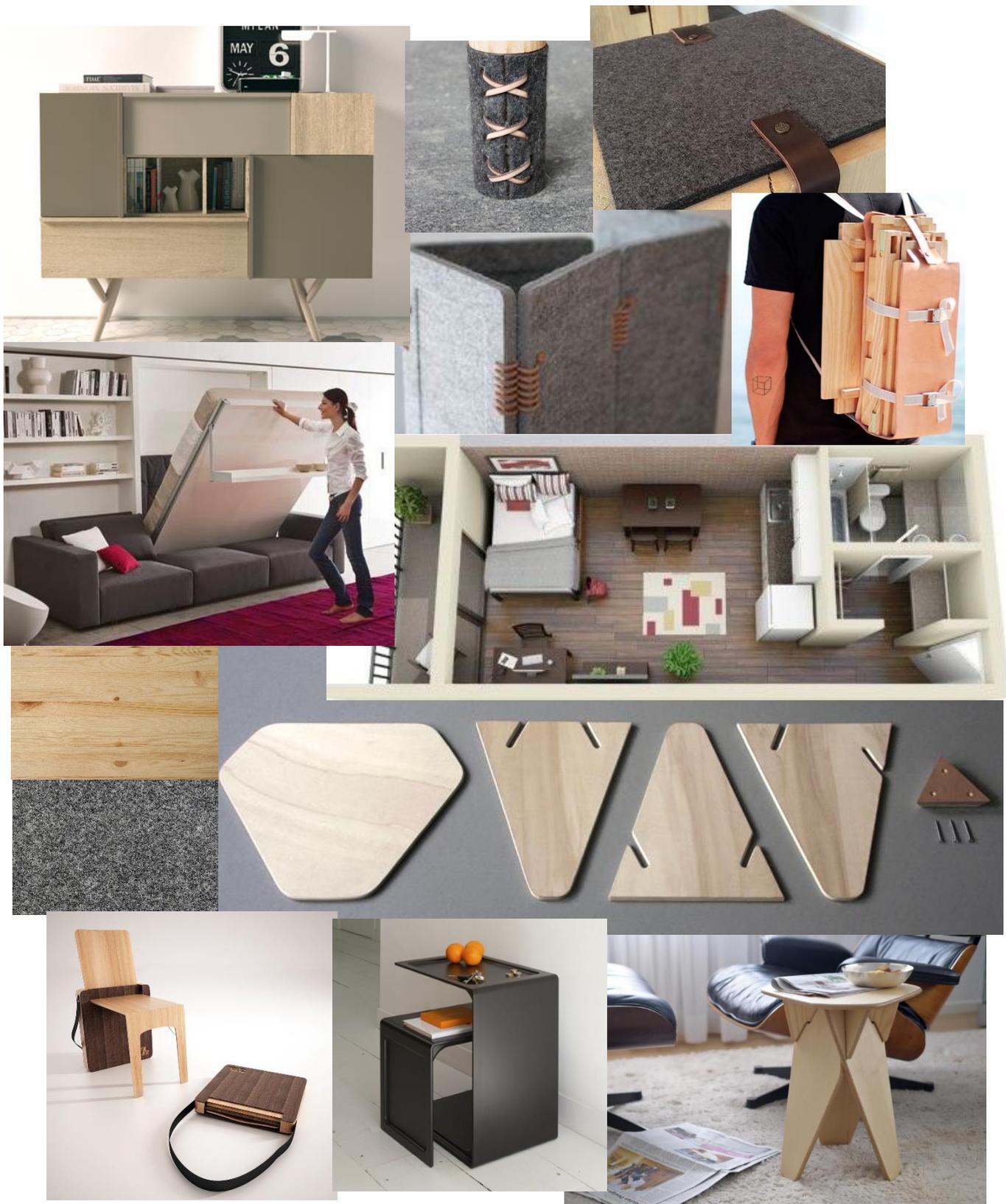
Product: Nomadic Chair	Designed by: Jorge Penadés
	
Dimensions: 820 x 420 x 340 mm (HxWxL)	Price: Undefined
Characteristics: <ul style="list-style-type: none">- An exponent of the movement "hacking" and DIYnamism.- It's made of Solid ash and powder coated steel.- Advocates for constant construction / deconstruction.- Light, removable and portable.- No tools required.	

Product: Mister T	Designed by: Antonie Lesur (Oxyo)
Dimensions: 300 x 400 x 600 mm (HxWxL)	Price: 6725 SEK (700 €)
Characteristics: <ul style="list-style-type: none"> - Occasional furniture consisting of a basket, a tray and two cushions. - Multiplify of ash, ABS / PMMA thermoformed, foam, and textile. - Available in 3 colours: blue, grey and green. - Mister T is neither a coffee table, nor a seat, nor a foot-rest, but a little of all this. - Light, multifunctional and saves space. 	

Product: 621 Side Table	Designed by: Dieter Rams (Vitsoe)
	
Dimensions: 525 x 450 x 320 mm (HxWxL)	Price: 2.605 SEK (272 €)
<p>Characteristics:</p> <ul style="list-style-type: none"> - Wipes clean with a damp cloth – no need for chemical or abrasive cleaners. - It is an injection-moulded, impact-modified polystyrene that gives this table its form and strength. - Available in 2 colours: black and white. - Adjustable feet for stability. - It has two possible positions making it multifunctional. - According to its author "An arrangement of surfaces". - 3-D modelled for precision. 	

Product: Lack Table	Designed by: IKEA
	
Dimensions: 450 x 550 x 550 mm (HxWxL)	Price: 96 SEK (9.99 €)
<p>Characteristics:</p> <ul style="list-style-type: none"> - It's easy to assemble, lift and move around. - The materials are different for the different parts. Table top: Particleboard, Fibreboard, Printed and embossed acrylic paint, ABS plastic, Paper. Leg: Particleboard, Fibreboard, Foil. - Available in 5 different colours: black, white, yellow, birch effect and black-brown. - Coordinates with other products in the LACK series. 	

3.4 MARKET MOODBOARD



3.5 CONCLUSIONS

After analysing the influences, the trends and the main characteristics of the products existing in the market, we extract the following ideas:

The final design should respect the basic principles of Dieter Rams as well as follow the trends of Small Design, Nordic Design, DIY or Nomadism.

For the dimensions of the product, as it can have several functions, the height analysis is done according to the type of product analysed, namely:

- Seat: measures more common between 370 and 480 mm of height, detecting a certain standardization around the 450 mm.
- Table: more common measures between 350 and 580 mm of height, we should take into account the height of other products like beds or sofas.

In addition, the change of function requires an interaction with the user, which implies basic knowledge and a certain time of assembly. On the other hand, there are multifunctional products that are easy and quick to assemble.

As for the price, in general, the prices of the furniture observed are very high because of: quality materials, exclusivity, prestige/fame of the design, etc. This makes products unattainable for much of society and especially for the target audience of this project. There are some exceptions such as, for example, the products of the Swedish multinational IKEA.

The main material in practically all products analysed is wood, which is used as a structural element, because of the ease of working it and the low price. It is also quite common to present it without finishes that conceal its nature. It is also very common to combine it with some fabric or felt. This agrees with the observed trend of Nordic design, the use of natural materials and also the trend of sustainable design.

Storage and transport are two factors to be considered. On the one hand, the folding of the product or its easy disassembly to be stored and, on the other hand, that is easy to transport to be able to use it where the user wants. This factor becomes relevant considering the trend of nomadism and small spaces.

To conclude, the final product must have a size that suits all spaces and situations, taking into account the tendency of small spaces. In addition, it should be multifunctional (stool and side table), to fill a gap in the market. We must find a balance between the price and the factors that characterize the final product, such as quality materials, excellent finishes or exclusivity. The materials to be used in this product must be natural and of a Nordic style. Therefore we must combine the wood with fabric or felt. Finally, the product must have an easy disassembly to be able to store it and must have a system to be able to transport it in a simple way.

4 OBJECTIVE USER

To determine what the potential user would be, an investigation of the type of user living in micro apartments has been carried out, as well as a study of the type of people who like Nordic design, DIY or nomadism. From these studies, we will extract a target audience that will later help us to perform an ergonomic study.

4.1 TARGET

Below we present the data of the objective users that would be potential buyers of the design to be developed. We will note that there will be two types, which, despite some differences, need to cover the same needs. Smart furniture can be used by a large part of the population, but for this project, I'm going to focus on the group of people who live in Micro apartments.

This group of people (between 20 and 45 years), has decided to live in a dense urban area which often means residing in a small space, whether it is a micro apartment or town home. However, a small apartment should not mean living with small and uncomfortable furniture. They are people who are socially active and with cultural concerns, including design. They are able to sacrifice a little money to acquire art or design products. They often receive guests at home or like to a movie with something to eat or drink. They need functional and ergonomic furniture. The product should take full advantage of the space. Simplicity and speed at the time of having to assemble and disassemble. They are intended to cover various uses of an occasional nature associated with the living room or bedroom, or even an outdoors environment.

4.2 HUMAN FACTORS AND ERGONOMICS

Human factors and ergonomics (commonly referred to as HF&E), also known as comfort design, functional design, and systems, is the practice of designing products, systems, or processes to take proper account of the interaction between them and the people who use them.

In essence, it is the study of designing equipment, devices and processes that fit the human body and its cognitive abilities. The two terms "human factors" and "ergonomics" are essentially synonymous.

The International Ergonomics Association defines ergonomics or human factors as follows:

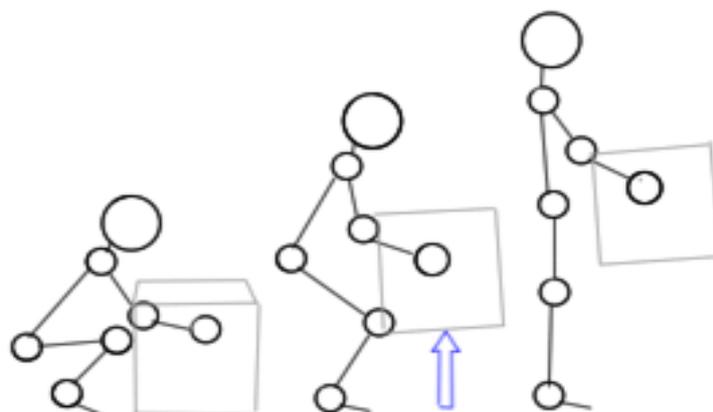
- Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

Ergonomics applied to furniture design requires that we take into consideration how the products we design fit the people that are using them.

Furniture + Subject + Homework = Posture

Since it is a multifunctional object and has to move constantly, it must be easy to transport, which means that it must have a suitable weight to be able to lift it and move it or to carry it to the back. In order for the user to lift and move it easily, a few simple steps have been taken as to how the user must correctly perform the postures necessary to move the object. They are the following:

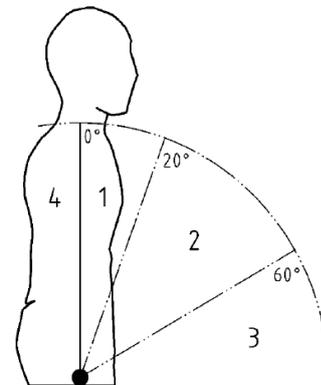
- Bend your knees, keeping your back straight. Keep the chin tight and do not force the neck. As shows the Image 1.
- Do not force the postures, nor turn the body too much.
- Avoid twisting your back or tilting it to the sides.



