Product

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Titel page

Project title	Cløver
Theme	Biodegradable festival chair
Report Type	Product Report- Master Thesis Industrial Design
Project group	Spriva - MSc. 4 - ID.6
Main supervisor	Thomas Arvid Jaeger
Co-supervisor	Mikael Raino Larsen
Project period	1st of February 2020- 3th of June 2020
Total pages	24

Preface

This report is created on the basis of the attached process report. Its main purpose is to give an insight in the end result of the very same process report. This report can be used as a magazine to pitch the result to potential investors.

Christofer Lee Pedersen

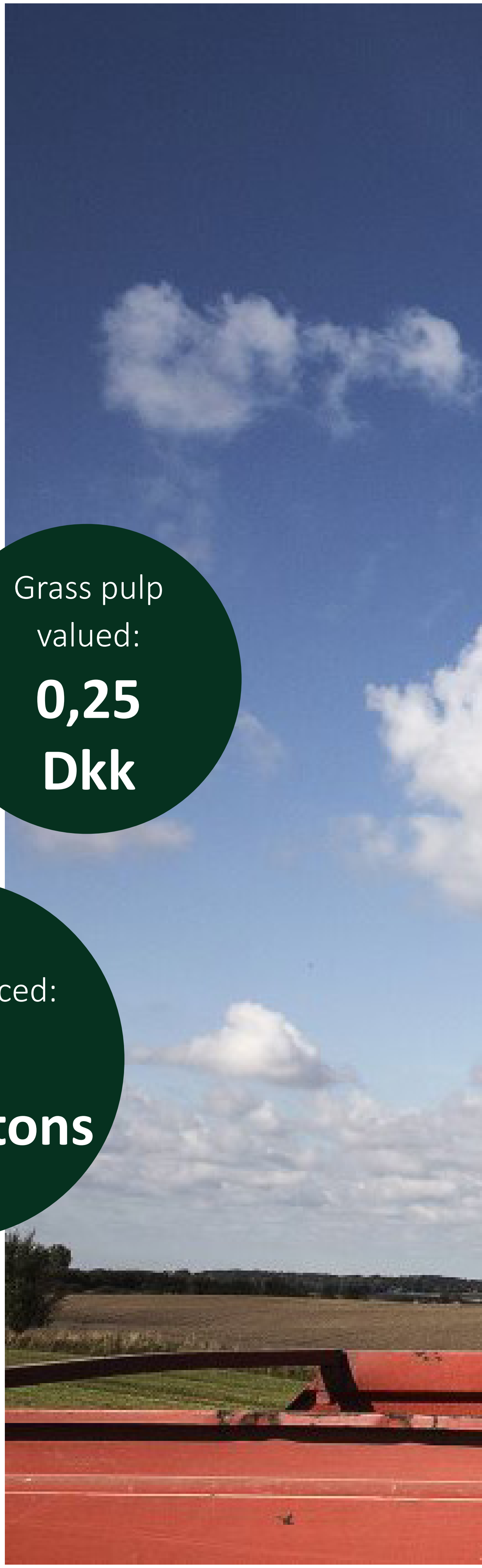
Christofer Lee Pedersen

Palle Høygaard-Jørgensen

Biorefineries

Biorefining is a process of deriving energy or proteins from biomass. In Denmark there is a growth within biorefining of grass, to derive proteins for feeding swine and poultry. The current feed is soy imported from the rainforests of South America.
The industry is currently in its early beginning of commercial implementation. It is estimated that the industry in Denmark alone will be worth 14-26 billion DKK. One of the issues presented with technology is the great amount of tailing grass pulp. It is estimated that 2,8 million tons of grass pulp are produced as tailings, which is the least valuable material produced from the biorefineries. As for now, the grass pulp is used for fuel in biogas ovens, where the burning value is around 0,25 DKK pr. kg. As well, the transport of such invaluable material is proving costly, due to the weight.

The question is if such material can be utilized for other purposes and where to use it as a valuable material?



Grass pulp valued:

0,25 Dkk

Grass pulp produced:

2,8 million tons

Profit of biorefineries:

14 - 26 billion tons


CLØVER™

Festivals

Music festivals are currently facing an issue with the waste that is generated at their sites. This can be seen within Roskilde Festivals which have produced 2297 tons of waste in 2018. This waste is mainly derived from tents, sleeping bags, and chairs from the camping sites. However, through the initiative of the community camp “Leave No Trace”, the festival guests were able to bring 100 % of their sleeping bags, and 91% of their tents back home. Yet for the festival chairs, it was only 50 % that were brought back home. This issue proves a challenge for festivals, as they are trying to convert themselves to be more sustainable.

This is here where the festival chair Cløver comes into the picture. Spriva has designed the biodegradable festival chair Cløver, which is made from the grass mycelium composite Growth™.
Cløver is made from solely biodegradable materials so disposal of the chair is done easily, and has no harmful effect on the environment. Also, Spriva approaches th sales of the chair, via a circular business plan. Fes guests will be able to purchase Cløver at Sprivas booths at the festivals, where they can after usage or if broken return Cløver, and get a deposit back. Via this business plan, Spriva not only helps in that the waste is biodegradable but also helps in reducing thrash produced. Further by the guest returning Cløver back, it can then be reused again, and thereby increase the lifetime usage of Cløver.

Chairs brought home:

50 %

Roskilde festivals wate in 2018:

2297 tons

GROWTH™

Growth™ is a composite that is made from the ingredients of pressed grass pulp and mycelium of oyster mushrooms. The pressed grass pulp is the tailings from the process of deriving grass protein via biorefineries. Mycelium is a fungus's root system, where Growth™ uses oyster mushrooms, as its chosen fungi.

Growth™ is made by cultivating the fungi via pressed grass pulp. After obtaining the grass pulp, it is sanitized by steaming, to eliminate all foreign microorganisms. When this is done, the mycelium is introduced to the grass pulp, where they are placed in the desired growth form. Here the mycelium accounts for 1% of the total weight.
Over the course of 4 days, the fungi will spread its mycelium, interweaving throughout the grass and eat it. It is the interweaving of the mycelium, which binds the grass and mycelium together, at a nanoscale. When this process is done the mycelium now accounts for 20 % of the total mass.

