NTNU
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Science and Technology

Designing Outdoor Furniture with Focus on Aluminum Casting

Design av utendørsmøbler med fokus på støpt aluminium

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Industrial Design
Submission date: June 2019
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DESIGNING PUBLIC FURNITURE WITH CAST ALUMINUM

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June 2019 - Trondheim
Master Thesis - Department of Design
Faculty of Architecthure and Design, NTNU

PROJECT DESCRIPTION

AND CHANGES MADE

The project has mostly been completed in accordance with the initial description, however we slightly changed our intentions for the end result underway. Rather than creating a larger series of products, it became apparent that it was more appropriate to create a single modular system that would allow for different uses through different configurations. This change is a result of the analysis and development performed and consideration of production limitations. Additionally, we selected to focus on furniture for public use, both indoors and outdoors, rather than just the latter.

NTNU
Fakultet for arkitektur og design
Institutt for design

Master's Thesis for Emil Lande Eriksen & Trygve Ørjasæter Sørlie

Designing Outdoor Furniture with Focus on Aluminum Casting
Design av utendørsmøbler med fokus på støpt aluminium

The goal of this project is to design a series of outdoor furniture, with aluminum as a part of the aesthetic and structural design. The furniture will be made for outdoor public spaces, and may include items such as tables, benches, trash cans and lighting. Even though aluminum offers great structural properties, it will be relevant to look at other materials in a combination.

The project is conducted in collaboration with Rolvsøy Metallindustri AS, who primarily works with casting and machining of aluminum parts. Their desire is to create a new source of income, independent from their normal operation and external parties, and fill gaps in current production. Rolvsøy Metallindustri AS have facilities for gravity die casting and pressure die casting, of which the aforementioned is the most suitable for medium to large parts in a low production volume. Other materials utilized in the design may entail collaboration with other businesses, likely as local to Rolvsøy Metallindustri AS as possible.

Physical results are emphasized in the project. Analysis of applications which are needed and viable, acts as a base for exploration of material and form to create furniture.

This project may non-exclusively cover:

- Gathering and analysis of information
- User studies and scenarios
- Idea and concept development
- Iterative prototyping with physical and CAD models
- Defining production methods
- Presentation and detailing with scale or full-scale physical model

The project is executed in accordance with "Retningslinjer for masteroppgaver i Industriell design".

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Co-supervisor: Martin Høgh Olsen
Co-supervisor: Harald Vestøl
Business contact: Terje Mass Andersen

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Einar Hareide
Ole Andreas Alsos

ABSTRACT

This assignment was initiated by Harald Vestøl and Terje Mass Andersen where the objective was to create a product to fill gaps in production at Rolvsøy Metallindustri AS. The project has had a focus on utilizing the benefits of casting aluminum to create public furniture that can be valued by the wide array of users. There has been an emphasis on gathering insights from users in both direct and indirect contact, physical prototyping and evaluating competing products. The result is a module system that can create several pieces of furniture with variations, using intercompatible parts with different features.

MOTIVATION

The project was initiated by Rolvsøy Metallindustri AS (RM), as they desired to create a product of their own in cast aluminum, allowing them to fill gaps in production. Their intent was to create one or more pieces of outdoor furniture for public use.

After meeting with RM and discussing the project it became clear that we had very similar interests. Our desire for the project was to work with a physical product with focus on form exploration and a possibility of realisation. Working with outdoor furniture would allow us to explore material aesthetics, form language, production methods and usability. We also felt highly motivated for the project because of its potential to be developed into a commercial product, which RM expressed as an intent.

We wanted to work with a high degree of conceptualization and spread our focus on all parts of the design, from early ideation to working towards production.

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MATERIALS AND IMPACT

ALUMINUM

STRENGTHS AND LIMITATIONS
Aluminum is a very light weight metal at only one third the weight of steel. Its low weight to strength ratio is not only good for creating lightweight and strong products, it also makes it easy to handle and transport, making aluminum an economically viable material with reduced energy costs from transport. Aluminum is very ductile, meaning that it can be shaped into a lot of different products. It is also possible to create many different alloys from aluminum that can serve different uses. Aluminum is well suited for casting.

Aluminum reacts with oxygen, creating a protective oxide layer making it very corrosion resistant. This means that aluminum requires less maintenance compared to other materials like steel or iron. Less maintenance is good for both production budget and the environment.[1]

A downside of aluminum is that it can be fairly soft compared to steel, making it more susceptible to damage and wear. Using the weight of the product as an anti-theft measure can be difficult when using aluminum because of it's low weight.

CASTING AS PRODUCTION METHOD
Casting makes it possible to create many different and organic shapes consistently. It gives a lot of freedom when it comes to form, as the metal is liquid when its poured into the mold, allowing the metal to copy the shape of the mold. Casting is also very efficient as you can eliminate a lot of unnecessary material and manually select where you want extra material for structural purposes.

When metal is poured into a mold it is very hot, and will naturally shrink when it solidifies. This means that the form has to be made to take this shrinkage into account, and allow for extra material to flow in. Another thing to think about when designing for casting is relief angles. Since the metal will shrink when cooled, it will shrink around any crevices and friction combined with the shrinkage will lock the product inside the mold. That is why it is important to have a relief angle of about 3-5° on all surfaces that will enclose a part of the mold. When pouring metal into the mold you want to come as close to laminar flow as possible, this means that it is best for the thickness of the form to be as even as possible. More laminar flow will create better surfaces with less pores and decrease the amount of air within the form.

When designing for aluminum casting we used the bicycle racks for the Trondheim Bysykkel bikes as a practical example for the structural properties we could expect. These racks consist of large and relatively thin shapes that challenge the physical capabilities of the material.

SURFACE TREATMENT

As mentioned earlier aluminum creates its own oxide layer protecting it against corrosion. This means that aluminum can be left outside without any surface treatment. However, since a casting mold will leave marks from split lines and risers, the surface of a part coming directly from the mold will not be very pretty. Designing with these in mind, and thinking of where to place risers and splitlines can be smart when working with cast parts. Cast aluminum parts can be sanded, sandblasted or machined to remove these marks and create a better surface finish. Another solution is to coat the parts in paint to hide any impurities. Corrosion resistant paints that can withstand most weather conditions are available for aluminum.

WOOD

STRENGTHS AND LIMITATIONS
Since casting very large aluminum parts is not sustainable, we wanted to look at other materials we could combine with aluminum. Wood is a natural material that has good structural and practical properties. Because of its cell-structure, wood has a high insulation rating, meaning that it will not feel very hot under warm conditions and not cold when its cold.[2] Other materials like steel will get very uncomfortable during extreme heat and cold. Wood will absorb moisture, meaning that it will not collect puddles of water on flat surfaces, making it suitable for sitting. Wood can be laminated to make it stronger and more reliable. It is relatively cheap when compared to other materials, and is easy to source.

Most types of wood can be treated with various surface treatments such as oil and wax that give different looks and properties. Some types of wood can also be chemically impregnated to prevent threats such as fungi and insects and prolong the woods lifetime. When used right and the right type is used, wood can be a very sustainable choice as it is naturally grown and removes CO2 from the atmosphere.

Although wood can have good structural properties when used right, it is weaker than metals and is exposed to twist and distortion with changes in humidity and temperature. The amount of twist and distortion varies with different species of wood, and from what parts of the tree the wood is collected from. Hardwoods like oak and ash are less prone to distortion than softer types like pine and fir. Another negative factor is discoloration, as wood absorbs moisture, it will be exposed to discoloration when introduced to different liquids. Wood will generally require more maintenance than metals, and since it is softer it will also be more susceptible to vandalism and general wear and tear.

In benches and tables, wood is often used as either laminated plates, or as planks. The advantage of using plates is that it will give a smoother surface. The disadvantage is that it will require an inclination or some sort of drainage to drain away rainwater. Another advantage is that the plate will more evenly distribute force, whereas in a plank formation, some planks will often take up more force than others.

TREATMENTS
Wood treatments that are suitable for public and outdoor use can be divided into two groups: Oil-based surface treatments and impregnation.