Example of how to lift an object.

Another factor to study ergonomically is the degree of flexion that the back will perform. As in principle, we will transport the product for more than 2 minutes, we will choose as maximum inclination 60° since it is included in zone 2 at low frequency.

Zone	Static posture	Movement	
		Low frequency (<2 min)	High frequency (≥ 2 min)
1	Acceptable	Acceptable	Acceptable
2	Acceptable with conditions	Acceptable	Not acceptable
3	Not acceptable	Acceptable with conditions	Not acceptable
4	Acceptable with conditions	Acceptable with conditions	Not acceptable



When you carry a bag or backpack, the adopted posture can be dangerous to the back if the weight is considerable (not to exceed 20% of the weight in an adult). Since the user can carry it to the back without suffering injuries and besides being comfortable, a few simple steps have been taken of how the user should carry a backpack or a bag. They are the following:



- The backpack: the backpack should not lower from the lower back to avoid pulling the shoulders back. The best would be to tie the bag at the waist to bring it as close to the back and hips as possible.

- The bag: if the bag is heavy, it is preferable to bring it closer to the center of gravity of the body, which would be in the area of the navel. Carrying it on your shoulder might be a good option, especially if you suffer a deformation in the spine.

The main factor to be assessed in seat evaluation is a comfort (Corlett, 1989). Comfort is a personal feeling experienced by the user while using the seat and understands many factors. One of these factors is the task that is developed. The same level of comfort is not expected in an armchair as in an office or dining chair. In addition, it is difficult to get a chair that is acceptable for all kinds of tasks, and the concept of 'ergonomic chair' does not make sense regardless of its use (Branton, 1969). Therefore, the assessment of the comfort of any seat should be performed by the user while developing the task or activity for which it is designed. In this case, the product should be comfortable as a stool, as a side table and also as a backpack or a bag.

4.3 WEIGHT

Percentile	Sex	Weight (Kg)
99	Men	109,3
	Women	107
95	Men	93,5
	Women	90,3
5	Men	57,2
	Women	47,2
1	Men	50,8
	Women	42,2

Studying the weight of the population by percentiles, we can extract the structural resistance requirements that our product must support in its multiple uses among others as stool or side table.

In the table above we note that the maximum weight to be supported as a seat will be 109 kg to support 99% of the population aged between 18 and 75 years. However, through a more exhaustive study, it has been noticed that for the target public - that is, the population between 20 and 45 years old - this measure is in the 110 kg; Measure slightly higher.

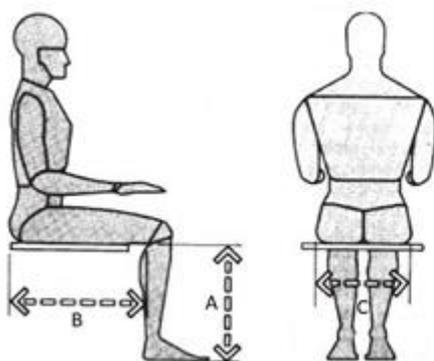
On the other hand, it is also relevant the weight that the final product must have. Since once disassembled, the user can carry it back, the maximum weight can not exceed 20% of the weight of the user. Given the weight obtained after the study carried out to the target public (110 kg of average weight) the final product should not weigh more than 22 kg. In addition, this is the maximum weight that a person must raise to avoid injury, which fits with the possibility of the user being able to move the product frequently.

4.4 FUNDAMENTAL MEASURES

At this point, we will discuss the most important measures of the product such as seat measurements and back measures, to allow the user to be comfortable when using it. The first measure we must take into account is the height that the product must have to offer a comfortable table function for the seated user. Reviewing the characteristics of different auxiliary tables, it has been concluded that the height must be within the range of 30.5 - 45.7 centimeters.

4.4.1 Seat dimensions

To define the main measures that our product must have to be comfortable when the user uses it as a seat, we will highlight three: popliteal height (A), distance buttock-popliteal (B) and hip width (C).

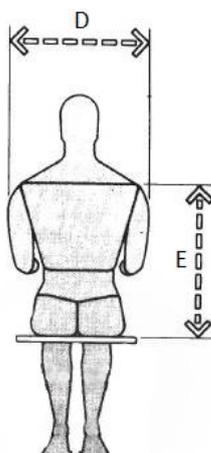


Measure	Men				Women			
	Percentile		Percentile		Percentile		Percentile	
	5	95	5	95	5	95	5	95
	In.	cm	In.	cm	In.	cm	In.	cm
A Popliteal Height	15,5	39,4	19,3	49,0	14,0	35,6	17,5	44,5
B Distance Buttock-Popliteal	17,3	43,9	21,6	54,9	17,0	43,2	21,0	53,3
C Hip Width	12,2	31,0	15,9	40,4	12,3	31,2	17,1	43,4

Measure "A" allows us to limit the maximum height of the product for its seating function in a way that offers support to the user in a passive and comfortable position. Measurements "B" and "C" allow us to obtain the necessary size to offer a safe seat that covers the surface of support required by the individual.

4.4.2 Back dimensions

The main measures that must be taken into account for the user to carry the backpack, which will be the product dismantled, in a comfortable way. These will be shoulder width (D) and shoulder height (E).



Measure	Men				Women			
	Percentile		Percentile		Percentile		Percentile	
	5	95	5	95	5	95	5	95
	In.	cm	In.	cm	In.	cm	In.	cm
D Shoulder Width	21,0	53,3	25,0	63,5	18,0	45,7	25,0	63,5
E Shoulder Height	17,0	43,2	19,0	48,3	13,0	33,0	19,0	48,3

4.5 CONCLUSIONS

The potential user for this product will be young people, between 20 and 45 years, who seeks to furnish a micro apartment, but without giving up the design. In addition, the product must be economical and versatile that allows the greater use of a space already reduced by itself.

Also, this product requires very long durability and intensive use is expected, which must be considered as determining factors in the environmental impact of the final product, trying to optimize them as much as possible.

When used as a table, the product will carry less weight than when used as a seat, so we conclude that the final design must support at least 95 kg of weight - measured slightly higher than the 95th percentile of the population. In order to be used by the entire population, it should support 125 kg. This would shield the product before exceptional cases such as a person with a child in arms, excess weight by falls or blows and also to a greater safety to the user.

We must bear in mind that the final product will bear loads, especially in the center of the same and in the edges of the seat.

Regarding the dimensions that the product should have, they are very similar to those extracted in the conclusions of the market section. The minimum height of the seat should be between 36 and 45 centimeters and 30 to 45 as a table. In addition, we must take into account the measures of the back being the maximum possible height of 48.5 centimeters for the 95th percentile. This indicates that the final product should have a minimum height between 36 and 45 centimeters since in this way will cover both the ergonomics of the seat and the table, and will be comfortable for the user's back.

To conclude, the final product will be aimed at an audience between 20 and 45 years old, lovers of design and who mainly live in micro apartments. The product should be of a size that is ergonomic and comfortable for the user. In addition, we must bear in mind that it will be used as a backpack too, and therefore must adapt to the back of the user. The maximum weight to be borne will be 125 kg, adapting to a large part of the population. These measures must be in line with the market study, adapting to small spaces.

5. FACTORS TO BE CONSIDERED

5.1 MATERIALS

In this section, we will discuss the possible materials that could make up the final product. Traditionally both tables and seats can be found in wood, metal or textiles; nowadays also they are made with plastics or even combining some materials.

In previous studies, we have highlighted wood in its use on tables and stools, so let's not deny that part as the favourite material. However, we must study the other materials available to know the possibilities they offer.

Such materials should fit the trends and the characteristics of the target user. Of all the materials, we have selected only 5 of which, wood, plastic, textile and felt.

5.1.1. About Wood

Wood is a porous and fibrous structural fabric found on the stems and roots of trees and other woody plants. It is an organic material, a natural compound of cellulose fibers that are strong in tension and embedded in a lignin matrix that resists compression. Wood is sometimes defined as only the secondary xylem in the stems of trees or is defined more broadly to include the same type of tissue elsewhere, as in the roots of trees or shrubs. In a live tree, it performs a support function, allowing woody plants to grow large or stand up by themselves. It also transmits water and nutrients between leaves, other growing tissues and roots. Wood may also refer to other plant materials with comparable properties and materials made from wood, or wood or fiber chips.

The multiple uses of this material include fuel and energy source; Material for construction or for making tools and weapons; to make paper and cardboard; and as it can not be otherwise, wood is the most abundant material in the manufacture of furniture. In addition, there are other uses such as the production of purified cellulose and its derivatives, such as cellophane and cellulose acetate.

Sweden is a country with abundant and sustainably-managed forests. Wood is one of their most commonly used materials due to its good availability, excellent material properties and unique sustainability. Wood is a renewable resource with an eco-efficient life-cycle; wood products can be reused, repaired, recycled and, at the end of their life, their energy can be recovered.

Swedish Wood spreads knowledge, provides inspiration and encourages development relating to wood, wood products and wood construction. Swedish Wood is a department within The Swedish Forest Industries Federation. Swedish Wood is supported by the Swedish sawmill and glulam industries.

There is a great variety of woods, but the most used ones for the manufacture of furniture are grouped in:

- White wood. They are those that come from trees with a fast growth and with a low density, they are worked easily thanks to that they hardly have resistance. They are generally cheaper than the hard ones, and among them are: Pine, Poplar and Fir.

All of them have a light colour, are light, malleable, economical and their main use is the manufacture of furniture.

- Hardwoods. These woods have a higher mismatch than the previous ones, but they grow more slowly. In this group are: Oak, Beech and Walnut.

These woods have varied colours, are robust, withstand the blows and are usually linked to the manufacture of luxury furniture.

Among all types of wood, I will highlight two, such as pine and walnut. Each of a group of the above cited but with similar characteristics.

Pine

Between about 100 species, among them, we find clear colourings with shades from reddish to yellowish. This wood has a great commercial utility and is common in practically all the world. Among all the species of wood, pine is the one that provides better acceptance of the treatments necessary to achieve a longer duration since it is easily impregnated, is also an abundant resource that offers good levels of mechanical resistance and above all is easily transformable and actionable. The intrinsic properties of pine wood generally fit the most diverse applications. Properly treated, solid, laminated or glued is easily machined and will offer an excellent finish. It can be used both indoors and outdoors in contact with soil and water. Its main applications are usually, the construction of houses or fences; Indoor and outdoor furniture; and toys or playgrounds. It is also used as raw material for papermaking.

Walnut

This dark wood is considered one of the noblest in the world. It is one of the most common and well-known types of wood, much sought after for interior design due to its aesthetic characteristics, its great finish and its ease of treatment. It is also the wood of choice of choice for many cabinetmakers because, despite its hardness, it is exceptionally easy to use. It is mainly used in the manufacture of furniture and in the wall covering in houses. It has a hardness comparable to that of oak, but easy to work with. It has a high dimensional stability. It is less sensitive to variation in heat and humidity than many other woods. Resistance is considered a medium density wood, strong and robust construction. It is not rigid, ductile, and resistant to decay and has an impact and flexion resistance in the average of the rest of the woods. Its properties make the treatment and the finishing of the wood are almost perfect, besides being very easy to work and have a beautiful grain.