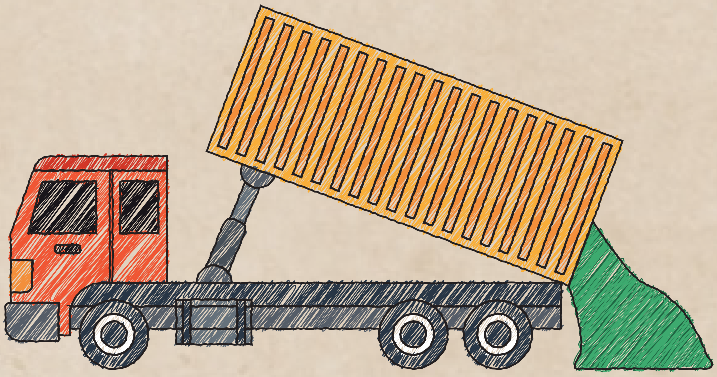
Growth™ Propeties

Yield Strenth	4,9	MPA
Compression Strength	4,9	MPA
Youngs's Modulus	332,2	MPA
Shear Modulus	147,64	MPA
Poison's Ratio	0,125	
Density	420	Kg/m^3
Moisture Absoption	164	%

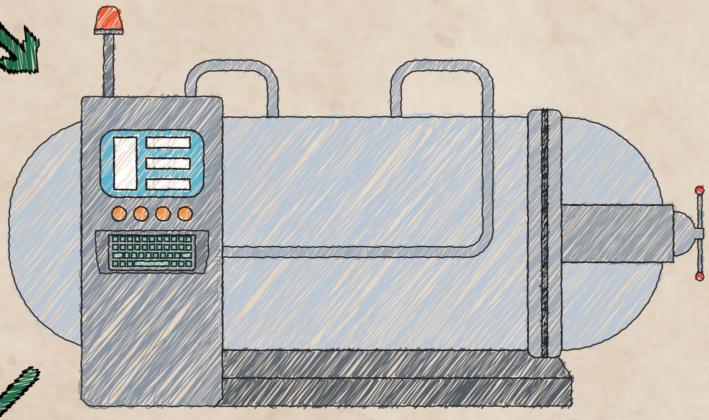
After the 4 days growth period, the composite is taken out of there molds. Thereafter they are placed in a hydraulic heat-press, which will press the material together for 10 min. This process strengthens the composite exponential and simultaneously kills the mycelium. This process results in the board material Growth™, which resembles other engineered wood boards such as OSB. Here the boards of Growth™ are placed in a fiber laser cutter, that will cut the boards into the desired shapes, to create the product Cløver.

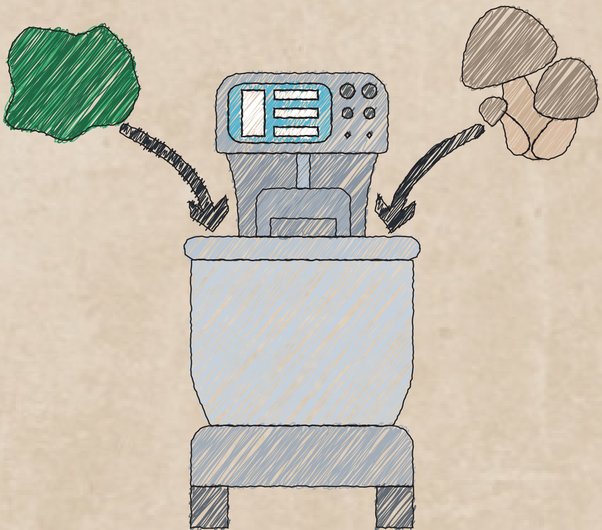
Production Line

PRESSED GRASS PULP IS
DELIVERED TO SPRIVA

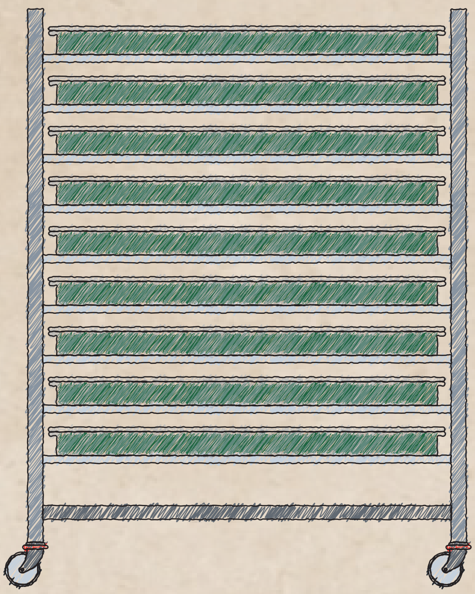


GRASS IS STERILISED, VIA STEAM, TO
KILL FOREIGN MICRO
ORGANISMS.

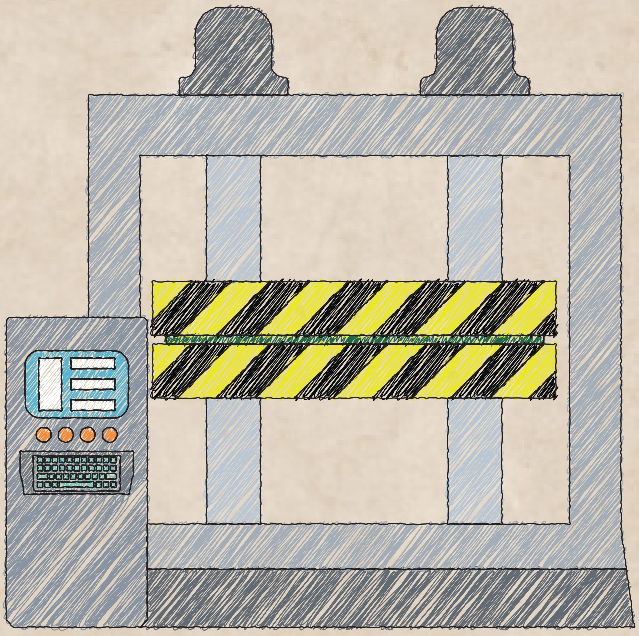




GRASS AND MUSHROOM
MYCELIUM, ARE MIXED TOGETHER, AND
PLACED IN MOULDS AFTER.

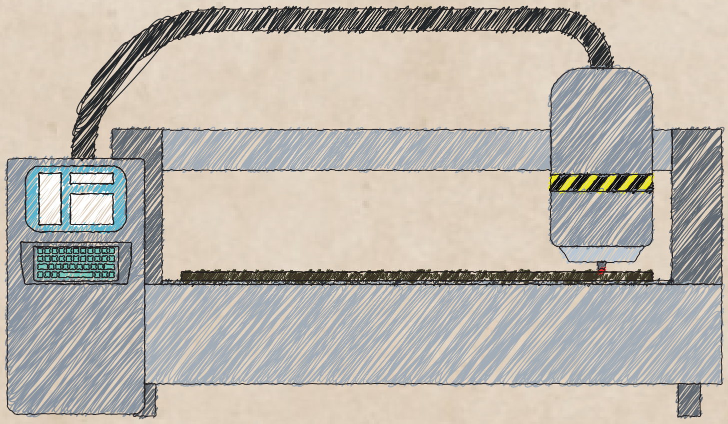


THE MYCELIUM GROWS, WHERE IT EATS
AND BINDS THE GRASS TOGETHER OVER
4 DAYS.