Softer wood types are often impregnated. Impregnation consists of applying active substances to the wood that provide protection through the toxicity of additives such as copper and other biocides. The negative effect of using toxins like these are that they often have adverse environmental properties that can affect the environment and humans over time. An alternative method for achieving durable wood that does not involve use of biocides or heavy metals is treatments such as Kebony. Kebony uses a bio-based liquid, derived from waste products from agriculture, to enhance softwoods. The treatment works on a cellular level, making the wood more stable and resistant to rot and fungi. Impregnated woods can be maintenance free, receiving a natural grey patina when left untreated.[3][4]

Hardwoods are usually not suited for impregnation, as they are much denser and do not take up toxins as well as the softwoods do. However, since hardwoods are denser, they are naturally more durable and are more resistant to rot. Hardwoods are often treated with oils and or waxes that penetrate the outer surface of the wood, creating a protective layer that reduces the amount of water absorbed by the wood that can lead to rot. Hardwoods will receive a grey patina if left untreated, but when treated regularly with oil the hardwoods will keep their natural color.

To choose the right types of wood we looked at the species that can be grown sustainably, are not endangered and that can be sourced from either within or close to Norway. We talked to Pasi Alto, the centre director for NTNU wood, who recommended pine, fir and oak as sustainable and good choices for wood in an outdoor application.

We have also looked into using planks made from recycled plastic, but have disregarded these as viable since wear and tear will produce microplastic waste, and because they lack the aesthetic properties we desire.

ENVIRONMENT

MATERIALS

We believe that it is important to choose materials that are sustainable, either through being naturally grown and decomposable, or by being eligible for recycling. With increased environmental focus in society as a whole, creating products with the environment in mind can be a win-win-win for producers, users and the environment. By showing buyers that a product is environmentally friendly, producers can increase sales, environmentally aware users will appreciate the product more, and the environment will suffer less impact.

ALUMINUM

Aluminum is the most abundant metal on the earth's crust and approximately 75% of all aluminum that has ever been produced is still in use. Aluminum is separated in primary and secondary aluminum.[5] Primary aluminum is pure aluminum mined from the earth's crust, while secondary aluminum has been used as something else, melted and recycled. Secondary aluminum is almost exclusively used in gravity die casting because it is more cost effective. Using secondary aluminum requires only 5% of the energy required to produce primary aluminum.[6]

WOOD

Wood is a renewable decomposable resource that will convert CO2 as it grows It's important to be aware of where the timber used derives from and that some types of wood are more sustainable than others. Certification is proving to be more and more important for timber producers, and certificates such as Svanemerket and PEFC are used to ensure sustainable and environmentally friendly timber production.[7][8] It's ok to use timber from species that grow slow and in limited numbers, as long as production is sustainable and controlled. Most softwoods are fast growing and are better suited for sustainable production, as resources used can be replenished more quickly.

CONSTRUCTION

It is important that the product is easy to disassemble to make recycling easier and more effective. By designing the product for disassembly you make it easier to properly discard each material when the products life cycle ends.[9]

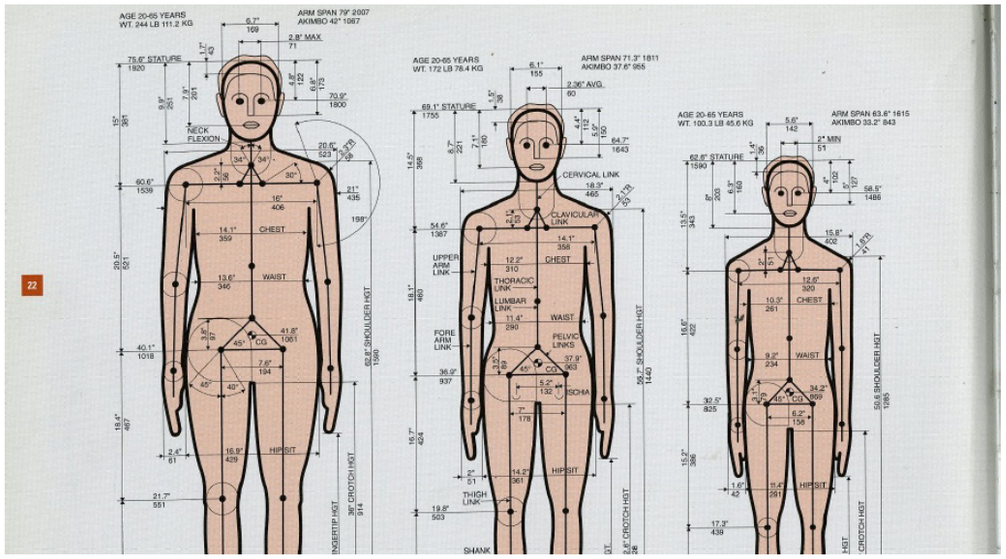
USER

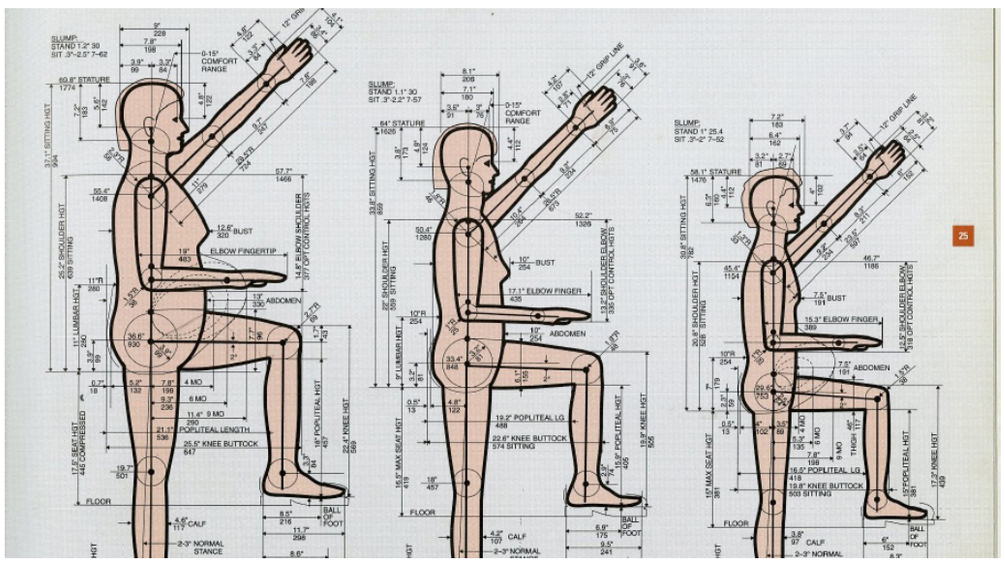
ANTHROPOMETRICS AND ERGONOMICS

One of the ways that the users introduces “limitations” to furniture design is through their physical aspects, namely the specific dimensions of their body. Ergonomics is the process of adapting a design to the intended user using anthropometrics, which is the process of describing the human body through measurements and percentiles. Percentiles are a way of dividing up the population by the percentage of people with lower or higher values.

The Measure of Man and Woman provides a good indicator of appropriate dimensions and measurement of the population. They provide extensive measurements of men and women in 99, 50 and 1 percentile. This means only 1% of the population is taller or larger than the 99 percentile, or shorter or smaller than the 1 percentile. The 50 percentile is the average of the population. In addition, the book also recommends dimensions for different types of sitting positions, depending on the nature of use.

When deciding furniture dimensions based on anthropometrics it is important to consider which are reach and clearance dimensions, as this defines whether the larger or smaller measurement is critical. The seat depth would be a reach dimension as it needs to be short enough for the smallest person to reach all the way to the backrest or else they would slump. The length of the bench, or the seat width, would be a clearance dimension as it needs to be large enough for the intended amount of largest persons to fit side by side.





The height and depth of the seat is defined by the popliteal (back of the knee) height and depth, which should be mainly considered as reach dimensions. For the 1 percentile female these are 381mm and 418 mm, respectively. However, if these dimensions are made too small they will negatively affect the sitting comfort of the larger part of the population. A smaller seat will reduce the distribution of weight as less of the thigh is on the seat. A lower sitting height will likely pull the knees up from the seat and place more of the weight at the ischial tuberosities, commonly known as the sitting bones, which is the part of the pelvis that has contact with the seat. Placing too much weight on the sitting bones will become painful over time. The length of the bench, or the width of the seat, will have to consider the largest width of a person, which is the shoulder width of the 99 percentile male and it is 523 mm. However, the width of well over half of the population is just above 450 mm.