Another important factor is how we have it when it comes to working it. The different commercial processes allow to modify the characteristics of the material as the maximum dimensions or the resistance. The different ways of finding the wood are: solid natural wood, whose dimensions are limited by the dimensions of the trunk; Plywood, is obtained by gluing an odd number of thin sheets of wood; fiber boards, formed of dry wood fibers bonded with synthetic resins which are compacted at high pressure and temperature; Agglomerated boards, composed of glued and pressed wood chips, which generates rough surfaces.

5.1.2. About Cardboard

Cardboard is a material made up of several layers of superimposed paper, based on virgin fiber or recycled paper. The carton is thicker, harder and stronger than paper. Some types of cardboard are used to make packaging and packaging, basically boxes of various types. The upper layer can receive a different finish called "stucco" which gives it greater visibility. Thickness and volume are significant aspects in the development of the carton; In the end, the product must support the weights of loads, luggage and other uses, maintaining its shape. They are usually composed of two or more layers to improve quality. Even with corrugated intermediate layers as in the case of corrugated board.

Carton is relatively inexpensive to manufacture so it makes it a convenient material for packaging and shipping products. It is also used for some prefabricated furniture and houses. The long, strong fibers used to make cardboard make it easy to recycle several times.

5.1.3. About Plastic

Plastic is a material consisting of any of a wide range of synthetic or semi-synthetic organic compounds that are malleable and can be molded into solid objects. Plastics are typically organic polymers of high molecular mass, but they often contain other substances. They are usually synthetic, most commonly derived from petrochemicals, but many are made from renewable materials such as polylactic acid from corn or cellulose from cotton linters. Plasticity is the general property of all materials that are able to irreversibly deform without breaking, but this occurs to such a degree with this class of moldable polymers that their name is an emphasis on this ability.

Due to their relatively low cost, ease of manufacture, versatility, and imperviousness to water, plastics are used in an enormous and expanding range of products, from paper clips to spaceships. In developed countries, about a third of plastic is used in packaging and another third in buildings such as piping used in plumbing or vinyl siding. Other uses include automobiles (up to 20% plastic), furniture, and toys. In the developing world, the ratios may be different - for example, reportedly 42% of India's consumption is used in packaging. Plastics have many uses in the medical field as well, to include polymer implants. The success and dominance of plastics starting in the early 20th century led to environmental concerns regarding its slow decomposition rate after being discarded as trash due to its composition of very large molecules. Toward the end of the century, one approach to this problem was met with wide efforts toward recycling.

5.1.4. About Textile

Textile is understood to mean a flexible fabric constituted by a network of natural or artificial fibers. Its most common uses are for clothes and for containers such as bags and baskets. In their use in furniture, they are generally used to constitute seats and backs, although they also make it possible to form joints by means of knots or to tighten and compact structures in their belt form. When selecting a fabric, you must take into account a good choice of material by its characteristics and the selection of weave that make up the fibers.

For its structural use or exposed to stress, it is imperative to reinforce the natural fibers of cotton, linen or wool with artificial fibers. Among these synthetic fibers, we highlight nylon, which has a great resistance, and polypropylene, which among its variety of uses I want to emphasize the tapes used to tighten the handles of the backpacks.

5.2.5. About Felt

Felt is a textile material that is produced by matting, condensing and pressing fibers together. Felt can be made of natural fibers such as wool, or from synthetic fibers such as petroleum-based acrylic or acrylonitrile or wood pulp-based rayon. Blended fibers are also common. It is very common to see felt in many Nordic style furniture as seat or as aesthetic part of a furniture. It is a very versatile material, thanks to its flexibility, variety of colour and its comfort. It is also used to drag furniture easily and without making marks on the floor.

5.2.6. About Foamed Fabric

The foamed fabric is a 100% polyester fabric bonded to a thin layer of foam. Its composition is based on the union of a polyamide and foam rubber with 3 mm of thickness. Its appearance is similar to plush or velvet with very short hair, used to upholster car seats and make curtains or dolls.

It is a fabric that has a great versatility and possibilities of use. It is also very easy to work, soft, easy to cut and does not fray. It has an economic price.

5.2 FABRICATION PROCESS

5.2.1. *How to make wood furniture*

After performing all the processes of felling, debarking, cutting, sawing and different drying, there are a series of steps for the manufacture of wooden furniture. These are:

1. **Sawing and brushing:** after obtaining the best quality wood, these are cut with appropriate dimensions, and then are brushed to perfect the edges and eliminate possible defects of appearance.
2. **Finishing:** Once the boards are cut and adjusted to appropriate measures, any marks left over from the previous process, such as brush marks or possible saw marks, are eliminated. This process is performed by a sanding process.
3. **Glue.** In the case of using wood panels, these are glued, to obtain a greater length and thickness. If this process is done correctly and the application of the glue is perfect, the joint can become as strong as if the panel were solid wood.
4. **Machining.** Among the main methods of machining, we find the turning, which consists of machining pieces of geometric form by revolution rotating the wood in a platform; The CNC cut, of which we will speak later; Or grooved, in which marks are drawn on the wood to optimize its fit with the rest of pieces.
5. **Polished.** After the machining of the pieces, they are polished by a machine to perfect the finish of the surface. This process leaves the parts smooth to the touch and smooth to the eye.
6. **Assembly.** At this point, each of the pieces that make up the product are assembled by the workers or, in some cases more and more frequent, the end user (Do It Yourself).
7. **Finished finish.** At this point, the surface protectors and preservatives are applied as varnishes, lacquers or enamels. In some cases, aesthetic and ornamental details are made.

5.2.2. How to make plastic furniture

To begin with let's define two basic concepts: molding and mold.

- The molding of plastics is to give the desired shapes and measures to a plastic by introducing plastics under pressure in the molds.
- The mold is a hollow piece in which the molten plastic is poured so that it acquires its shape.

Depending on the type of pressure, we have these two types:

High pressure molding.

It is made by hydraulic machines that exert sufficient pressure for the molding of the parts. Basically, there are three types: compression, injection and extrusion.

- Compression. In this process, the plastic powder is heated and compressed between the two parts of a mold by the action of a hydraulic press, since the pressure required in this process is very large. This process is used to obtain small pieces of bakelite, such as heat-insulating handles from containers and kitchen utensils.

- Injection. It consists of introducing the granulated plastic into a cylinder, where it is heated. Inside the cylinder is a worm which acts in the same way as the plunger of a syringe. When the plastic softens enough, the auger injects it under high pressure into a steel mold to give it shape. The mold and the injected plastic are cooled by internal channels through which water circulates. Due to its economy and speed, injection molding is very suitable for the production of large series of parts. By this procedure basins, cubes, carcasses, automobile components, etc. are manufactured.

- Extrusion. It consists in molding products continuously, since the material is pushed by a worm through a cylinder that ends in a nozzle, which produces a strip of indefinite length. By changing the shape of the nozzle you can obtain bars of different profiles. This method is also used for the manufacture of pipes, by injecting pressurized air through a hole in the tip of the head. By regulating the air pressure you can get tubes of different thicknesses.

Low Pressure Molding

It is used to shape plastic sheets by applying heat and pressure to a mold. Two procedures are basically employed:

- The first consists in effecting the vacuum by absorbing the air between the sheet and the mold, so that it adapts to the shape of the mold. This type of molding is used to obtain containers of food products in molds that reproduce the shape of the objects to be contained.

- The second method is to apply air under pressure against the plastic sheet until it is adapted to the mold. This process is called blow molding, as in the case of extrusion, although these are two totally different techniques. It is used for the manufacture of domes, plastic bottles, hollow pieces, etc.

5.2.3. 3D printing

3D printing, also known as additive manufacturing (AM), refers to processes used to create a three-dimensional object in which layers of material are formed under computer control to create an object. Objects can be of almost any shape or geometry and are produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file.

The futurologist Jeremy Rifkin claimed that 3D printing signals the beginning of a third industrial revolution, succeeding the production line assembly that dominated manufacturing starting in the late 19th century.

The term "3D printing" originally referred to a process that deposits a binder material onto a powder bed with inkjet printer heads layer by layer. More recently, the term is being used in popular vernacular to encompass a wider variety of additive manufacturing techniques.

Since a few years ago, there has been a great growth in the sale of 3D printers, and for this reason, the cost of the same has been reduced. This technology also finds use in fields such as jewelry, footwear, industrial design, architecture, engineering and construction, automotive and aerospace, medical industries, education, geographic information systems, civil engineering and many others.

5.2.4. CNC Machining

Computer numerical control or CNC is the automation of machine tools by means of computers executing pre-programmed sequences of machine control commands. This is in contrast to machines that are manually controlled by hand wheels or levers, or mechanically automated by cams alone.

In modern CNC systems, the design of a mechanical part and its manufacturing program is highly automated. The part's mechanical dimensions are defined using computer-aided design (CAD) software and then translated into manufacturing directives by computer-aided manufacturing (CAM) software. The resulting directives are transformed (by "post processor" software) into the specific commands necessary for a particular machine to produce the component and then loaded into the CNC machine.

Among all the variants of CNC machining we can find:

- Cutting by CNC milling machine. Most CNC milling machines (also called machining centers) are computer controlled vertical mills with the ability to move the spindle vertically along the Z-axis. This extra degree of freedom permits their use in die sinking, engraving applications, and 2.5D surfaces such as relief sculptures. When combined with the use of conical tools or a ball nose cutter, it also significantly improves milling precision without impacting speed, providing a cost-effective alternative to most flat-surface hand-engraving work. Milling is the most common form of machining and consists of a chip start process performed by a multi-edged rotary tool that executes movement on as many axes as the machine arranges. A numerical control mill with the right accessories is able to perform a wide range of milling, among which we can find flattening, cutting, grooving, copying, tapping, chamfers, etc. It is important to note that the duration and therefore the cost of the milling process increases with the following factors (sorted from highest to lowest impact): change of position of the workpiece to be machined, tool change and downtime. The speed of milling depends on factors such as the diameter of the milling cutter, the thickness of the wood and the power of the machine.
- Laser machining. Laser cutting technology uses, as the name implies, a laser to cut materials. The laser cutting is a machining without contact of the material and free of forces that allows cuts of any geometry. Two-dimensional (2D) and three-dimensional (3D) sections can be made. The process is flexible, easy to automate and offers high cutting speeds with excellent quality, as the laser has the ability to operate very complex cutting profiles with very small radii of curvature. In addition, it is a clean technology, without any contamination. Most lasers used in the industrial cutting of iron, wood and plastics are CO2 lasers, so named because of the type of gaseous flow they use as medium. Apart from its use in the industry, it is beginning to be used by schools, small businesses and amateurs thanks to its safety and ease of use. This process requires a high investment in machinery, the more heat conductors, the more material and the greater difficulty in cutting.

5.3.2.1 How open source platforms operate

The open source platforms have a functioning that can be variable. The user can download, make or buy furniture. On the one hand, the platform can offer the designer the option to publish their files with or without license restrictions, but you can also choose to upload them for free for non-commercial use or charge for downloads. This works, for example, the well-known OpenDesk platform. When designing the OpenDesk system, they had two goals. Anyone, anywhere in the world, is able to download designs for local making and they provide the viable model for designers to benefit when their designs are sold via the OpenDesk network.