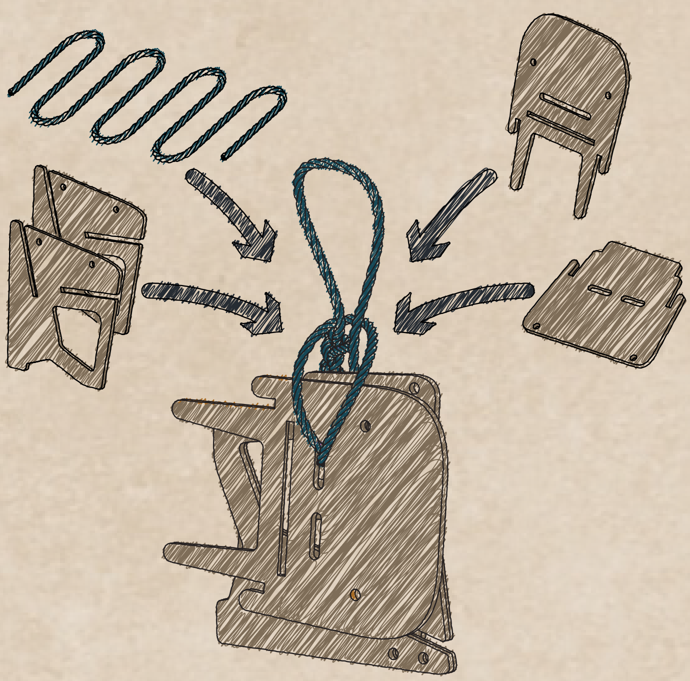


THE FINISHED CULTIVATED COMPOSITE IS PRESSED, TO STRENGTHEN AND KILL THE MYCELIUM. GROWTH™ IS MADE.

GROWTH™ IS CUT OUT INTO DESIRED SHAPES, VIA A FIBER LASER CUTTER.

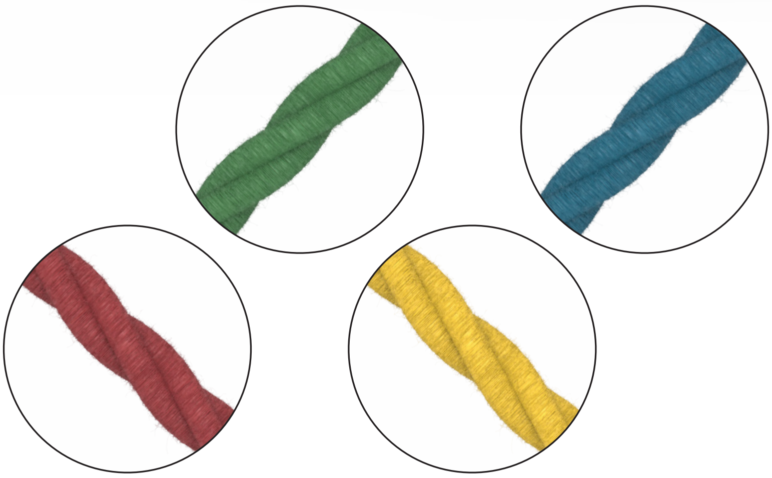


THE LASER CUT PARTS, AND JUTE ROPE IS ASSEMBLED TO CREATE THE FESTIVAL CHAIR CLOVER.



Can holder

The rope surrounding Cløver is multi-functional. One of its functions is as a cupholder. After the jute rope has been assembled towards the chair, a cup holder is created at each side. The cupholder is created in such a way that it can store a 330 ml can. If a bigger or larger can or bottle is to be used, the rope can either tighten or loosen. This also functions as handles for lift.

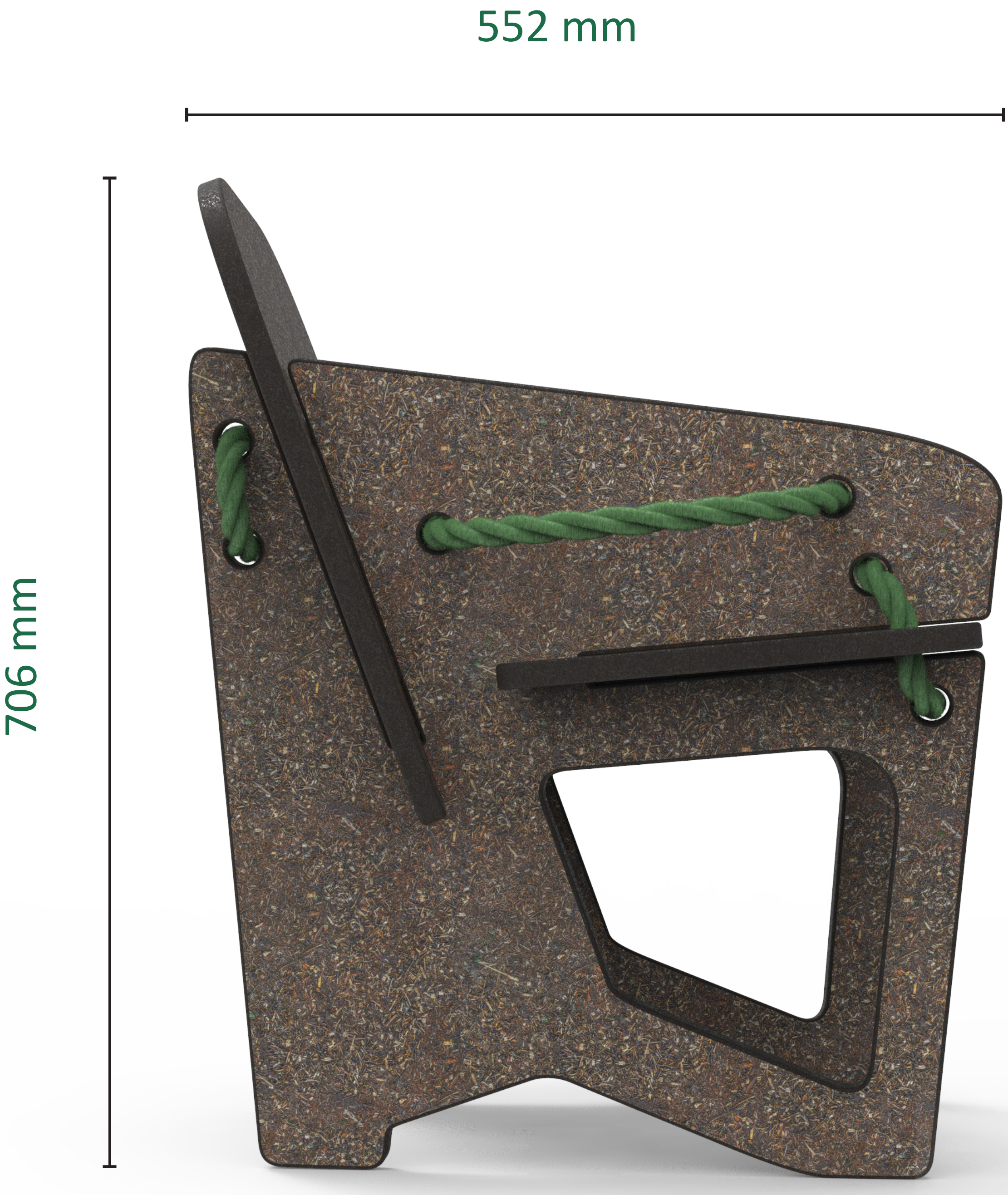


Colours

To lighten up the festival even further various colors can be chosen for your Cløver chair. Even though the chairs are all created in the same material, Growth™, the jute rope comes in green, red, blue and yellow.