Regarding a backrest for the bench, the aim should be to at least provide proper lumbar support and have an angle suitable for relaxation without sloping too much backwards. According to The Measure of Man and Woman a backrest need to be 292 mm high to provide lumbar support for most, but the lumbar height while seated for the 99 percentile male is stated as 300 mm. It also states that if the backrest is no higher than 400 mm, the user will be able to reach over the back with their arm, which could be preferable. For the seat angle, the book recommends 90-105 degrees between the seat and back for a more attentive sitting position and 105-115 degrees for a more relaxed position, both with a horizontal or slightly angled seat.

Placement of the users arms will be affected by the height of the armrests and the table height, if the user is sitting by a table. For armrests, The Measure of Man and Woman recommends a height between 191 mm and 254 mm, depending on whether it is a large or small user. However, these are recommendations for work chairs where the user usually sits with their arm straight down and elbow bent at a 90 degree angle. This might be too low if the armrest is supposed to be an aid in standing up and sitting down, so a taller armrest might be sensible. For a 99 percentile man to reach down to the armrest from a standing position, it needs to be 751 mm over the ground. When sitting at tables like dining tables or work tables it is common to have a height taller than the placement of their elbow straight down. The distance between the seat and the underside of the table needs to be more than 197 to clear the thighs of the 99 percentile male.

Given the information from The Measure of Man and Woman we established a set of intervals for the main dimensions. They serve as an indication and many of the dimensions will be dependant on others, so testing will be necessary.

Seat height:	400-500 mm
Seat depth:	380-450 mm
Seat width:	1400-1600 mm
Back angle:	90-115 mm
Back height:	300-400 mm
Armrest height:	600-800 mm
Table height:	600-800 mm

INVOLVING THE USERS

Public furniture as a product is to be made available for the entire public, meaning it must accommodate almost everyone rather than a specific user group. Additionally, the product is not necessarily used as furniture for long periods of time and it's aesthetic appeal in the space might be considered as important as comfort.

To ensure we would accommodate the users properly we conducted informal interviews about public furniture usage, mainly with elderly as users with any degree of physical impairment are most affected by decisions regarding ergonomics. We also conducted observations of how public furniture was used in the Trondheim city center and the surrounding areas along the river, to establish what normal usage was.

INTERVIEWS

The purpose of the interviews was to define what features were important to aid physical impairment and two features stood out. A backrest for the bench was considered important to properly relax and sit for longer periods of time. Armrests was important for standing up and sitting down. For some, the armrest was a matter of comfort, but an absolute necessity for others. Some public benches might be considered unavailable because of a lacking armrest.

OBSERVATIONS

We wanted to establish what people needed and wanted from the furniture and decided to use observations to avoid subjective answers from people. Our intent was to observe for how long people sat down, how many people used a piece of furniture at a time, how they used the features of the furniture and which specific activities were performed while sitting down.

We had assumed beforehand that we would likely see people sitting down for varying amounts of time, some of those being very short periods. However, all of the people observed sat for more than ten minutes. Based on activities performed and sitting positions, we would estimate for well over 20 minutes for most of them.

Based on the interviews, we assumed we would see armrests used extensively by elderly and this was also the case, even more so than expected. Every elderly person we observed had positioned themselves at the end of their bench, indicating use when sitting down and standing up. Most also used the armrest while sitting. Interestingly, we also observed that practically every person that was assumed to be below 60 years of age positioned themselves at the middle of their bench, not using the armrest at all. However, we did observe that in the same group of people, a large number would use the top of the backrest as an armrest. When people sat together this would often be the case, as they sat sideways to face each other, placing the backrest at their side. Another trend we observed was that people below 40 would very often sit hunched forward while using their phone, not utilizing the back rest at all. We also observed several young people sitting this way without using their phone. This led us to suspect that

phone usage has had a significant effect on how people sit.

The most common activity performed while sitting down was phone usage and there was also several people who sat down to eat, either meals or small snacks. A fair number of people seemed to be taking a short break, either from a walk, bicycle trip, walk with a stroller or from shopping. The most unusual activity was people sitting down to just observe the area around them. We also observed a few people laying down on benches, just to relax or take a short nap. Close to half of the cases were people sitting alone, but most sat down with someone else. In a couple of cases there were large groups of people together, leading them to occupy two or more benches and also sit on the ground.

SCENARIOS

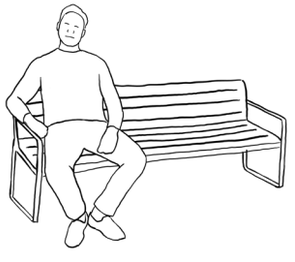
Based on the observations we wanted to create a set of scenarios depicting how people use benches. People's sitting positions are dictated by what is comfortable for them, how many people are sitting down together and what activities they are currently performing. From our observations we have compiled the following reasons for why people usually will utilize a public bench:

- Taking a break from a trip on foot
- Taking a break from a trip with bicycle or stroller
- Taking a break from shopping
- Sitting down to eat a meal or snack
- Sitting down to read or use phone
- Sitting down to look at surrounding area and people
- People sitting down to talk to each other

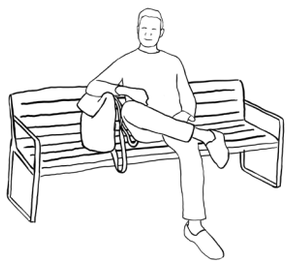
Our findings are summed up in the following visualizations, depicting people's sitting positions and their behaviour alone or with other people. These will act as our definition of usual behavior moving forward in the project, enabling us to evaluate ideas, concepts and design decisions with the users in mind.

Sitting at the middle of the bench, leaning back against the backrest.

Sitting at the middle of the bench, leaning forward with their elbows on their thighs.



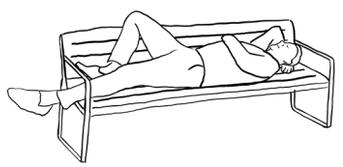
Sitting at the end of the bench, using armrest either while sitting or getting up and down.



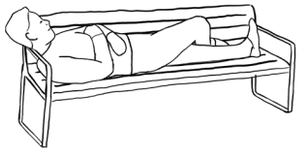
Sitting at the middle of the bench, using their backpack or other objects as armrest.

Sitting at the middle of the bench, using the backrest as an armrest.

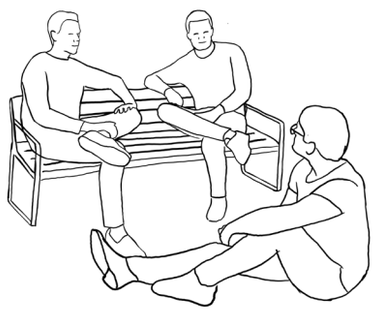
Sitting at an angle to face the other person they are sitting down with.



Laying down flat on the bench and completely relaxing the body.



Laying down on the bench, leaning back against the armrest to prop themselves up.



Sitting down as a larger group, requiring several benches or standing and sitting on the ground.

USE AND ABUSE

UNINTENDED USE

We expect the furniture to be used mainly like we observed in our user observation: By people sitting, however, this is not always the case. What we didn't observe, was unintended use such as climbing, skateboarding, graffiti and vandalism. Although we didn't see these uses, we have to be aware that they exist and try to design with them in mind.

DEFENSIVE DESIGN

In a lot of cities around the world, use of certain urban places is discouraged through designed objects. Birds are deterred with spikes and predator-imitating kites. Metal spikes and studs are preventing skateboarders from using rails or edges to perform tricks. Uncomfortable bumps and spikes along ledges prevent people from sitting on them. Benches are designed with extra arm-rests and edges that make them uncomfortable or even impossible for homeless people to sleep on. These objects alter the way we perceive the urban spaces, and is by some people viewed as a solution that will only make homeless people and other users affected feel excluded from society.[10]

"While designs can encourage positive behaviors, often they are designed to stop the opposite. Defensive design goes by many names: hostile architecture, dystopian planning, natural surveillance. But the goal is all the same: control behavior and limit the ways an object or space can be misused."

-Carlos Waters[11]

THE CAMBDEN BENCH

The Camden Bench is a piece of concrete furniture designed to decrease unwanted behaviour. The two tonne concrete bench is made with no cavities in order to limit drug deals. It has sloped surfaces on all sides, making it difficult to lie on, while at the same time limiting skateboarders. It has become a symbol of hostile architecture, and has received both criticism and design awards.