Thus, a small scheme could be defined on how these platforms work:

1. Presentation: Free presentation of proposals of unpublished designs that can be manufactured with simple means.
2. Selection: A Product Committee selects the new additions to the platform.
3. Contracting: a contract is drawn up for the distribution of the product, between the designer and the platform.
4. Documentation: the selected projects are adjusted to the presentation parameters of the platform and final documentation is delivered.
5. Catalogue: the product is incorporated into the catalogue of the platform and the link to the designer's page is activated.
6. Economy: with some downloads of the designs, a percentage of the price is credited to the designer.

To download the files, the client usually has to provide his name and email address, as well as mention what use will make the furniture and accept the license and privacy policy of the platform. Here is an example of how to download projects on the OpenDesk platform:

- Select furniture: create an account to build your basket with furniture, or get in touch.
- Request quotes: Get quotes from local manufacturers in your area, delivered to your inbox within 48 hours.
- Choose your manufacturer: choose the offer and the manufacturer that works best for you and they will start.
- Receive your furniture: Get the furniture delivered to your door in 2-4 weeks, direct from the manufacturer.

When you download a non-commercial Opendesk design, you have two options:

1. Download the design to be made for non-commercial use. To order himself/herself of the construction, either making it with his own means or looking for a workshop on his own.
2. Buy the Opendesk product or a manufacturer registered in the Opendesk network. Order the construction of the platform, which is in charge of finding a nearby workshop for the manufacture of the product.

In the second case, when you buy an Opendesk, a royalty payment is automatically taken into account in the cost you pay.

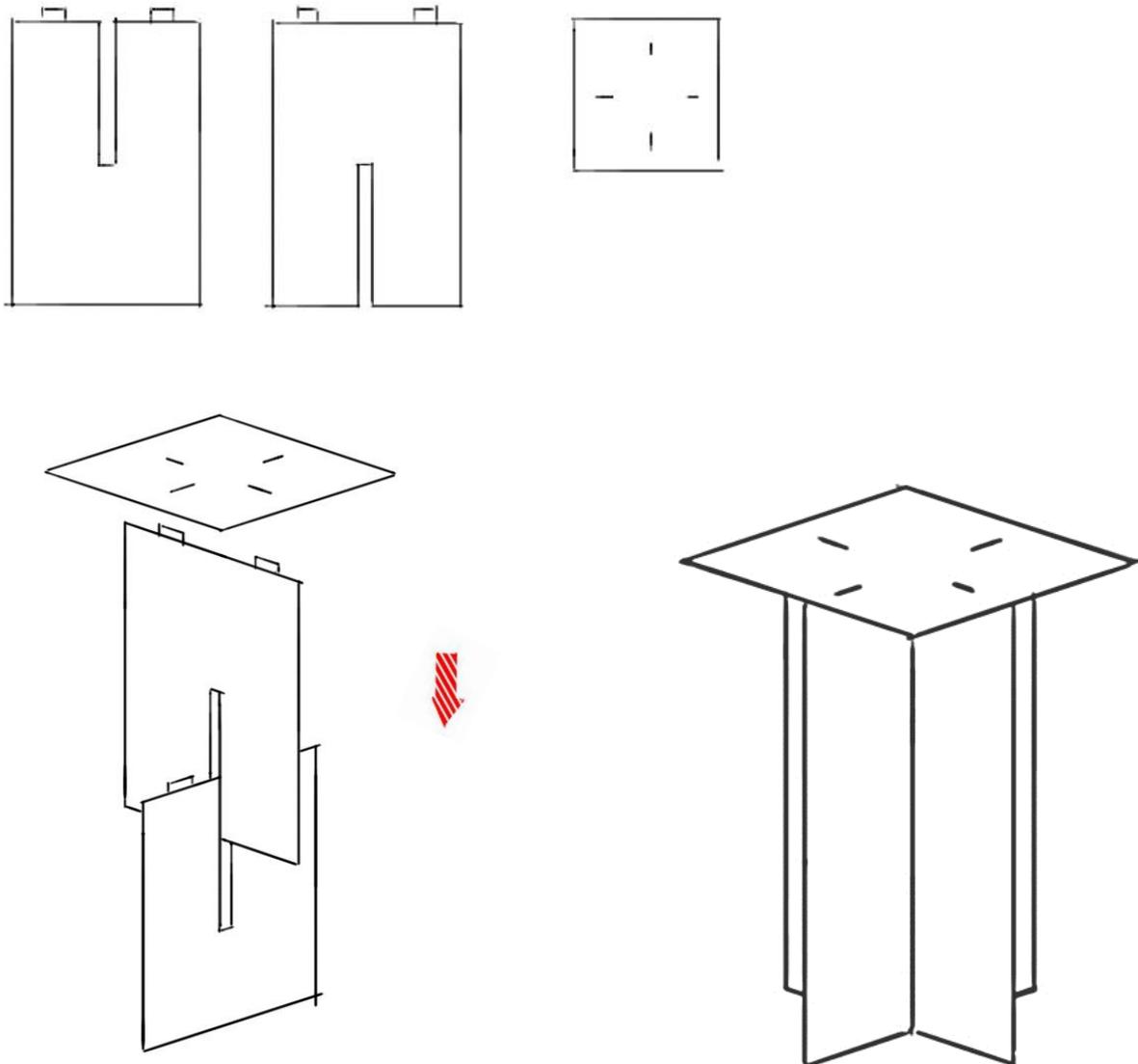
Open source products are commonly manufactured using CNC (Computer Numeric Control) technology or numerical control. The system controls the movements of the working tool relative to the working coordinate axes, which in the case of milling machines also includes vertical movements. They can also be manufactured using other means of digital manufacturing such as 3D printing or laser cutting.

6. DESIGN DEVELOPMENT

6.1. DESIGN ALTERNATIVES

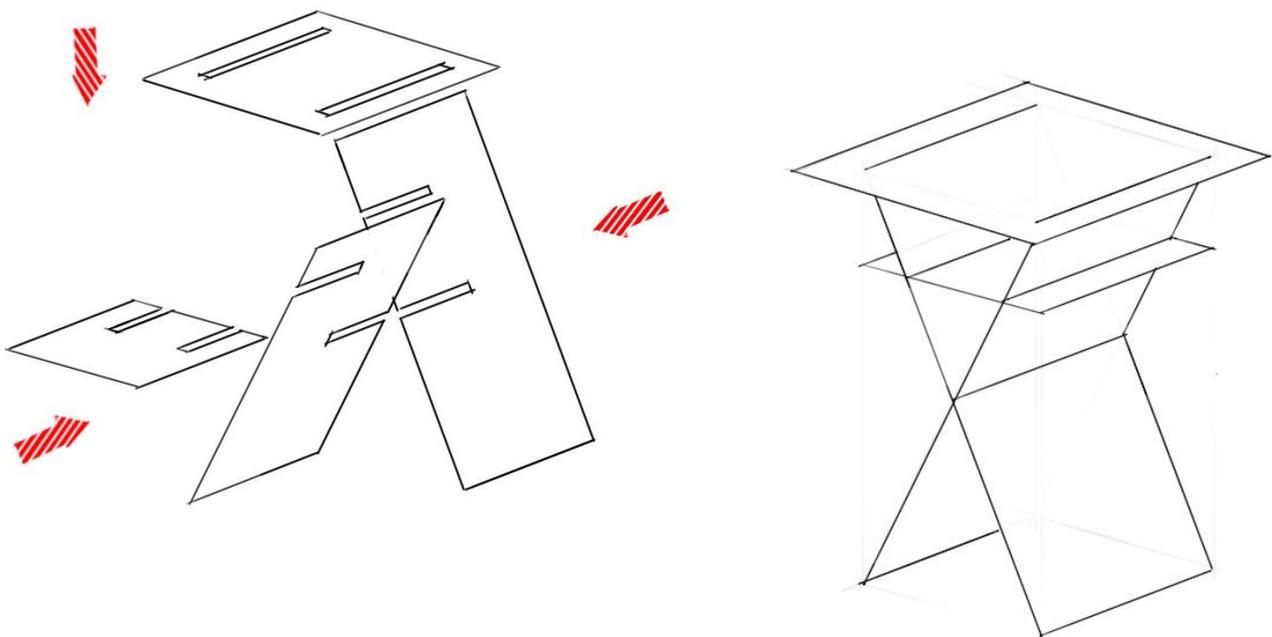
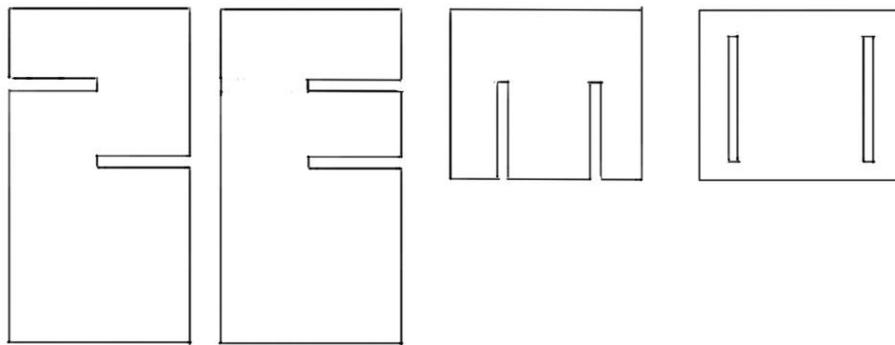
Below is the different design alternatives for this project.

6.1.1. Alternative 1



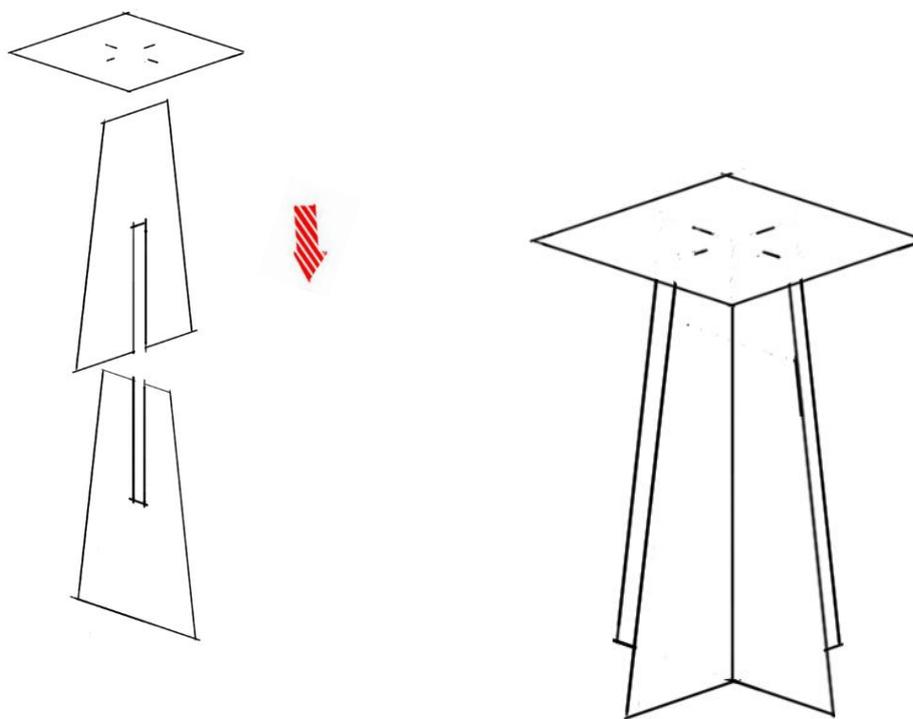
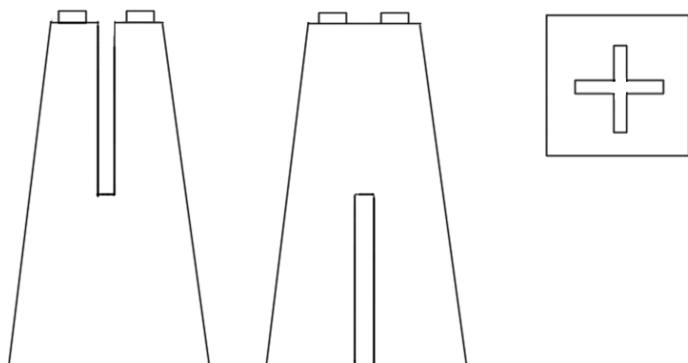
In this proposal, the simplicity to mount and dismantle stands out. It consists of three pieces, two legs that join together fitting the two pieces and a seat that joins to the legs fitting also.