Rope lock

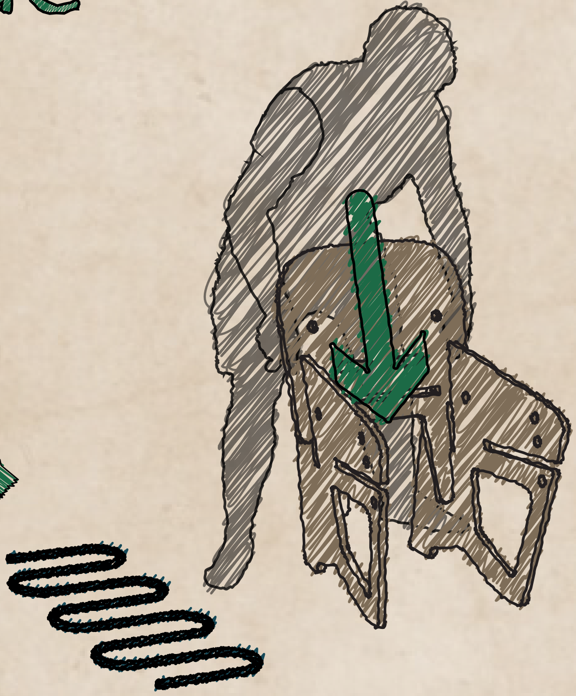
The rope does not only function as transportation or cupholder. One of its main functions is to keep the chair parts in place. The rope connects all parts of the chair, in such a way that in order to move any of the parts, one will have to disassembly the rope.
The rope can be ended with a standard knot or even no knot at all, the parts will still be locked. To figure out how the rope is to be mounted, there is an attached assembly guide to the Cløver chair, when it is bought.


552 mm
706 mm

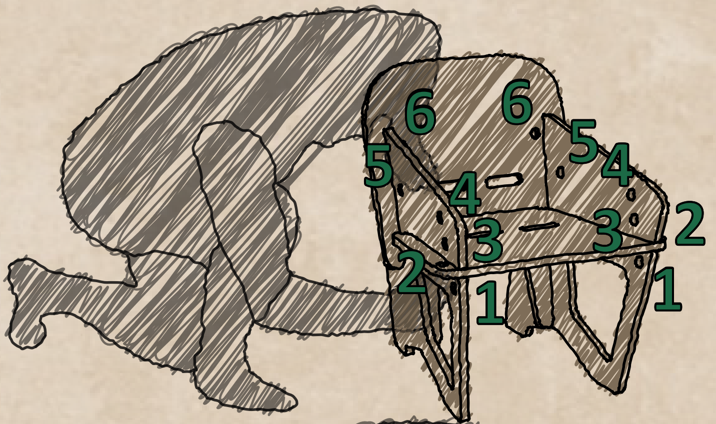
587 mm

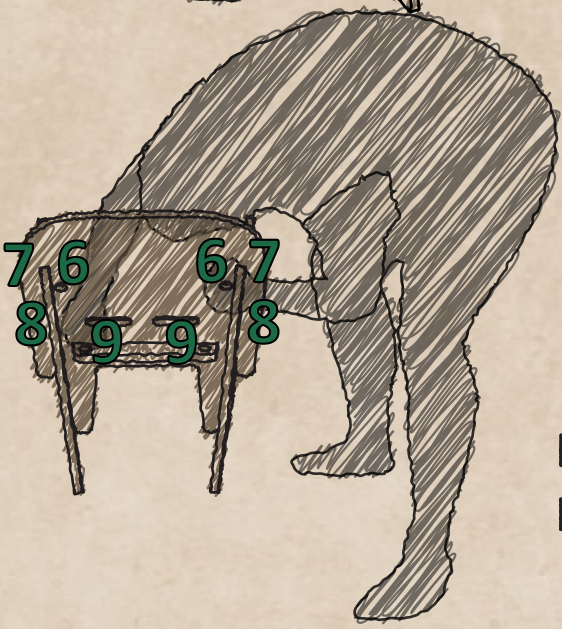
Assembly Guide

UNPACK THE CHAIR, AND HAVE THE PARTS IN FRONT OF YOU.



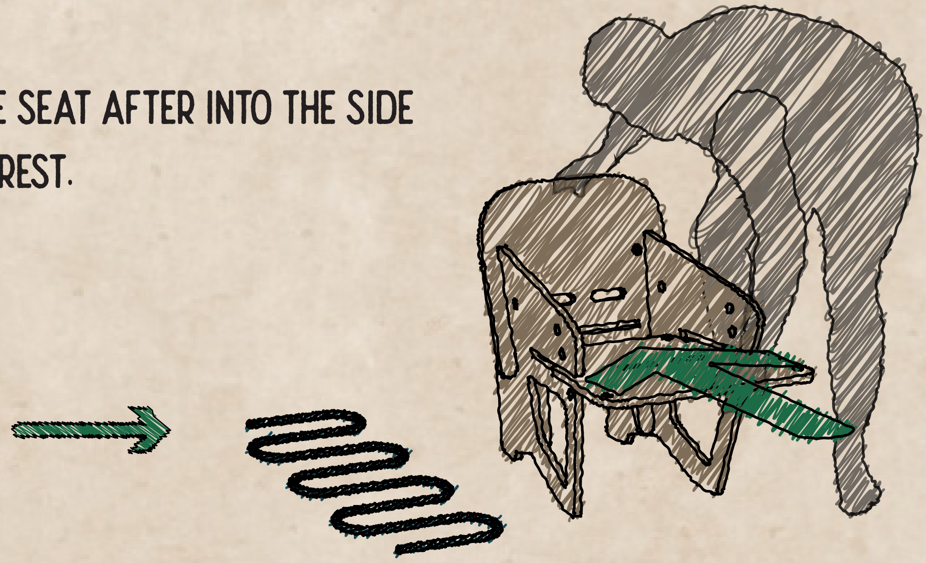
INSERT THE BACKREST INTO THE SIDE.