OUR VIEW ON USAGE

While defensive design can be effective in limiting unintended use, it can also affect other users and uses that are not harmful or unwanted. Unintended use often stem from a deeper source, such as a lack of homeless shelters and skateboard parks, and could therefore be limited in other ways.

Another way to contradict defensive design is by asking if the unintended use really should be avoided. Should we instead let homeless people sleep on park benches and in that way raise awareness that some people are without shelter?

We do not want to have a big focus on limiting certain uses with our design. A public bench should be a place for everyone to take a break and relax, regardless of who you are. We believe it's important to treat every user with respect, and want to focus on designing for users and use, and not against.

The picture above shows how a bench can be designed to be resist wear from skateboards instead of preventing.

PUBLIC SPACES

SPACES

It was our intention to create furniture that would be suitable for most public situations and spaces. For this to be possible it is necessary to achieve a certain balance in the visual language, to function in both formal and informal situations, calm and energetic and so on.
An interesting additional note on public furniture is its tendency to be immobile, either because of weight or being fixed to the ground. This is often an anti-theft measurement or it may be desirable to achieve a static placement and division of a space. The following spaces are the ones we wanted our furniture to be appropriate for:

- Streets/walkways
- Squares
- Parks
- Transportation hubs
- Public buildings like museums
- Outside restaurants/cafés

Adapting furniture for a public space means taking several factors into consideration. The space inhabits users, both the ones using the furniture as physical objects and the ones considering the furniture as a visual element of the space. The users will interact with the object in both intended and unintended ways. These factors have been mentioned previously, but as part of a situation they affect the mood and feeling of the space, which can either be substantiated by the furniture, as part of the space, or attempted to be altered toward a mood and feeling that is deemed more desirable. Additionally, there will be different wants for what kind of attention the furniture is to generate. It might be desirable for the furniture to blend into the space or to stand out, either to draw attention to itself or to something in connection with it, like a storefront.

Creating a single design that will feel at home in such varying environments is rather unrealistic, but if the design is created with customizability it can be adapted to fit in, given that the form language is versatile enough. For a café you might want a calm and informal atmosphere. A bench outside a bank should maybe be more formal, use more high-end materials and enhance the presence of the bank rather than itself. In a park you might want to have furniture that will blend into the greenery. Furniture for train stations can be made to feel energetic to communicate mobility and transportation. There are a vast number of different situations and ways of adapting for them using form language, color, materials, reflectivity and so on.

WEATHER

As most public spaces are outdoors, weather will have a significant impact on the form and material of the design. Outdoor furniture will be subjected to rain, snow, sunshine, dust, pollution and other factors leading to wear and tear. These factors will also affect usability and aesthetics, depending on decisions on material and form topology.

Avoiding the collection of water and moisture is important for outdoor furniture and increasingly so when wood is part of the construction. To a certain degree, moisture is unproblematic as wood naturally absorbs it, but without proper drainage, rainwater and melted snow will collect. Collections of water will usually not look good, wet seats will deter users and in the long term this could lead to structural damage. The wood is especially at risk in places with end grain or where the wood is cut across the fibers, as this leads to open capillaries in the wood, which more easily absorb water.

An interesting effect of the weather is the fact that it will age materials, altering their look over time. This effect will depend on the way the material is treated, and possibly retreated if continuous maintenance is intended. Aluminum is naturally resistant to wear and tear, so even untreated it will likely stay much the same. Wood on the other hand, will have a more visible transformation. It is possible to either counteract this with treatment, but also possible to embrace it, choosing a treatment that will protect the wood, but intentionally let the wood appear aged.

MARKET

CLEAR INTENTIONS

We started by doing extensive collection of existing designs of public furniture from all over the world. While doing so we found that many designs that are meticulously crafted with aesthetics in focus are not usually the ones you see in the real world, even though they are impressive when viewed online. Being aware that our project has a focus on realism and actually being produced, we realized we were looking to much into projects that were made to look impressive. The furniture that can actually be found in the public space are usually much more grounded, focused on production, efficiency and viability. With this in mind, we directed our focus towards developing concepts focused on aesthetics, but with a demand for realism regarding production and cost.

INTENDED MARKET

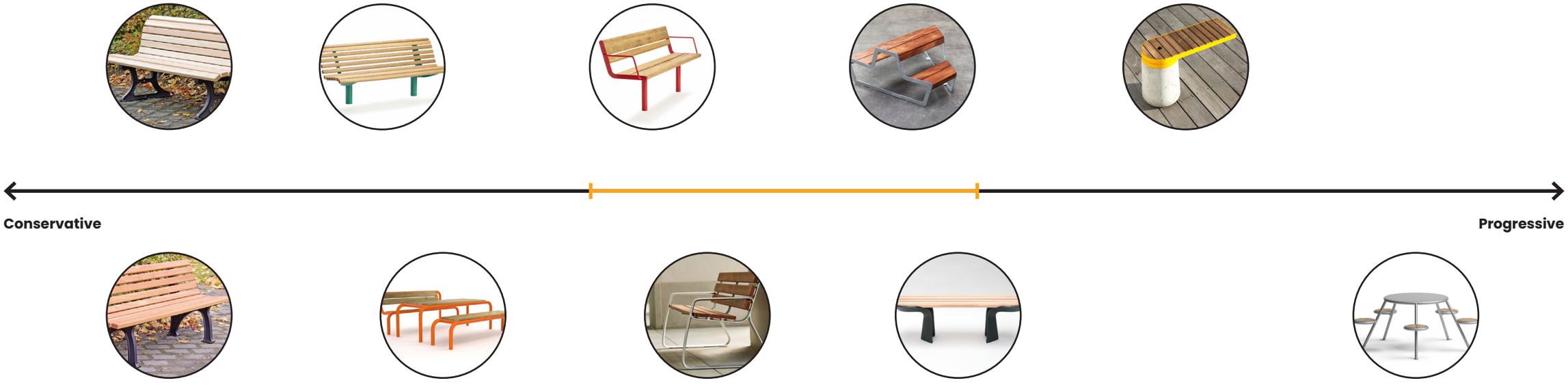
PLACEMENT

PRICE RANGE

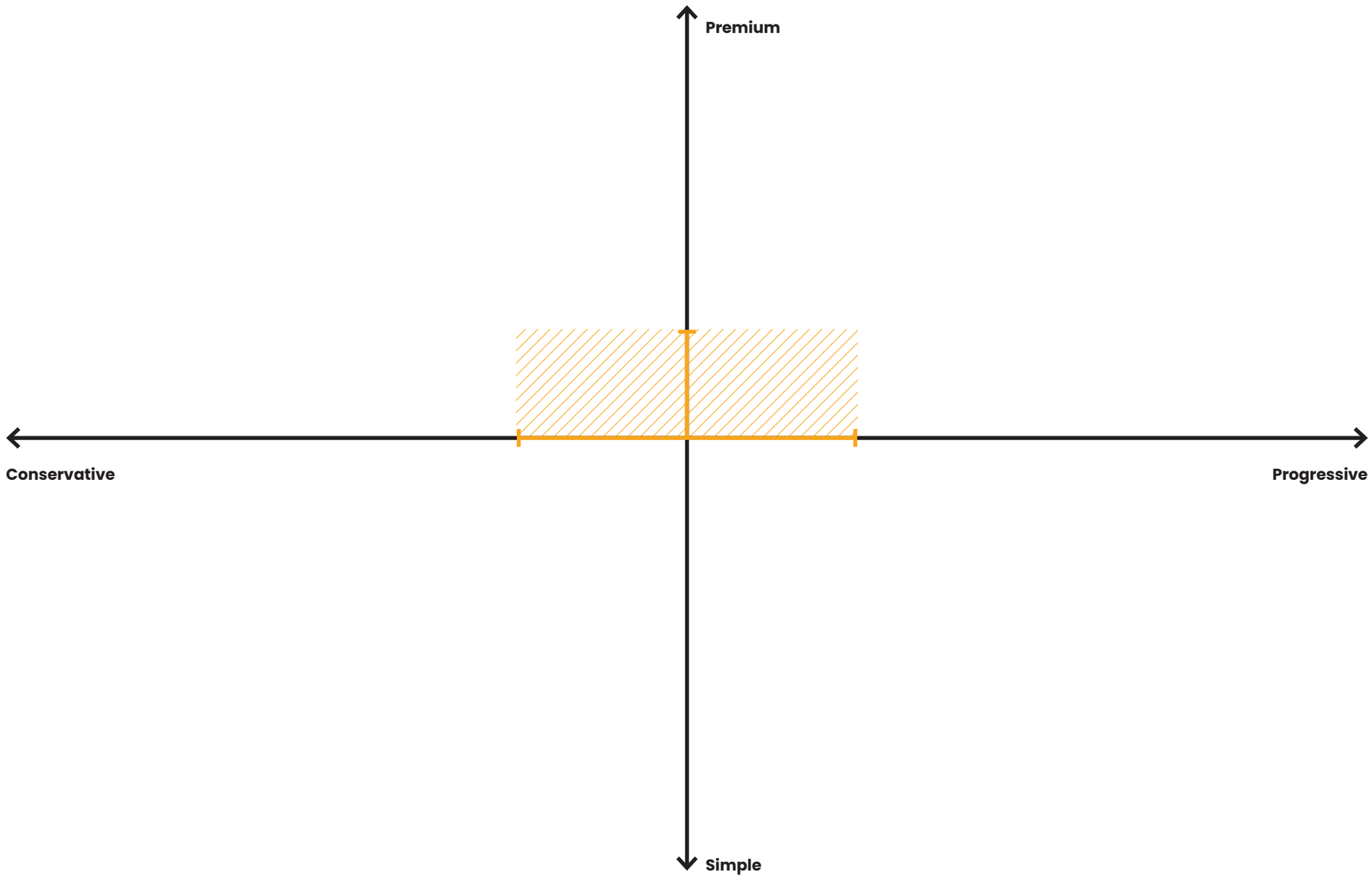
We want to position ourselves slightly above the average. We do not intent to create a very expensive and exclusive product, but we want the product to be exciting and of quality. As such, we want to have a large variety of materials and treatments available, which requires a slightly higher price. However, not so high that the product is unavailable for the general public space.