6.1.2. Alternative II



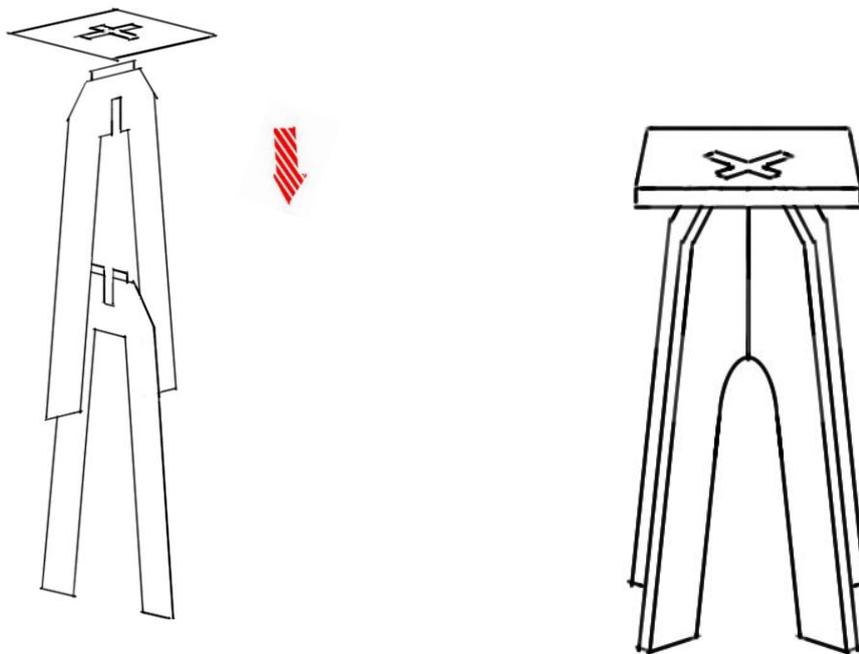
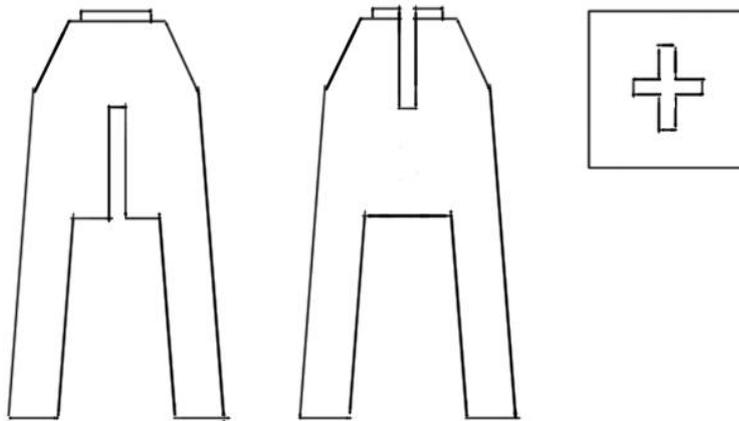
This proposal consists of 4 pieces that fit and form a table/stool. It has a shelf under the seat, which adds a small space for storage.

6.1.3. Alternative III



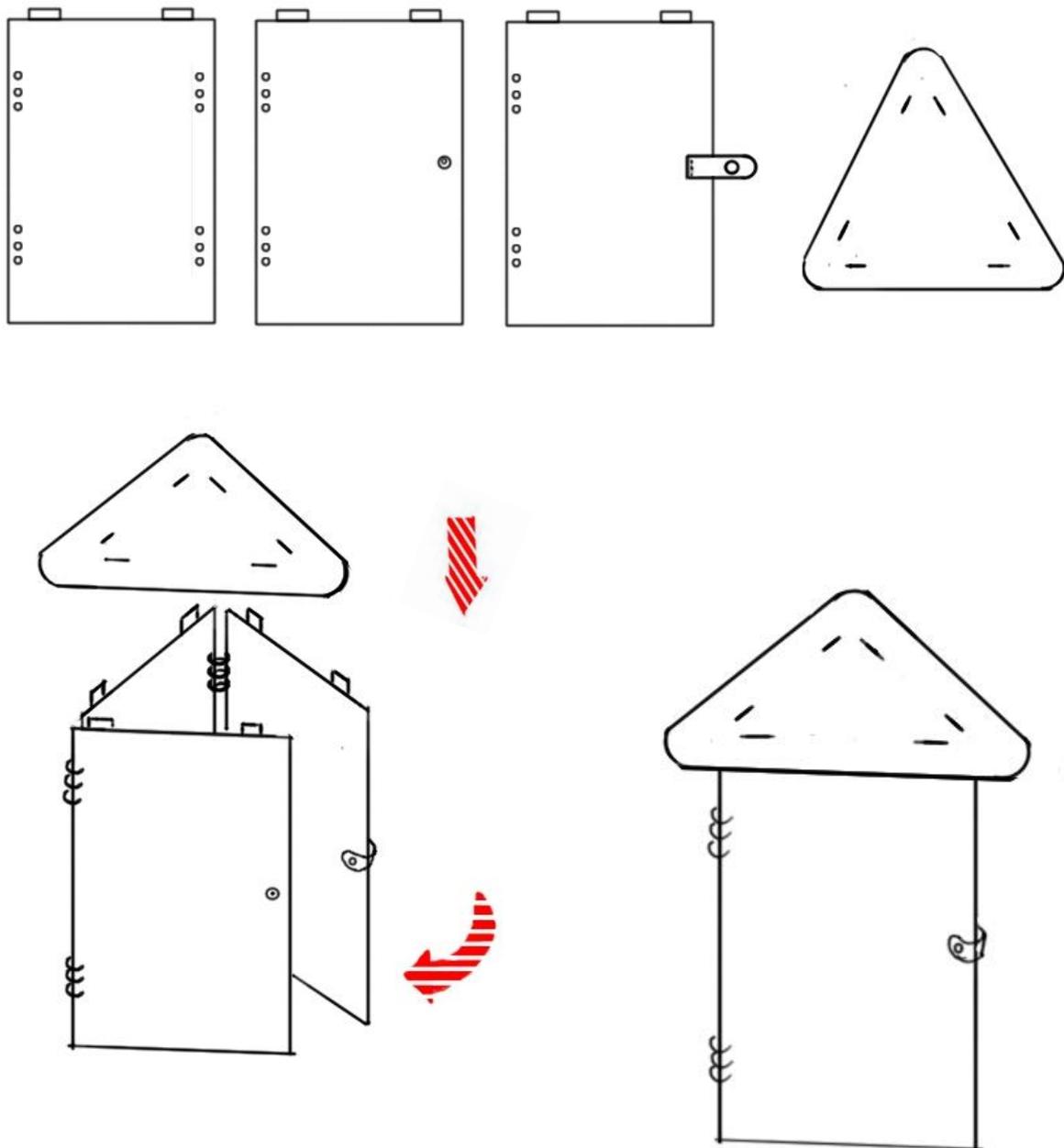
This one is the same as the Alternative I, but changing the shape of the legs.

6.1.4. Alternative IV



This alternative consists of 3 pieces that fit together. The shape of the pieces that form the legs is similar to the reinforcements that have the backpacks of mountain in the back, and they adapt perfectly to the form of the back.

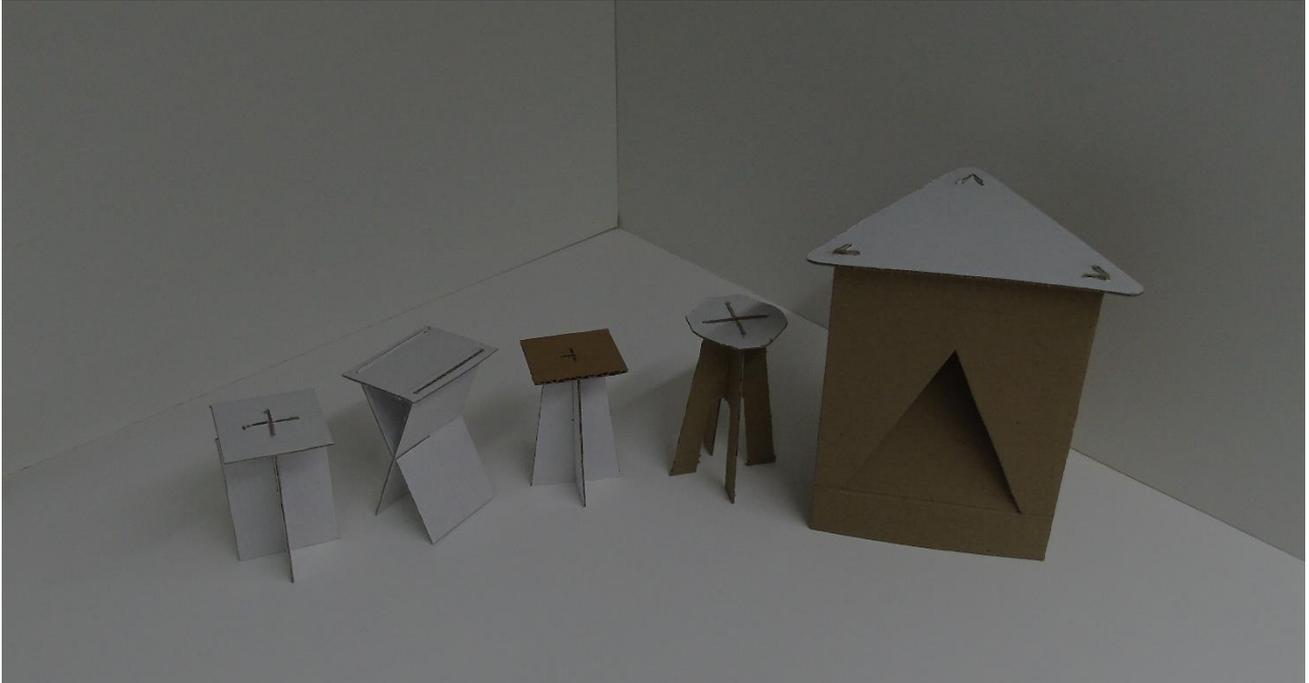
6.1.5. Alternative V



This proposal consists of 4 pieces. The three pieces of the legs are joined by ropes and the seat is attached to the legs with a fitting. The final shape is a triangular prism.