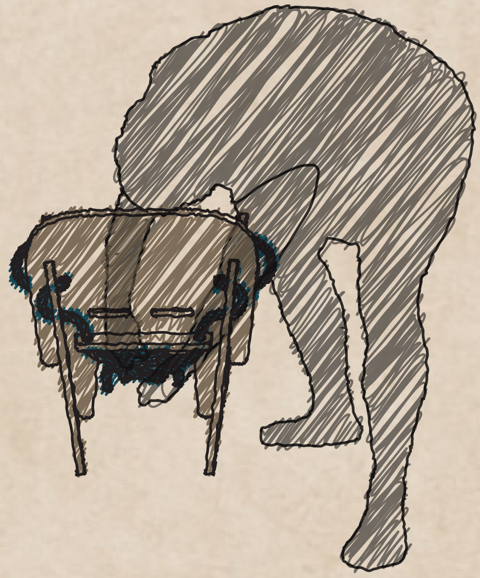


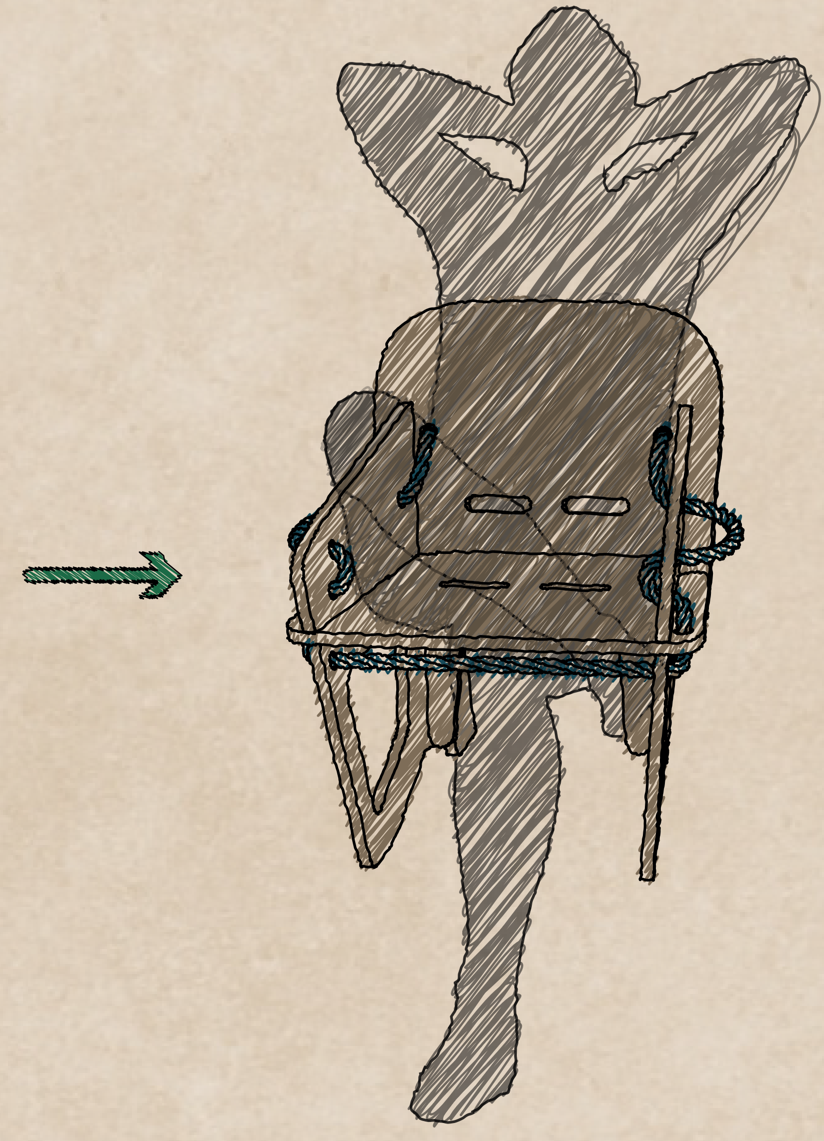
INSERT THE ROPE THOUGH THE CIRCULAR HOLES. FOLLOW THE ORDER OF WHICH HOLES.

INSERT THE SEAT AFTER INTO THE SIDE AND BACKREST.



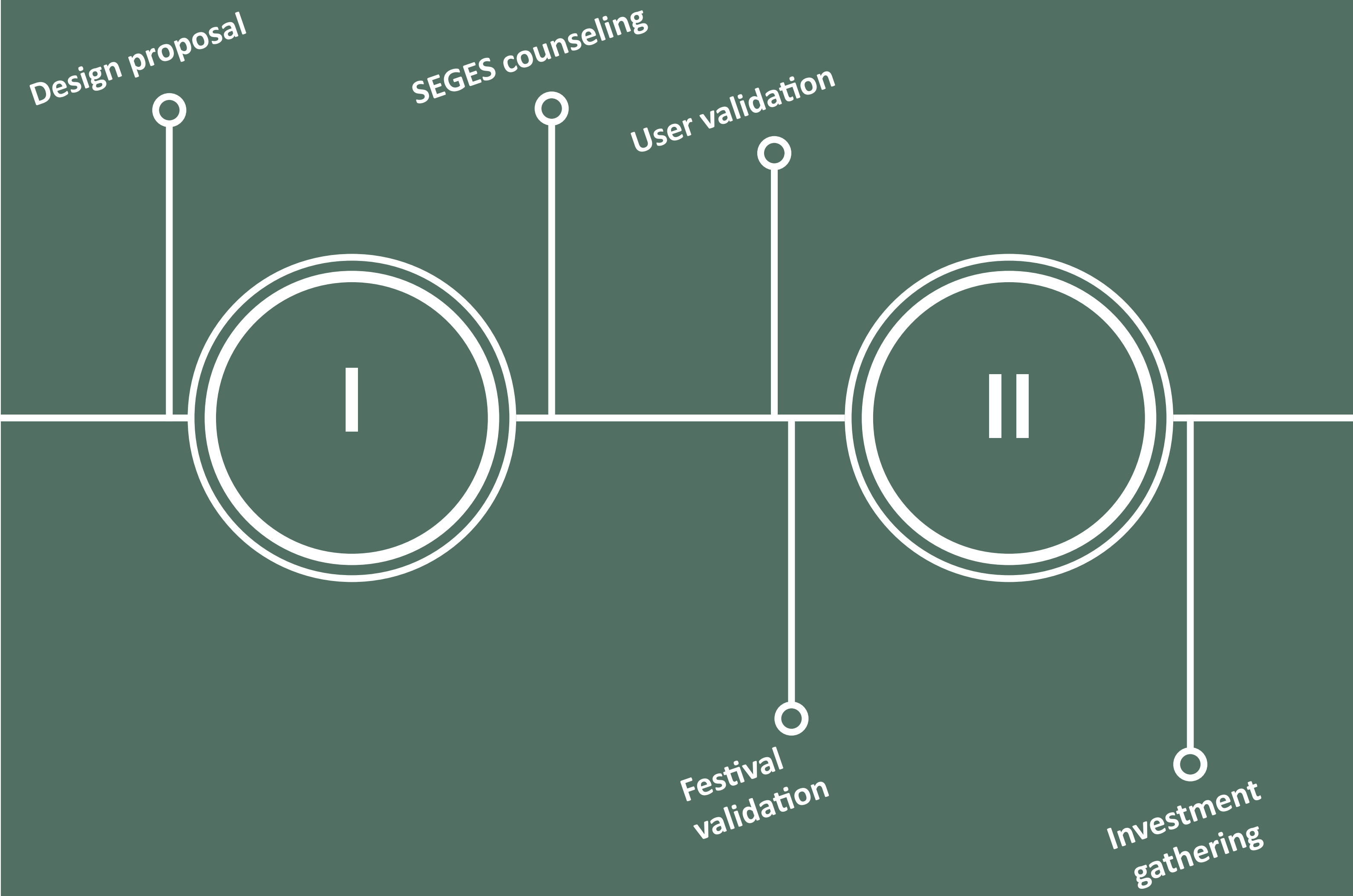
ENJOY YOURSELF





INSURE THE ROPE IS TIGHTEN. THROUGH THE HOLES. TIE A KNOT AT THE BACK. FOR INSURANCE.