FORM LANGUAGE

We want the product to be exciting and we want the project to focus on form exploration, but as previously mentioned, appropriate for a variety of common places. Furniture with very radical aesthetics and perhaps more focus on artistic expression than usability will only work in some situations and spaces, which is undesirable. We will focus on functionality, but we want to move away from conservative visual language, so our position is around the average.



MARKET MAP
This map shows how we have evaluated the market and our intended placement in it.

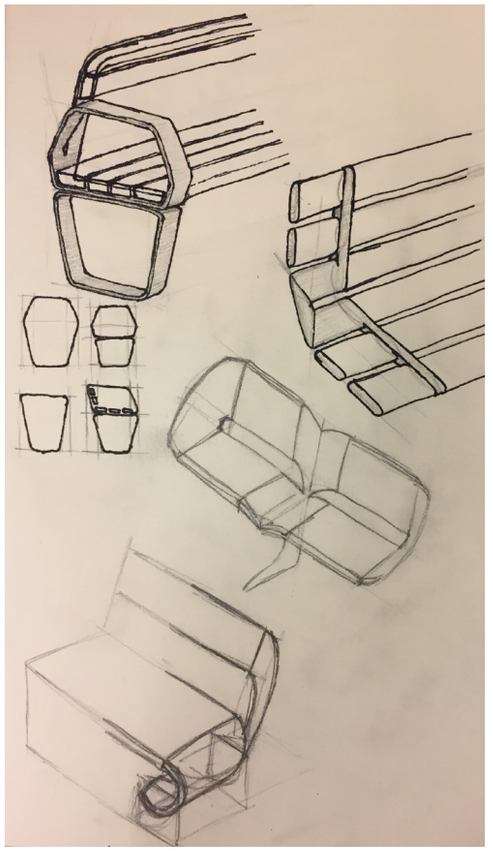


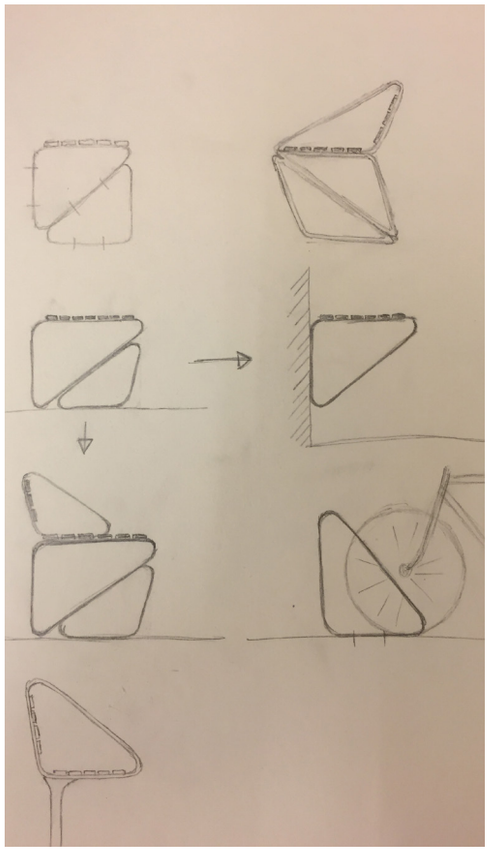
FINDING A THEME

INITIAL IDEAS OF FORM

We started to ideate fairly broad, as we had a very open brief. Much of the initial exploration focused on the interaction between the aluminum and wood and overall shapes for benches. As we knew the structural parts would be cast, we focused a lot on exploring freeform and complex shapes. This quickly led to many extravagant form languages, which could be perceived as a more exclusive look than we intended. With this, our form exploration rapidly became more detailed was productive and we decided to take a step back.

We decided on creating more simple and quick sketches to make exploration more rapid and using industrial production as an over-arching theme, especially focusing on shapes that would benefit the process of casting aluminum. It quickly became apparent that it would be beneficial to have mirrored parts, that can be used on each side of the bench, reducing the number of cast parts by half. Additionally if the cast parts are made to allow the wood to pass through, the bench can be elon-gated and allow more variations of construction.