6.2 PROTOTYPE OF ALTERNATIVES

Below are the models of the different alternatives. You have been able to see the alternatives in a 3D view and to see what their flaws or virtues might be.



7 SELECTION CRITERIA

Then we will use different selection criteria, to finally obtain which is the best design alternative. These selection criteria will be majority rule, weighted sum, Copeland rule, and data method.

7.1 RULE OF MAJORITY

This Rule makes a comparison of alternatives two to two. For each criterion, the best alternative is chosen, and the most effective alternative is chosen.

This Rule can lead us to contradictions, so we will use other methods.

CRITERIA	ALTERNATIVES									
	A I - A II	A I - A III	A I - A IV	A I - A V	A II - A III	A II - A IV	A II - A V	A III - A IV	A III - A V	A IV - A V
Nº OF PARTS	A I	=	=	A I	A III	A IV	=	=	A III	A IV
WEIGHT	A I	A III	A IV	A I	A III	A IV	A II	A IV	A III	A IV
EASY ASSEMBLY	A I	=	A IV	A I	A III	A IV	A V	A IV	A III	A IV
MATERIAL SAVING	A I	A III	A IV	A I	A III	A IV	=	A IV	A III	A IV
AESTHETIC	A II	A III	A IV	A V	A II	A IV	A V	A IV	A V	=
SEAT	A II	=	A I	A V	A II	A II	A V	=	A V	A V
PRICE	A I	A III	A IV	A I	A III	A IV	A II	=	A III	A IV
TOTAL	A I > A II	A III > A I	A IV > A I	A I > A V	A III > A II	A IV > A II	A V > A II	A IV > A III	A III > A V	A IV > A V

7.2 COPELAND RULE

It is a variant of the rule of the majority that avoids the problem of the non-transitivity of the ranking of alternatives. The rule says that the number of times an alternative, compared to the others, has preference according to the rule of the majority, is a measure for the value of the alternative.

ALTERNATIVES	WINS	LOSES	TOTAL
A I	2	2	0
A II	0	4	-4
A III	3	1	2
A IV	4	0	4
A V	1	3	-2

7.3 WEIGHTED SUM

The weighted sum tool is useful if you want to maintain the resolution of the model or if decimal weights are required. To do this, a percentage value is given to the criteria and a rating is assigned (with a scale of 0-5 in this case) to each alternative. Weighted sum multiplies the field values designated for each input by the specified weight and will give us the most appropriate solution.

CRITERIA	ALTERNATIVES					$\lambda_j \%$
	A I	A II	A III	A IV	A V	
NUMBER OF PARTS	5	2	5	5	2	20
WEIGHT	4	3	4	5	2	20
EASY ASSEMBLY	4	3	4	4	2	10
MATERIAL SAVINGS	2	1	4	5	1	5
AESTHETIC	2	4	4	5	4	20
SEAT SURFACE	3	5	3	3	5	5
PRICE	5	3	4	4	3	10
BACKPACK SHAPE	3	3	4	5	3	10
TOTAL	3,75	3,1	4,1	4,55	2,8	

7.4 DATUM METHOD

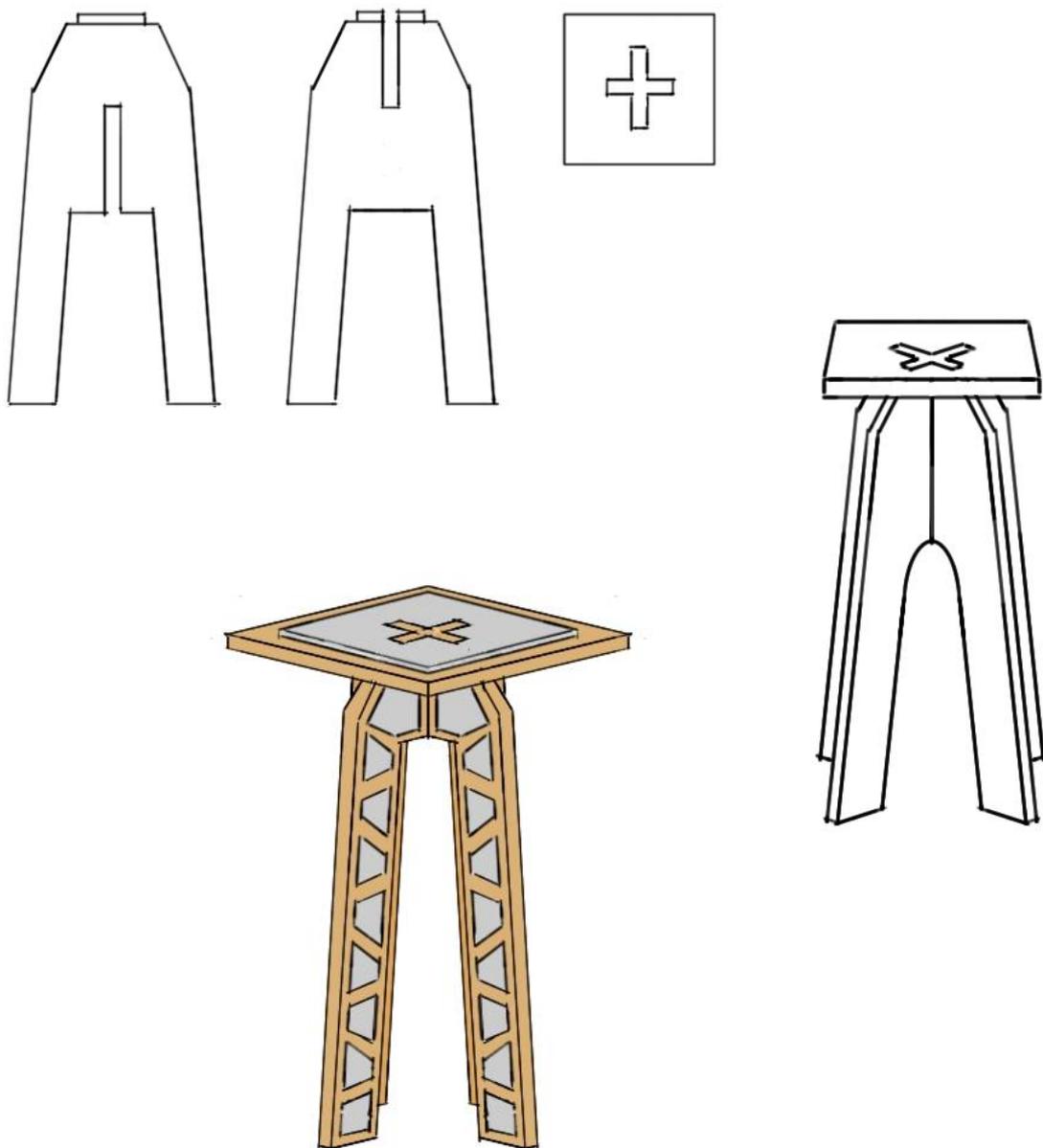
1. Choose one of the alternative solutions like DATUM or basis of comparison.
2. Compare the adaptation to each objective of each alternative solution in relation to the "Datum". If the solution performs better than the target, a (+) sign is placed, which fits worst if a sign is placed (-) and if there is no big difference in its adaptation a (=) is set.
3. Calculate separately the sum of signs (+), signs (-) and (=), for each alternative and these results, serve as the basis for making a reasoned decision.
4. Often it is necessary to choose a new "Datum" and repeat the steps 3 and 4 to better classify ideas.

CRITERIA	ALTERNATIVES				
	A I	A II	A III	A IV	A V
NUMBER OF PARTS	+	*	+	+	=
WEIGHT	+	D	+	+	-
EASY ASSEMBLY	+	A	+	+	-
MATERIAL SAVINGS	+	T	+	+	=
AESTHETIC	-	U	-	+	+
SEAT SURFACE	-	M	-	-	=
PRICE	+	*	=	+	=
BACKPACK SHAPE	=		+	+	=
$\sum (+)$	5		5	7	1
$\sum (=)$	1		1	1	5
$\sum (-)$	2		2	0	2
	MEDIUM		MEDIUM	STRONG	WEAK

7.5 CONCLUSIONS

After performing this process to choose which alternative best fits the criteria that have been proposed, a satisfactory result has been obtained for alternative A IV. It has been the best results are all methods used.

In spite of being the best alternative, we must make some changes and improvements to obtain a good final product. Thus, alternative A IV will be developed in the next section.



8 ADOPTED SOLUTION

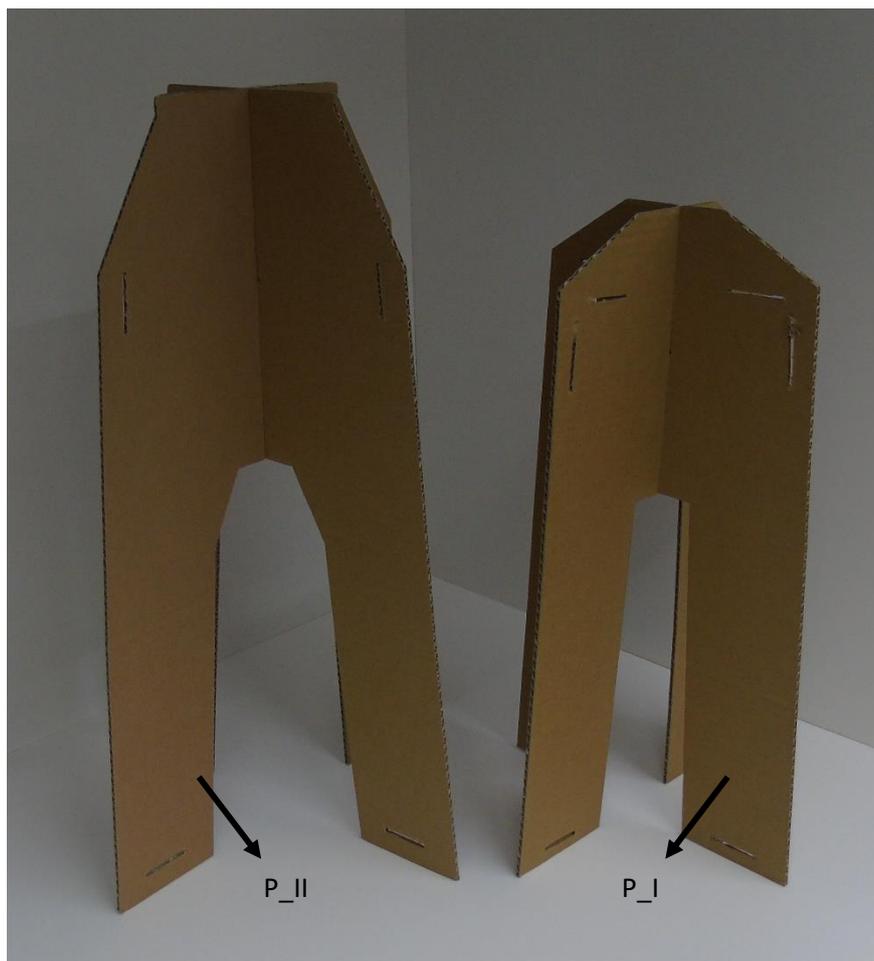
8.1 DESCRIPTION

After all the research work done throughout this report, the following has been determined.