Implementation

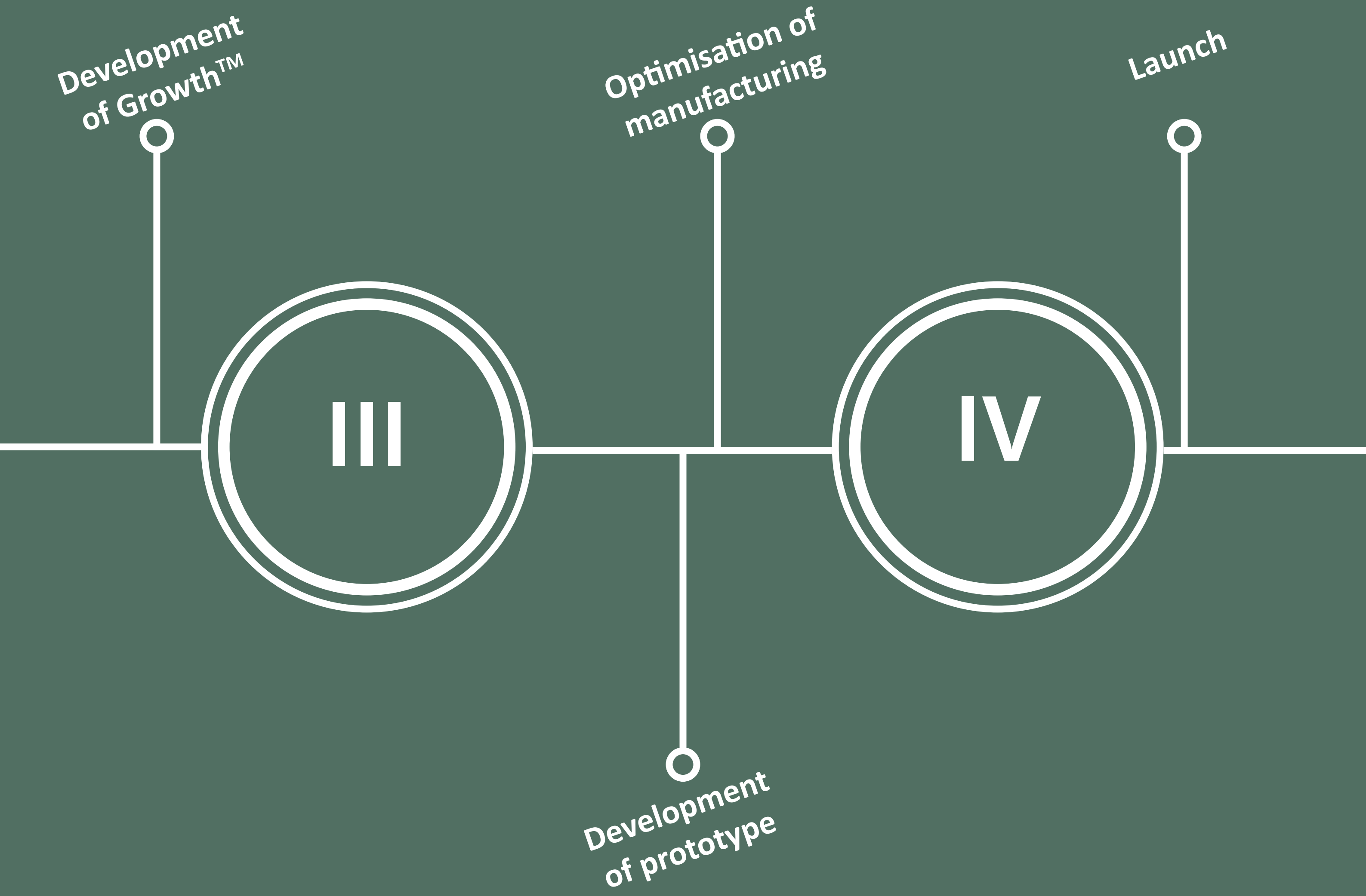


Phase I

Within the first phase of the implementation, it is a desire to seek counseling with SEGES. SEGES can contribute with focus areas to seek investments with the biorefinery sector. Afterward, it is important to get validation from both festivals and users. This is done to have concrete information and validation to present for investors.

Phase II

In this phase investments will be sought, this might be done in steps. First an investment for developing the material, to optimize mechanical properties and the cultivation of the material. This is done for the investors to see progress, before investing in the next phase.



Phase III

With the development of GrowthTM now defined, the next step is to develop Cløver further via prototypes. This is both to identify if any improvements are needed, in terms of functions, and aesthetics. Also, another segment that will be improved by prototyping is the manufacturing process of Cløver, identifying if other methods could be more efficient in time or cost. Next step would be for Spriva to seek new investments for the production of GrowthTM and Cløver.

Phase IV

The final phase will be the launch phase. When the first festival season closes up, all focus will be put on marketing, communication, and human resources. In this phase, the festivals will play a huge role.

Budget

Production cost

The production cost is around 27,5 DKK pr. chair. With the margin contribution of the sales price, the production price will be 51,5 DKK.

Sales price

The sales price has been set on the basis of the product cost, however also by influence of the users. A satisfactory price ended on 120 DKK, a price users are willing to pay, and a profitable budget price.

51,5 DKK

120 DKK

Break-even

Break-even point:
2nd year

Total sales:
137.319 Chairs


Exchange of grass pulp
0,5 DKK pr. kg
Short distance
Ausumsgaard
Production
Production cost 27,5 DKK
Transport of broken chairs to production for recycle of material for new tents.
Transport of chairs to festival.
20 % contribution
Product cost incl. contribution:
51,5 DKK
Festival ground
CLØVER
120 DKK
40 DKK
Festival Guest
Cløver in bad shape
Cløver in perfect shape

AALBORG UNIVERSITY
DENMARK

Process

Aalborg University
June 2020
Industrial
MSc04 ID6

Christofer Lee Pedersen

Palle Høygaard-Jørgensen

0.1 | Titel page

Project title Cløver

Theme Biodegradable festival chair

Report Type Process Report- Master Thesis Industrial Design

Project group Spriva - MSc. 4 - ID.6

Main supervisor Thomas Arvid Jaeger

Co-supervisor Mikael Raino Larsen

Project period 1st of February 2020- 3th of June 2020

Total pages 96

0.2 | Preface

The following project is a Master's thesis in Industrial Design at Aalborg university. It consist of two reports; a process rapport showcasing the process development and a product rapport presenting the product and its features. This project also includes an appendix and an a technical drawing folder. The project was conducted between the 1st of February 2020 to 3rd of June 2020.

0.3 | Acknowledgement

The team would want to express thanks to the supervisor Thomas Arvid Jaeger and Mikael Raino Larsen for their feedback and guidance throughout the project. The team would also thank the knowledge and feedback gathered from the different collaborators throughout the project, that helped develop the Cløver.