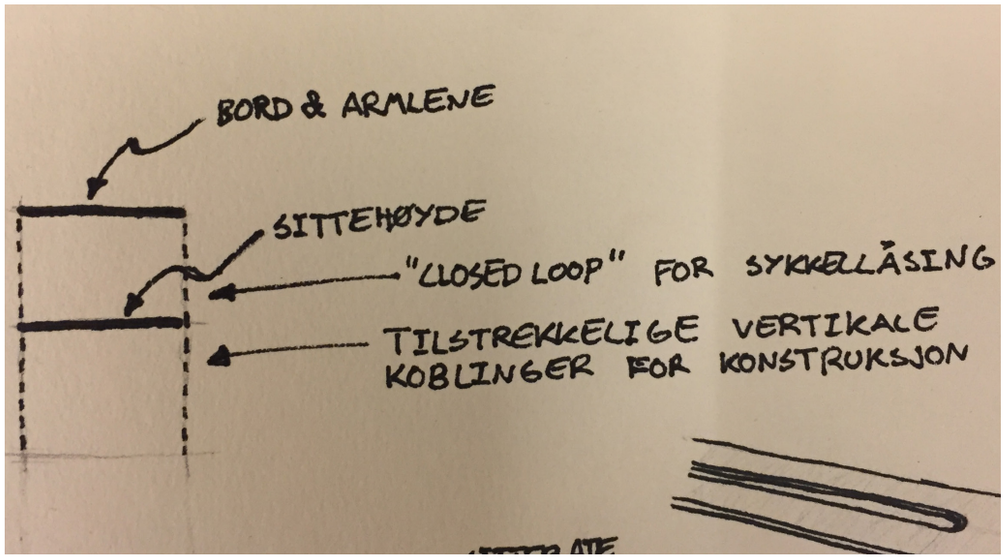


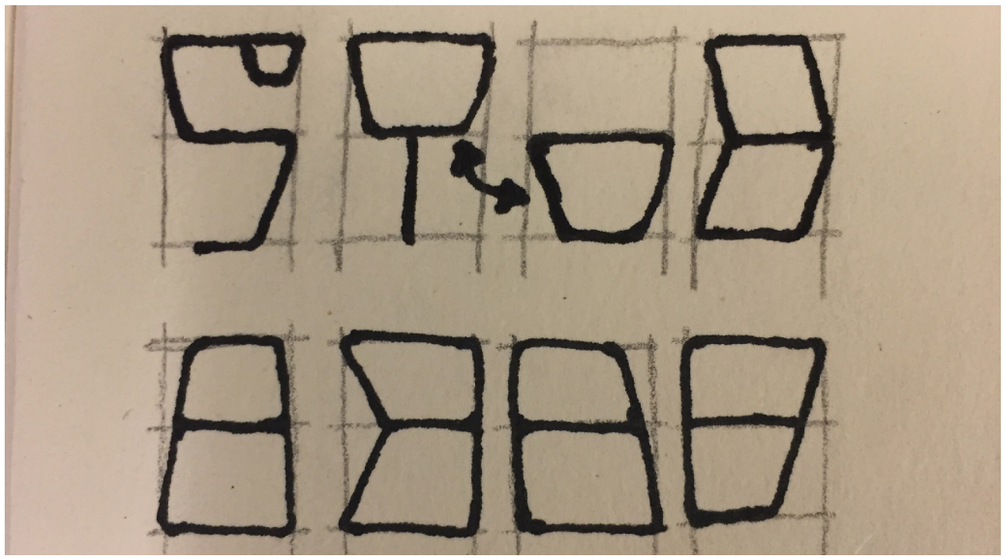
CONCEPT DEVELOPMENT

SEVERAL PRODUCTS FROM ONE PART

Our initial concept stemmed from our exploration of a form benefitting the casting process. The viability of a product made from cast part is heavily influenced by the number of casting forms that must be produced. So the fewer tools for a single product, the easier it is to create profit, lower product price and reduce investment risk. The intent of our concept is not only to create a piece of furniture that would only require a single cast part, but several pieces, all using the one part in combination with wood. This would create a highly cost efficient series of products and probably a series with the same defining part creating a clear common language. This solution was meant to at least provide a table, variations of benches and possibly bike racks and trash cans.

Initial exploration of this concept was limited to very basic sketches, using only a few lines to describe a shape. This was done to discover the basic shape-components needed to accommodate features from different types of furniture in a single shape, and explore how altering the overall shape would affect functionality. We defined a framework for exploring different shapes consisting of two horizontal planes for table/armrest and seat, vertical connection that could give a backrest and with a closed loop somewhere it could act as a bike rack as well. These requirements acted as the basis of further exploration with simple sketches. Some shapes were also tested in CAD to inspect how different furniture would interact.





EVALUATION

While working with basics shape for the concept we quickly discovered some issues and decided to properly evaluate the concept before moving on. The positives have largely been mentioned, but the following are the strengths of a series using the same aluminum part with wood passing through.

- Only one casting mold will lower cost drastically
- With one part being used so much, each part will be drastically cheaper to produce
- Wood passing through the construction allows for variation and customizability
- Using the same part as a defining part of each product should create a common form language

However, we also discovered some problematic issues as well as some unwanted limitations.

- It would be impossible to create a bench without armrests
- The armrests would limit access if benches are used with a table
- The amount of requirements will restrain some configurations a lot visually

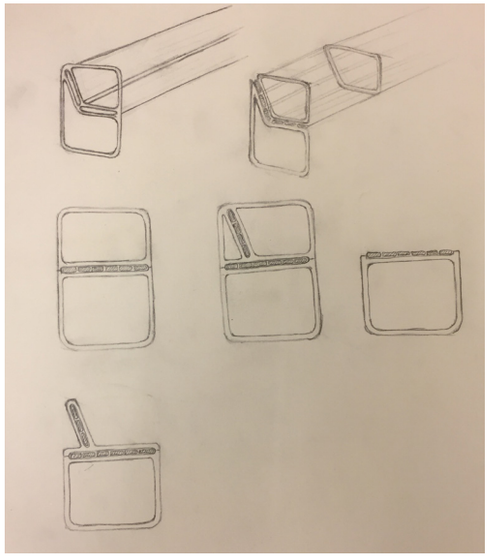
The most significant issue with the concept is that we could not see a proper way in which the bench would work with the table. It would become very difficult to get in and out of and probably be unavailable as a furniture for most with physical impairments. The only possibility we could see was to either make the backrest very unergonomic or remove it all together. We could also try adding parts to make the design work, but both measures would negate the whole point of the concept.

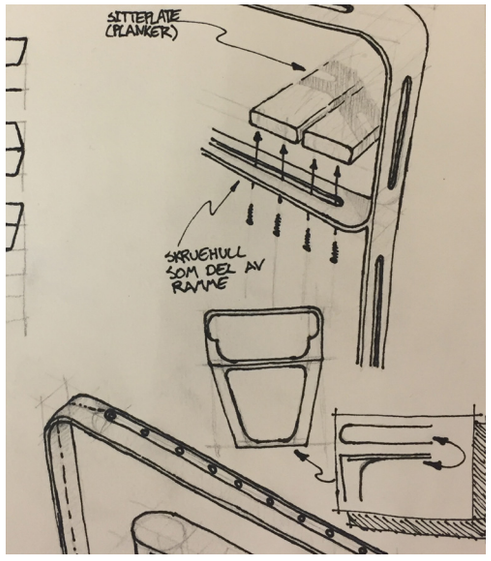
DIVIDING THE ENDS

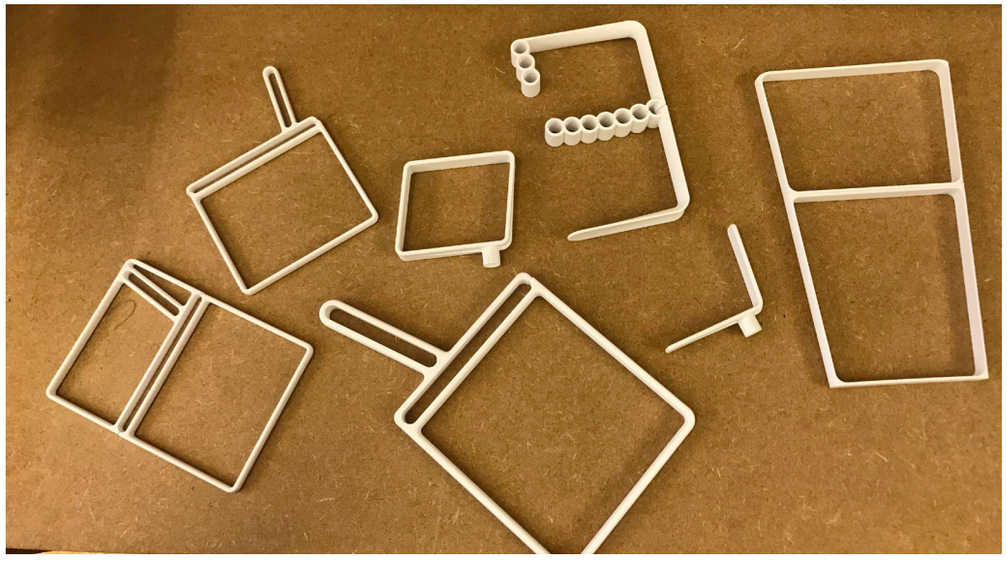
The issues of the concept were too significant to ignore and we had to alter the concept. Wood passing through the aluminum parts and mirrored parts on each side of the furniture would of course be preserved as they did not affect any other features and were critical to enable as much variability as possible. However, rather than limiting ourselves to only part we explored how these ends could be divided, such that the part count was as low as possible without affecting functionality or aesthetics. As long as we kept the part number low and ensured customizability and variability, the main intention of the concept would still be preserved.

At this stage we created more detailed sketches and 3D-printed simple models in scale to evaluate them. Being able to evaluate ideas physically provided much more nuanced impression. It was also easier to spot structural problems with the shapes by seeing how the prints would bend and locate the critical areas.

We did not want to hide away the fact that the ends were split and we looked into how this could be a feature of the design instead. How the wood and aluminum interacted was also of interest, especially with the wood passing through and if it might have to be joined along the way.