The final solution will be a stool/side table, following a Nordic style design, with the motto "less is more" Dieter Rams and also that can be personalized by the user (DIY). Finally, the final product will consist of 3 pieces of plywood cut with a CNC machine and felt in some parts, which will be presented later. To mount it, the user simply has to fit the two pieces of the legs and then fit the seat.

In addition, as will be explained below, the product can be used as backpack and the user can carry the product wherever he wants.

The prototype P_I was the first design proposal, with a height of 42 cm and a base 25 cm wide. However, some modifications were made to reach the P_II, with 50 cm of height and 30 cm of base.



8.2 MATERIALS

Finally, we have chosen to use two materials that by their characteristics are the most suitable for the final product. These materials are Pine Plywood and Polyurethane Foam.

Pine Plywood

Plywood is a sheet material manufactured from thin layers or "plies" of wood veneer that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another. It is an engineered wood from the family of manufactured boards which includes medium-density fibreboard (MDF) and particle board (chipboard).

All plywoods bind resin and wood fibre sheets (cellulose cells are long, strong and thin) to form a composite material. This alternation of the grain is called cross-graining and has several important benefits: it reduces the tendency of wood to split when nailed at the edges; it reduces expansion and shrinkage, providing improved dimensional stability; and it makes the strength of the panel consistent across all directions. There is usually an odd number of plies so that the sheet is balanced—this reduces warping. Because plywood is bonded with grains running against one another and with an odd number of composite parts, it is very hard to bend it perpendicular to the grain direction of the surface ply.

A typical plywood panel has face veneers of a higher grade than the core veneers. The principal function of the core layers is to increase the separation between the outer layers where the bending stresses are highest, thus increasing the panel's resistance to bending. As a result, thicker panels can span greater distances under the same loads. In bending, the maximum stress occurs in the outermost layers, one in tension, and the other in compression. Bending stress decreases from the maximum at the face layers to nearly zero at the central layer. Shear stress, by contrast, is higher in the center of the panel, and at the outer fibres.

Polyurethane foam

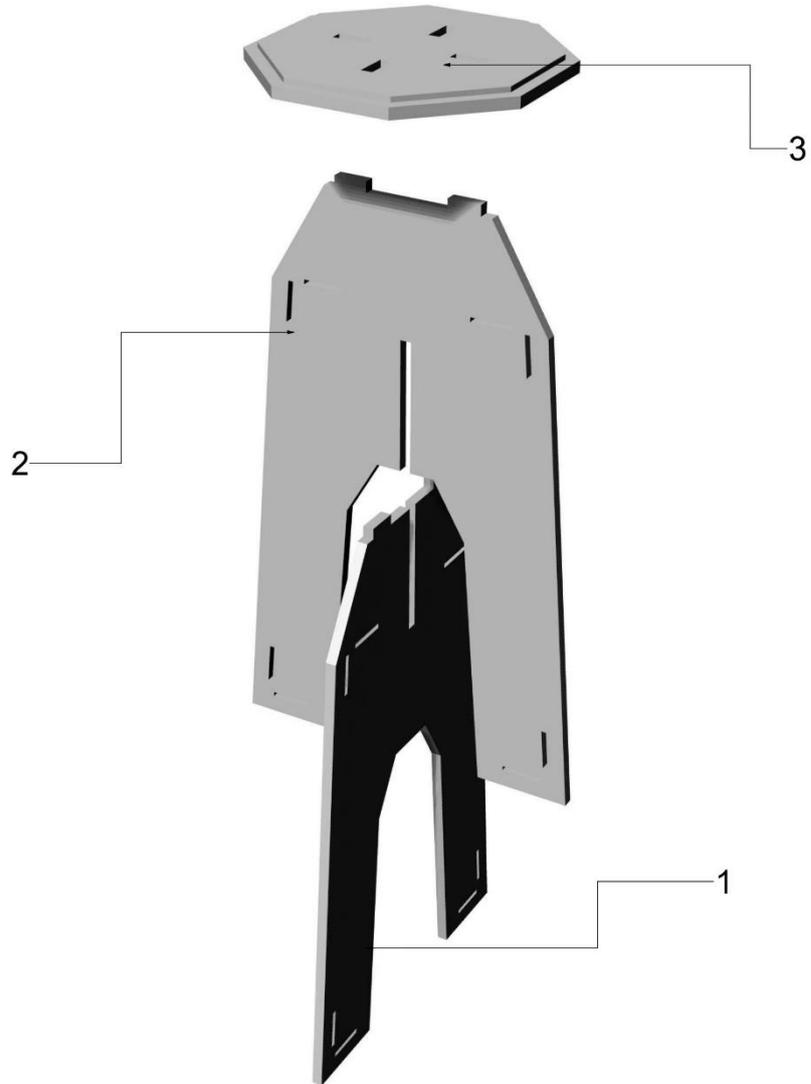
The foamed fabric is a 100% polyester fabric bonded to a thin layer of foam. Its composition is based on the union of a polyamide and foam rubber with 3 mm of thickness. Its appearance is similar to plush or velvet with very short hair, used to upholster car seats and make curtains or dolls.

It is a fabric that has a great versatility and possibilities of use. It is also very easy to work, soft, easy to cut and does not fray. It has an economic price.

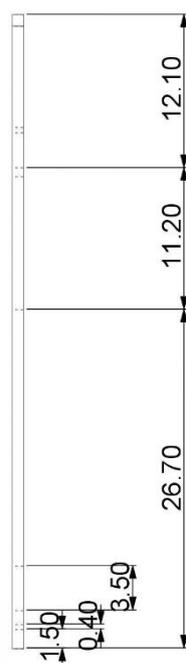
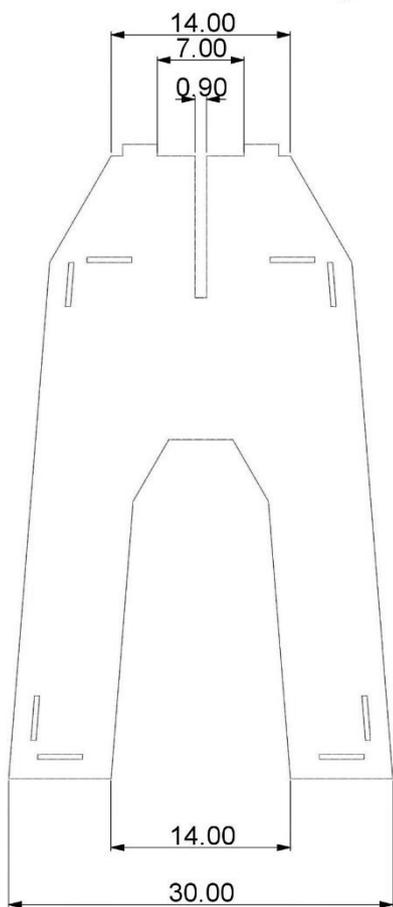
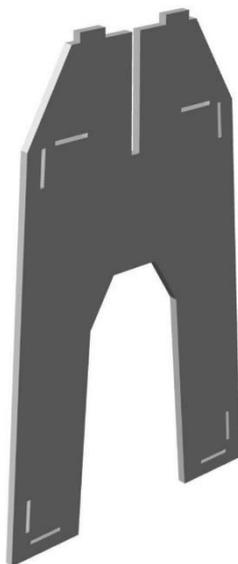
With this foam, we will get comfort in the seat as well as aesthetics for the product. Also, the backpack will be made completely with this material.

In addition, these materials fit perfectly with the Nordic style. The wood will be bare, untreated, very characteristic of this style. On the other hand, the contrast with the foam fabric with the wood and the use of a neutral color scale are also important characteristics of the said style.

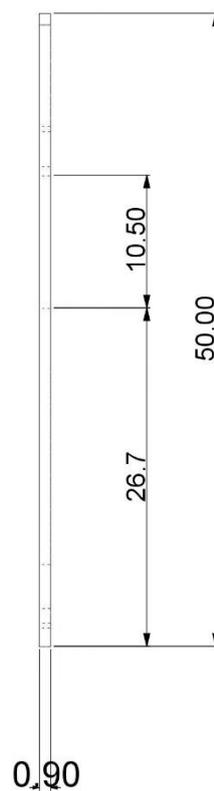
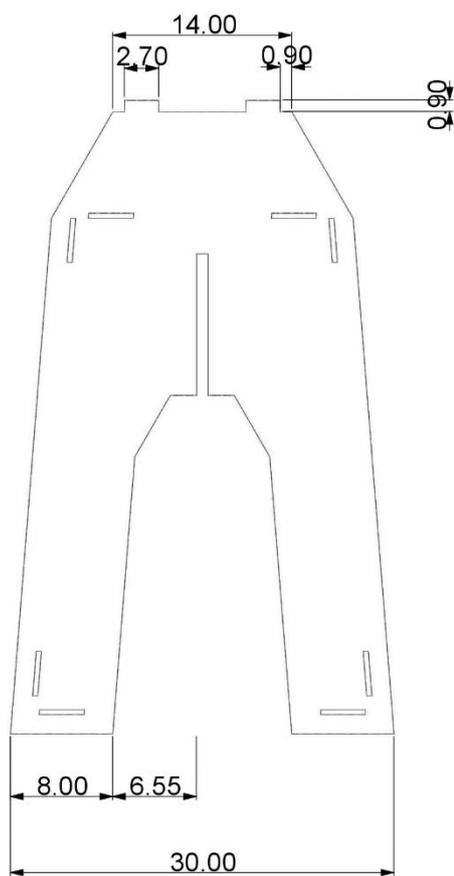
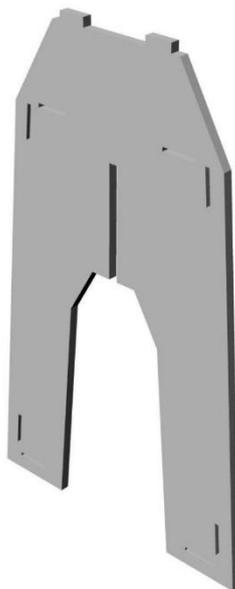
8.3 TECHNICAL PLANES