Jacob Lave
Theis Kjedsen
Mette Lübeck
Mogens Kjeldal
Kristian Lundgaard-KarlsHøj
Rie Berggren
Jakob Thorup
Michael Folmer Wessman

Future farming, Seges
Foulum
Aalborg University
mKjeldal
Ausumsgaard
Nibe festival
Smukfest
Dansk Live

Pedro Mapurunga Azevedo
Katharina Hölz
Jan Berbee
Kasper Sørensen

Carnauba do Brazil
Tresta Design
Grown.Bio
ByStonic

0.4 | Abstract

This thesis was developed by the team Spriva, who consist of two Industrial Design engineering students from Aalborg University. The project presents the development process behind a design proposal of a biodegradable composite material that has been used to develop a sustainable festival chair.

A growing new industry in the agriculture field in Denmark called biorefinery, where protein is extracted from the grass. Here, considerable quantities of residual grass pulp are produced. It is estimated to be 2,8 million tons of tailing only in Denmark. The only use of the grass pulp is for silage and burning in a bio gas furnace with a value of 0,25 Dkk per kilo. Here, a biodegradable material GrowthTM was developed, consisting of the remaining grass fibres, and the mycelium of Pleurotus ostreatus also known as oyster mushrooms, which is the root system of the fungus. The composite material has been developed via a systematic approach, with analyses of the material's ingredients, processes, and tests of its mechanical properties.

This composite material has been used to develop the festival chair, Cløver, as Danish festivals currently are facing challenges with waste produced, such as Roskilde Festival where 2297 tons were produced in 2018, and their strife for changeover of being sustainable. Cløver has been developed through analysing the festivals and their guests' requirements for a functional and competitive product, as well as a systematic ideation and prototype modelling. The composite materials and the product were developed to promote the world's endeavours, toward a sustainable future.

0.5 | Reading guide

Documentation

The project is segmented in three reports, and it is recommended to read the reports in the following order for the right understanding of the project.

Product rapport: Presentation of Growth™ and Cløver. Here insight into the functions, aesthetics, and market strategy is presented.

Process rapport: Present the documentation and development of the process of the project, from its initial stages to the final stages.

Technical drawing folder: Present schematic drawings of the Cløver.

As the following rapport is the process rapport, its construction is as follows. The process rapport is segmented into five chapters. At the start of each chapter, a brief is stated of the following content.

Understand: Initial investigation to identify and frame the project and problem.

Conceptualization: Initial ideation and investigation of material and product.

Detailing: Finalization of the design proposal.

Implementation: Investigation in the steps to realize the design proposal.

Epilogue: Evaluation of the project, product, and process.

The rapport also includes a marking system that highlights key findings that are found throughout the project. There are four types of markings used in the rapport.

An important insight was identified, that could aid in the process. **!**

Validations of previous finding or insight. ✓

Finding or insight was disprove or dismissed. **X**

A working principle toward the concept was chosen.

Reference

The references used in the rapport is based on the Harvard method of referencing. A reference list is shown at the end of the rapport.

Each task will reference to the worksheet associated with"WS #" in its objective. These worksheets can be found in the internal appendix.

Illustrations are reference with caption text, with a number as presented "Ill #", with the following name. At the end of the report, a full list of the illustration will be placed with reference to the source.

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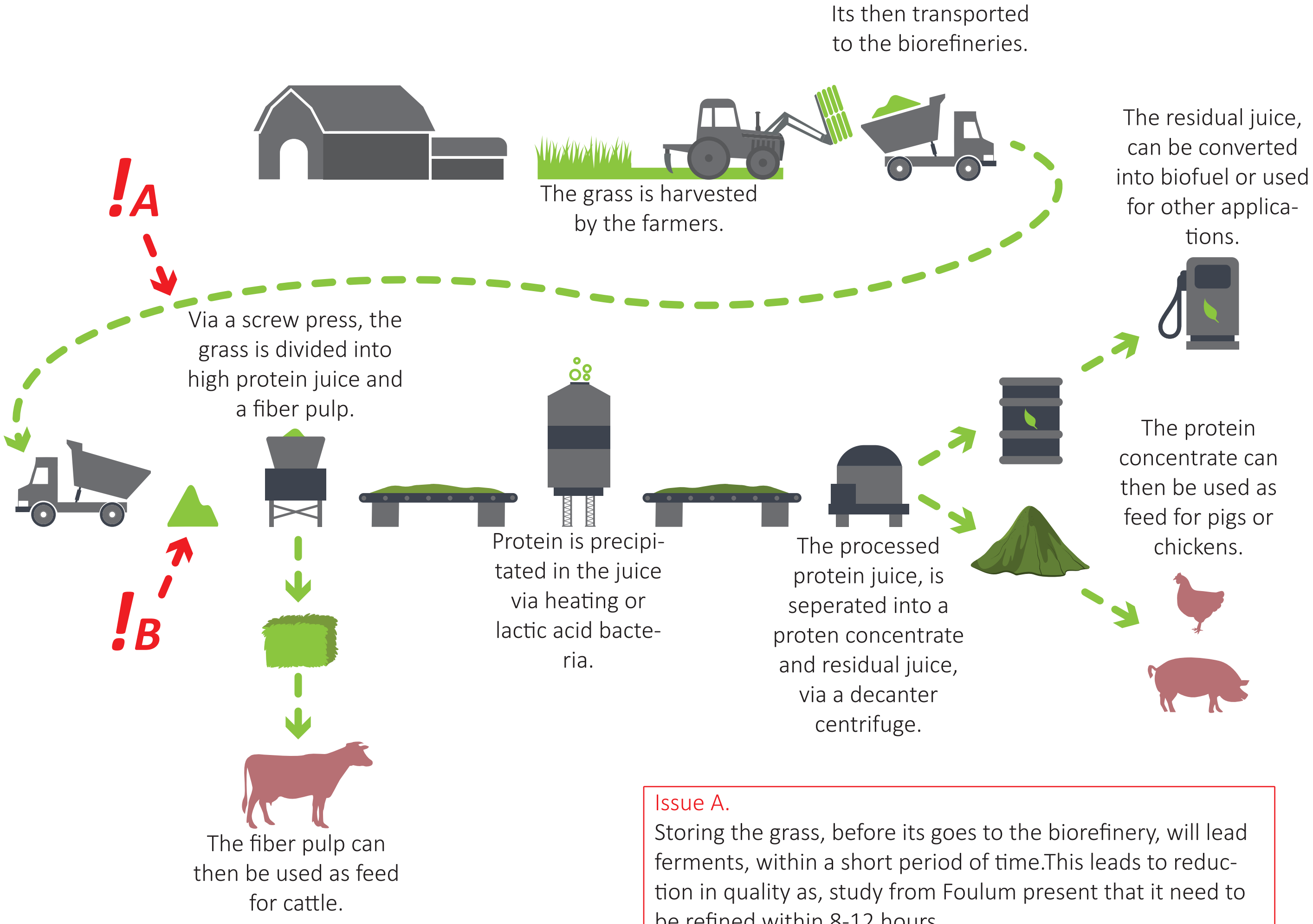
1 Understand

The following chapter is the initial investigation via analysis, interviews with people of interest, and research of biorefineries. Further along also music festivals. These studies resulted in a project brief, defining the framing of the project, of developing a biodegradable festival chair, with a grass composite material.