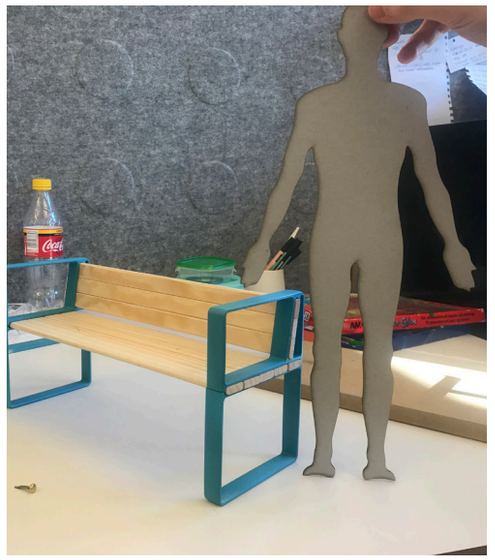




ITERATING AND IMPROVING

A MODULAR SYSTEM

The ideas we developed eventually moved towards a modular system, where the same parts could be used in different configurations in order to create several combinations of furniture. We designed the parts to be intercompatible, making them more versatile.



USING STANDARD PARTS

After first working only with cast aluminum parts, we looked into using standardized aluminum parts in combination. We did this because standardized tubes and other items are very cheap and readily available, making them beneficial for production while allowing us to explore even more possibilities and forms. We added a new part to the concept that is meant to be attached to an aluminum tube that is cast into the ground. This means that the tube will define the height of the bench, allowing it to be any height. This again means that the bench can be heightened to be used as a table, making the parts even more versatile. Another great benefit with using a tube cast in the ground is that the bench won't be as dependent on level ground to be stable, meaning that a lot more locations will be available.

DETAILING

TESTING THE ERGONOMICS

We used a rig we have made specifically for testing ergonomics and seating dimensions. The rig is made to test seat height, backrest angle, backrest height and armrest height. We chose users with a wide range in dimensions, to get feedback from different sources. The dimensions we used were mainly within the recommendations from Measure of Man and Woman.

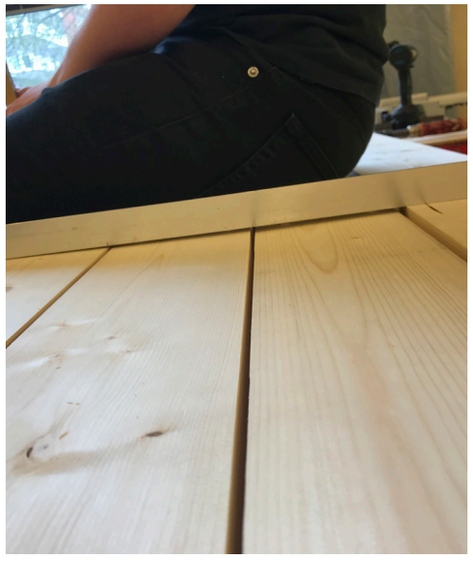
We also went on a field trip around Trondheim to test different benches and take measurements, to get an overview of the different dimensions that are already in use throughout the city.

We used the measurements from the test rig and the field trip and iterated with these and our CAD-model to find the best suited measurements for both ergonomics and aesthetics.

PLANKS AND STRUCTURAL TESTING

After talking to Pasi Alto about different types of wood, we made a structural test to see how strong we could expect the planks to be, and how long they could be without flexing too much under load. In the test we started out with boards that were 2 inches thick, and slowly shaved them down until we had the desired thickness. The width of the planks are defined by the dimensioned set from testing. The two planks in the backrest are similar to the outermost planks on the seat and are what defines the width of the two inner planks. The radius on the edges is there to make all the planks appear similar in width.

When testing we discovered that the planks would flex more in the front of the bench, as these were the ones receiving the most load. We found that by connecting the planks with an aluminum profile on the bottom, the load would be spread out much more evenly. We found that a thickness of 38-40 mm is the sweet spot for strength and aesthetics.



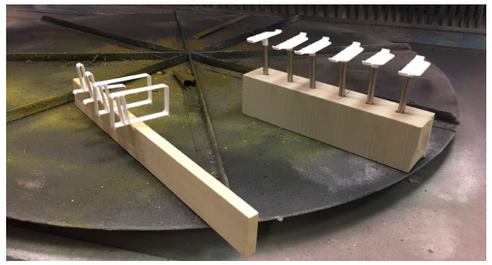
PROTOTYPE AND MODELS

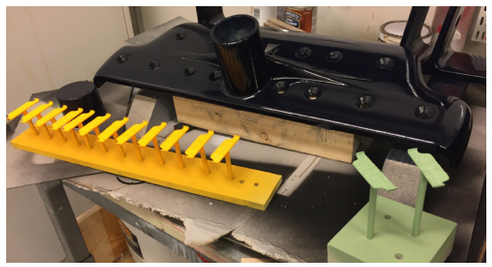
WORKING PROTOTYPE AND

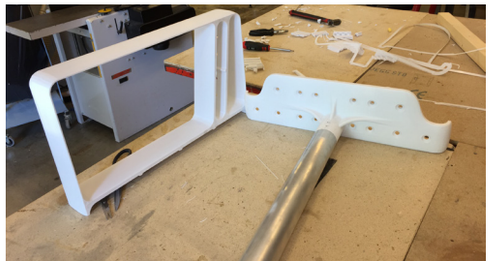
1:10 SCALE MODELS

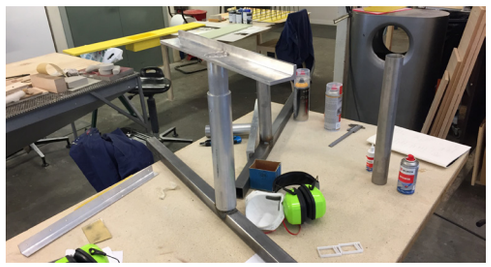
We wanted to create an accurate representation of the product with a full scale prototype with the right colors, materials and ergonomic measurements in order to see if our ideas and designs translated well into full scale. The model is a 3D-printed shell with an aluminum frame hidden inside to make it strong enough for testing. The wood is Kebony Clear, made from radiata pine, sponsored by Kebony.

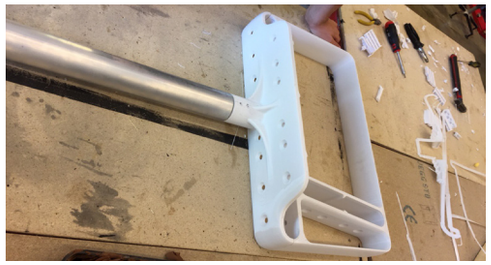
Since the modular system can create many different combinations we also wanted to create small scale models that could show some of the different combinations available. We used Kebony and oak to display our main choices of wood and both the full scale prototype and scale models were painted with accurate RAL-colors.

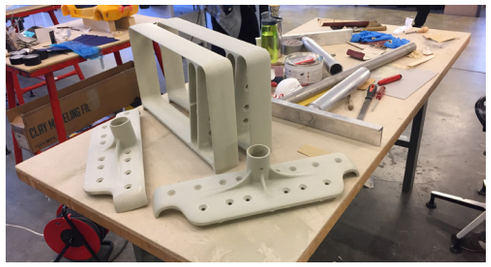












FINAL DESIGN

CHOICES MADE

The final design consists of a modular system containing four cast aluminum parts, standardized aluminum tubes and wooden planks. The wooden planks are made from either Oak, Kebony treated pine, or linseed-impregnated pine.

FINISHES

We have selected a set of four finishes for the aluminum parts and two types of wood, based on the different environments and situations considered. For the aluminum we have chosen the following finishes.

- A sand blasted finish to show of the aluminum itself.
- RAL 1028, an energetic and lively colour for playful areas.
- RAL 5004, a calm and stable colour suitable for formal and modern locations.
- RAL 6021, a friendly color that is informal without being flamboyant.

For inside use we recommend using a hardwax oil on oak, and either naturally oiled or untreated kebony. Outdoors we recommend oiled oak, Kebony pine, or linseed-impregnated pine.

RAL 1028
Melon yellow

RAL 5004
Black blue

RAL 6021
Pale green

CONFIGURATIONS

The modular system can be used in a lot of different configurations. By utilizing the extended wooden planks cut in different angles, the different backrest options and the different legs, one can create benches and tables for most scenarios.