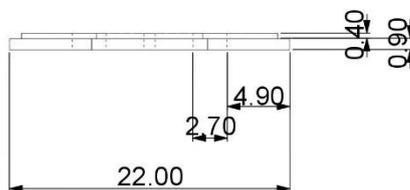
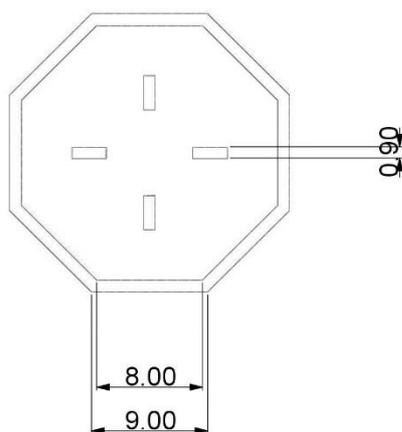
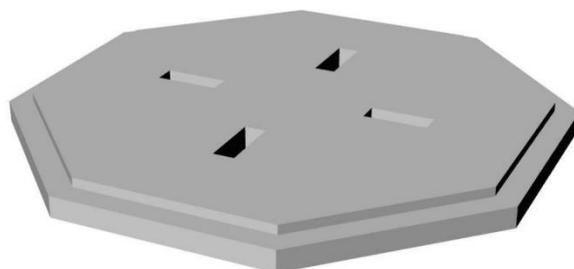
PART N°	DESCRIPTION	MATERIAL	DRAWING
1	Leg 1	Pine Plywood	002
2	Leg 2	Pine Plywood	003
3	Seat	Pine Plywood & Foamed Fabric	004
PROJECT: STOOL	NAME: TÅBST		
DATE: 24/05/2017	PART: Exploded View	A4	
UNITS: cm	SCALE: (2:1)	DRAWING: 001	



MATERIAL: PINE PLYWOOD	PROJECT: TÅBST	
DATE: 24/05/2017	PART: Leg 1	A4
UNITS: cm	SCALE: (2:1)	DRAWING: 002



MATERIAL: PINE PLYWOOD	PROJECT: TÅBST	
DATE: 24/05/2017	PART: Leg 2	A4
UNITS: cm	SCALE: (2:1)	DRAWING: 003



MATERIAL: PINE PLYWOOD & FOAMED FABRIC	PROJECT: TÅBST	
DATE: 24/05/2017	PART: Seat	A4
UNITS: cm	SCALE: (2:1)	DRAWING: 004

8.4 FABRICATION PROCESS

8.4.1 CNC cutting

Cutting by CNC milling machine. Most CNC milling machines (also called machining centers) are computer controlled vertical mills with the ability to move the spindle vertically along the Z-axis. This extra degree of freedom permits their use in die sinking, engraving applications, and 2.5D surfaces such as relief sculptures. When combined with the use of conical tools or a ball nose cutter, it also significantly improves milling precision without impacting speed, providing a cost-effective alternative to most flat-surface hand-engraving work. Milling is the most common form of machining and consists of a chip start process performed by a multi-edged rotary tool that executes movement on as many axes as the machine arranges. A numerical control mill with the right accessories is able to perform a wide range of milling, among which we can find flattening, cutting, grooving, copying, tapping, chamfers, etc. It is important to note that the duration and therefore the cost of the milling process increases with the following factors (sorted from highest to lowest impact): change of position of the workpiece to be machined, tool change and downtime. The speed of milling depends on factors such as the diameter of the milling cutter, the thickness of the wood and the power of the machine.

8.4.2. CNC cutting requirements

In order to be able to make cuts of the pieces using a CNC machine, there are a number of requirements such as file type and nesting.

File Type

AutoCAD DXF (Drawing Interchange Format, or Drawing Exchange Format) is a CAD data file format developed by Autodesk for enabling data interoperability between AutoCAD and other programs.

DXF was originally introduced in December 1982 as part of AutoCAD 1.0 and was intended to provide an exact representation of the data in the AutoCAD native file format, DWG (Drawing), for which Autodesk for many years did not publish specifications. Because of this, correct imports of DXF files have been difficult. Versions of AutoCAD from Release 10 (October 1988) and up support both ASCII and binary forms of DXF. Earlier versions support only ASCII.

DXF coordinates are always without dimensions so that the reader or user (In this case the CNC machine) needs to know the drawing unit or has to extract it from the textual comments in the sheets.

Before sending the .DXF file for CNC cutting, we need to check that the file has the good measures and the good scale.

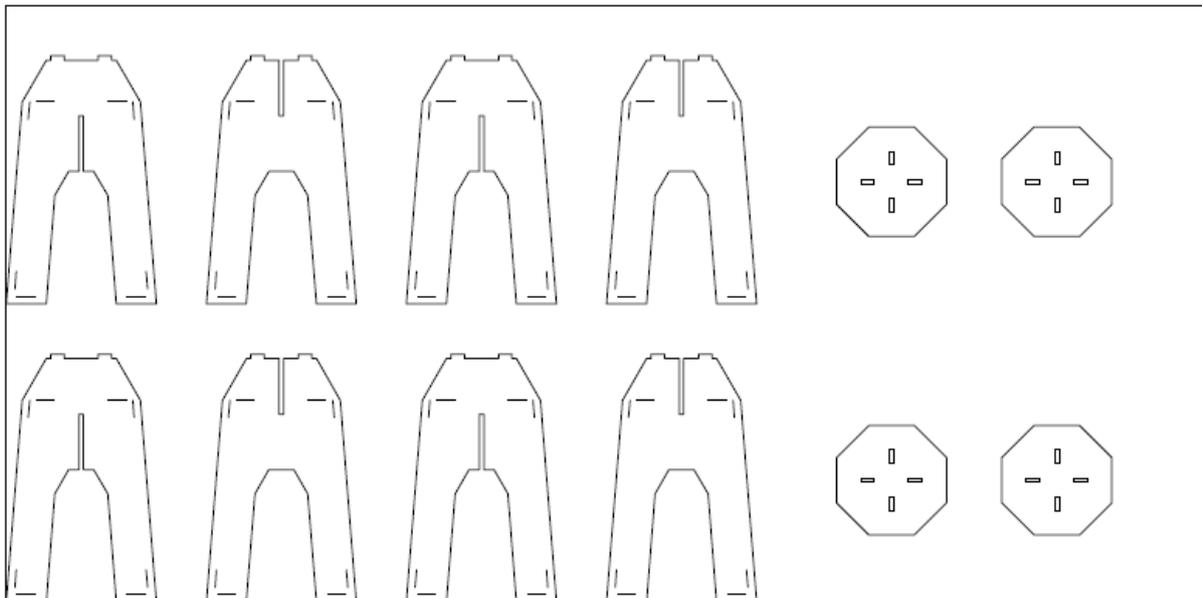
Nesting

The objective of this process is the optimization of the material. Nesting is the way to place the pieces on a board in the way that optimizes the material to the maximum. How to organize these parts can be a problem when using cutting tools by laser, CNC, or others.

The best solution to position the pieces in the best possible way is the SVG software. In order to obtain the nesting file, we must load an SVG file. The scale on which the drawings will be found will be 1:10.

The program is dedicated to moving the pieces through many iterations to optimize the space until the user decides that he is satisfied with the result.

For this product, a unit has been placed on a standard 120 x 240 cm board, and then test the maximum number of tables that can be placed on the board (maximum number is 4). When placing them, it is only necessary to take into account that the minimum space between pieces must be be 15 mm.



8.5 BUDGET

Being an Open Source product and will not be produced in series, only one budget have been made: a budget for 4 stools (we can determine the price of one).

Below we will detail the budget mentioned above with their variables. The budget is going to show the breakdown of prices piece by piece and corresponds to the manufacture of 4 stools obtained from a single board.

The user will be the one who will transport and assemble the final product once it has been cut, therefore no transportation, packing or assembly costs will be considered in the budget. In addition, the product plans can be downloaded freely thanks to the Open Source. By not selling in a store or belonging to any entity, the total price will not be increased to make a profit, but the user will pay for the purchase of the raw material and labor. There is the possibility that the user has the necessary machinery to make the cuts, so the final budget will be formed solely by the cost of the material.

8.5.1. Stool

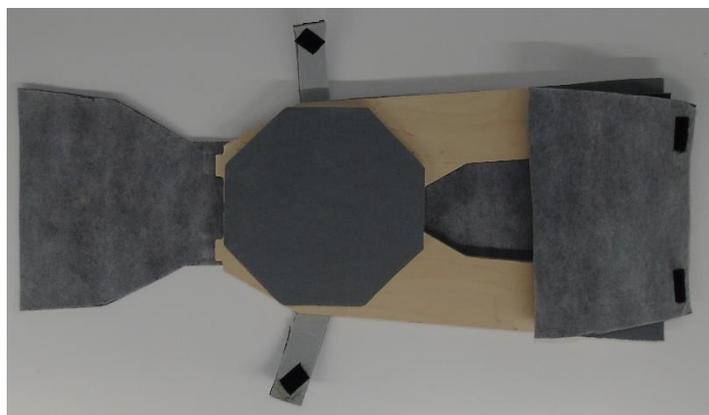
STOOL				
COST OF MATERIALS				
Raw material				
<ul style="list-style-type: none"> · Pine Plywood 120x240x0,9 cm - Price: € 14,32 - Quantity: 4 pieces 				
				Subtotal 1: € 3,58
Subcontracted products				
<ul style="list-style-type: none"> · Spherical cutter Ø4 mm 720040-TRIBON - Price: € 99,90 - Lifespan: 100 000 pieces 				
				Subtotal 2: € 0,00099
				TOTAL PARTIAL 1: € 3,6
COST OF THE LABOR				
Direct labor				
<ul style="list-style-type: none"> · SUPERMAX YCM-40 CNC MILLING MACHINE 3 AXIS STK 14510E - Price: € 4472,84 - Machine / minute price: 0,75 € · Salary 1st: 30 € / hour · Salary 2: 20 € / hour · General expenses: € 0.30 				
OPERATION	OPERATOR	OPERATION TIME	RATE TIME	TOTAL
Programming	First Officer	20 min.	10,000 €	10,300 €
			0,300 €	
Outer contour	Second Officer	15 s	0,083 €	0,271 €
			0,188 €	
Inner contour	Second Officer	25 s	0,139 €	0,452 €
			0,313 €	
Circular cashier	Second Officer	15 s	0,083 €	0,271 €
			0,188 €	
Straight rearing	Second Officer	10 s	0,056 €	0,181 €
			0,125 €	
Subcontracted operations				
				Subtotal 2: € 0.00
				TOTAL PARTIAL 2: € 11,475

MANUFACTURING COST: TP1 + TP2 = € 15,75

8.6 3D MODEL



8.7 FINAL PROTOTYPE









9 PRESENTATION FEEDBACK

Place: Möterum 3, Linköping Universitet, Sweden.

Present: Renee Weber, David Eklöf and Torbjörn Andersson.

Date: 05/24/2017 10:30 a.m.

During the presentation of the final prototype, some changes were proposed that will be mentioned below. But first I will make a little review to the course of the same. It was presented, through a slide show, the influences and the different proposals. Later, a review of the materials used was made and finally, the prototype was presented.

After the presentation, some changes began to be proposed. It was proposed to change the shape of the seat by a circular and slightly increase the surface of the seat; and also reduce the top of the legs, which would fit more with the Nordic style. It was also commented that the height could be too much and we should consider reducing it from 50 cm to 46 cm.

Another proposal was to put color on the bottom of the legs, to give a distinctive touch to the stool. In addition, the holes for the backpack could be maintained, but considering changing the shape of the backpack, and make one in which you can carry more things.

All these changes will be shown below by a photorealistic image of the 3D model.



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