Listed are just some of the different possible solutions:

- Bench/table extended with several legs in straight line
- Extended bench with corner bends
- Extended bench in zig-zag pattern
- Extended bench in many-sided loop
- Extended bench with backrest on alternating sides
- Amphi stand

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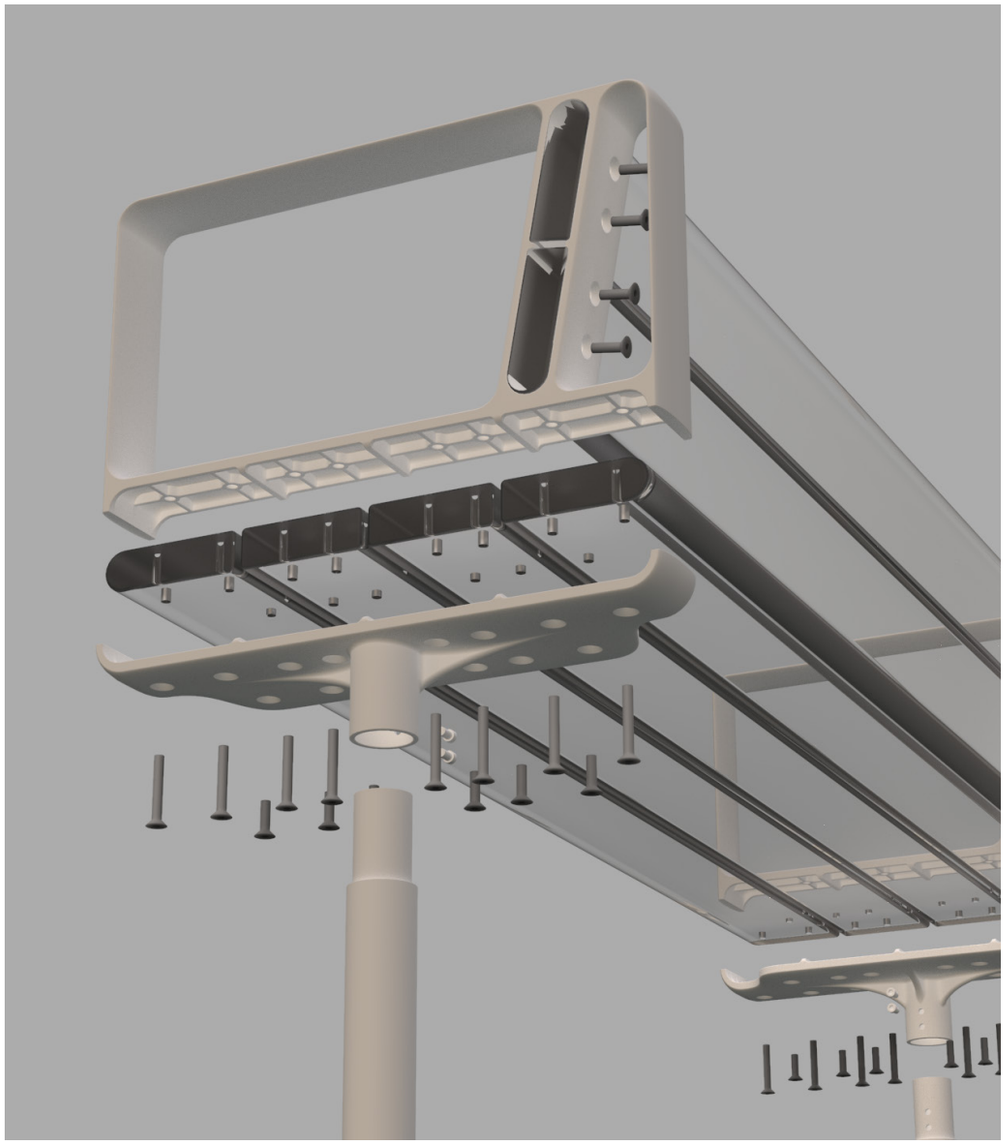
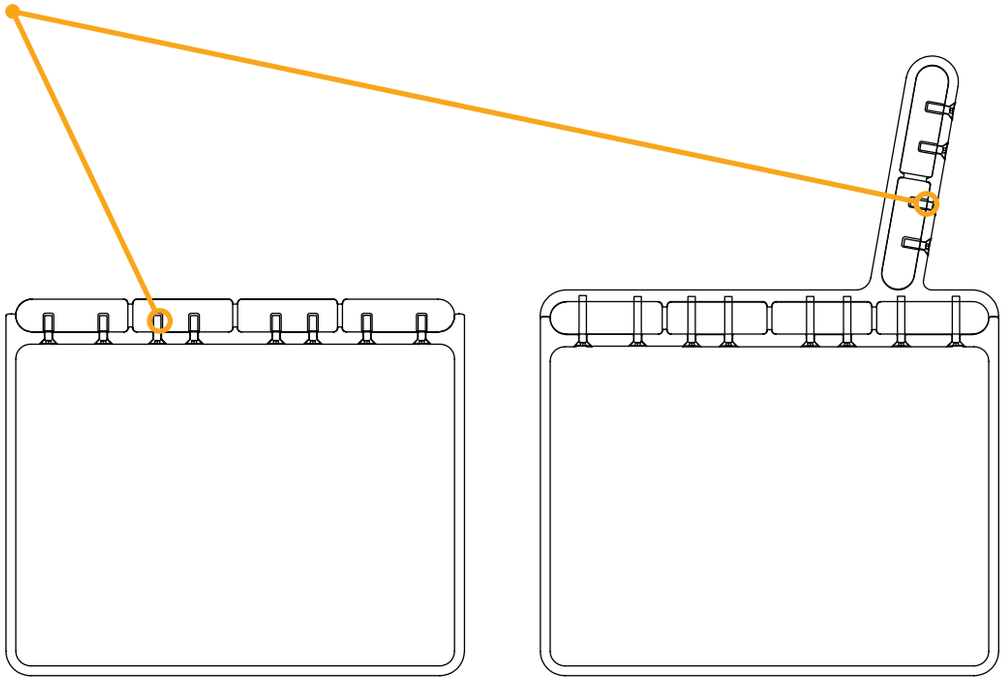
PRODUCTION

The aluminum parts are made specifically for aluminum casting, shelled with structural ribs to save material while keeping strength. After casting, holes in the top part will be threaded, to allow screws to attach the top part to the bottom. In a configuration without the top part, threaded inserts are screwed into the planks to allow machine screws to attach the planks to the aluminum parts. The backrest also utilizes threaded inserts. The end of a standard Ø60mm aluminum tube is turned down to Ø50mm and inserted into the cast bottom part where it's secured by two screws. All screws except the ones securing the tube are countersunk. The planks are cut to length and width, rounded, and drilled where needed for the specific setup.

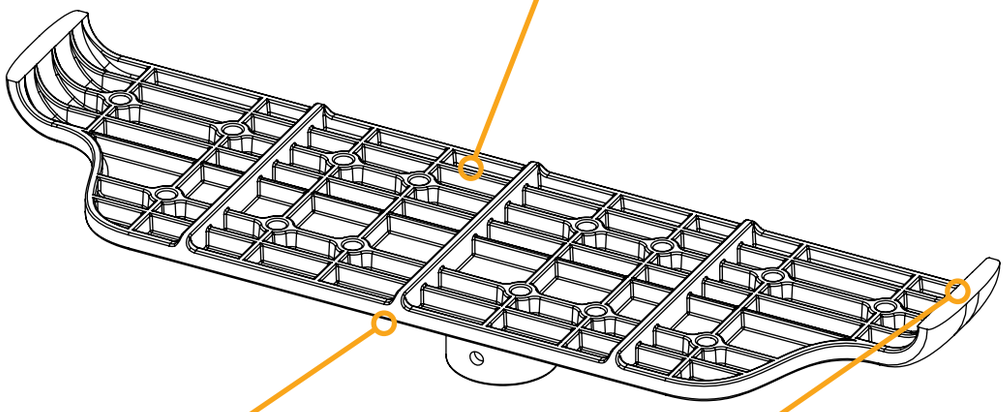
The products are made to be disassembled easily for better recycling. All materials are either eligible for recycle or decomposable and all use of glue or other harmful fasteners are avoided.



THREADED INSERTS
Threaded inserts are screwed into the wood allowing the planks to be fastened by machine screws.



SHELLED WITH RIBS
The parts are shelled with ribs with a 5 degree release angle, holes are under dimensioned, allowing for more precise drilled holes after casting.



FLARED OUT
The bottom parts are flared out to create a larger surface that attaches to the planks, increasing stability without compromising aesthetics.

CONCAVE AND CONVEX SHAPES
The ends of the bottom part have a domed shape, while the top parts have a cupped shape, making the fit smoother while making the surface smoother when used without a backrest.

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