1.0 | Scope

To initialize the project a problem or a potential were to be found. The team had a natural interest in the agricultural theme and started digging into the topic. Through searching, Jacob Lave who is the development manager of Future farming at SEGES, was contacted. Here the team was introduced to the emerging industry of biorefining, and what issues they had. Therefore a base knowledge was needed of the biorefineries, and if there was a potential for us to work with. This was conducted via desktop research (WS 1.0)

Biorefining is a technology, to produce protein from common grass, within agriculture. The purpose of the project is to create protein that can be used for feed for poultry or pigs. Currently, protein feed is imported soya protein, from either South America or Asia. To be more self-sustaining, and improve environmental impact the project was initialized to create protein feed locally, by utilizing an overlooked resource that is grass. The process of biorefineries would not only produce protein feed, but also a dry feed for cattle and residual bio fluids that can be made to bio fuel. Biorefineries are presented as a potential new industry within agriculture in Denmark, which is estimated to generate 14-26 billion DKK in revenue and create 12000-24000 new jobs (Future farming: White paper Bioraffinering, 2018). In illustration 1, the current process of how the biorefineries work is presented, with the initial problem.



Issue A.
Storing the grass, before its goes to the biorefinery, will lead ferments, within a short period of time.This leads to reduction in quality as, study from Foulum present that it need to be refined within 8-12 hours.

Issue B.
Transportation of the grass is difficult. As the grass contains up to 80% water, the mass of the grass result in expensive, and difficult transportation.

Ill 1 Process line of biorefineries

Sum up.

The research presented that the industry of biorefineries is emerging and show great economic, and environmental possibilities. The issues presented also presented a possible angle of approach to the subject. Therefore with knowledge gained here, the potential for solving a problem, that also would have economic value is indicated.

1.1 Context of Bio refineries

To formulate the problems identified with biorefineries from a technical to a design problem, additional information and perspectives were needed. Therefore to redefine the problems the team was to contact people of interest, within biorefineries, and investigate their connections regarding biorefineries and between each other. The information gained from these people of interest was noted, with supplying desk research (WS 1.1, WS 1.2, WS 1.3, WS 1.4).

Contact person, whom the team was introduced to the subject of biorefineries. Works for SEGES, which is a development and innovation company within agriculture, in Denmark. SEGES have been partners in supplying knowledge, and expertise to a multitude of projects associated with biorefineries, such as SuperGrass Pork, OrganoFinery, MultiPlant and Green Eggs (10 Udvalgte om grønne proteiner, 2020)

Jacob Lave.
Development Manager.
Future Farming, SEGES.

Contact person, and tour guide at the visit at Au Foulum. Foulum has been one of the key partners for the different projects that have been conducted with biorefineries (WS 1.1). We were referred further to Mette Lübeck, a biochemical engineer.

Theis Kjedsen.
Master of Engineering, Department of Engineering- Biological and Chemical Engineering, Foulum

Referred by the visit from Au Foulum, and was mentioned by Jacob Lave, Mette Lübeck has worked on the project OrganoFinery that investigated the growth for organic agriculture via the concept of biorefining of grass (OrganoFinery, 2020). It was pointed out that the technologies of refining the grass are mostly complete and the team referred to the known issue of fermentation, and how when it is pressed and converted to protein juice, it is even more prone to fermentation. It was noted that solving the issues would require a highly technical or chemical solution, therefore a reference to Morgens Kjeldal, a retired technical adviser, who has helped out with the biorefinery projects.

Mette Lübeck.
PHD, Chemistry and bioscience.
Aalborg University.

Fermentation.

As pointed out by different sources fermentation is a problem. The reasoning is that fermentation is a metabolic process where chemical changes though enzymes occur. This is when different factors are present. Fermentation occurs when a lack of oxygen is present. When the oxygen is present the process is named Aerobic respiration, to convert carbohydrates into ATP, the microorganism used for energy. Fermentation thereby uses other matter, instead of oxygen to produce ATP, which results in by-products (www.masterclass.com, 2019). These are often either lactic acid, ethanol, or acetic acid. It is therefore these by-products that result in the fall in the quality of grass protein when fermentation has occurred. As fermentation is a biological process it requires certain temperature conditions, and humidity (www.masterclass.com, 2019).

Mogens Kjeldal.
Retired technical advisor, Danish machine stations and contractor

New and additional knowledge was gained from Morgens Kjeldal. The information gained was regarding issues of transportation cost, and a large amount of grass pulp generated, and what to do with it. As the biorefineries process the grass, a large amount of grass pulp is generated. It has been presented that the facilities have had issues to ensilage the pulp, with a capacity of around 17-18 tons per hour. Further reference to a farm named Ausumsgaard was given, who was the first commercial farm to have a biorefinery.

Transportation.

Transportation is the highest cost associated with biorefineries. If the harvested grass is transported unprocessed, it has a density of around 250 kg/m3, and a trailer can then haul around 20-22 tons. An idea was if the grass is pressed with mobile pressers, the protein juice can be hauled instead. It has a density of around 1000 kg/m3, and therefore a trailer can haul 36-38 tons instead. It was pointed out the issues with the fermentation of the protein juice, but via cooling to 5 degrees an increase of storage time would occur. Also if the biorefineries were mobile, the weight of transportation would be around 10 percent of the total mass.

Kristian Lundgaard-Karlshøj
Owner
Ausumgaard

Ausumsgaard is a larger farm located close to Holstebro, which has approximately 850 hectares, where they harvest corn, rapeseed, broad beans, and clover grass. As they are a larger farm, they were the first farm to have a biorefinery, both to get data and to be a demonstration facility to present other farmers for the idea of commercial biorefineries. The team contacted owner Kristian Lundgaard-Karlshøj. Here information was gained associated with the problem of the amount of grass pulp produced via the biorefineries.

Grass pulp.

There was identified a hidden issue with the grass pulp, which was found as they have a farmer's perspective. The problem was about what to do with the amount of pulp generated from biorefineries. Currently, they can harvest around 12-13 hectares per hour for the biorefineries, resulting in around 16 tons of biomass. From these it is estimated to be around 13 tons of pulp they produce per hour. It was gathered that the pulp is primarily used for silage since there are enough options for feeding cattle. Ausumsgaard currently uses a biogas oven to convert the excess grass pulp to energy. This was also the highest value as they currently can gain from the pulp, with a value per kg of 0,25-0,50 DKK. It was learned the use of silage and biogas ovens are coping mechanisms used by Ausumsgaard. They were seeking ways of creating more value for the pulp itself, as they saw the excess amount of pulp, as the largest problem further on with the biorefineries, as there is no idea of what to do with the pulp to increase its value.

A new problem has been identified with the excess amount of pulp, and what to do with it, to increase its value !

The solving area of fermentation and transportation, will require a highly mechanical or chemical solution. X

1.2 | Framing of pulp

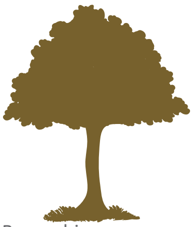
With the identification of the excess grass pulp, a better understanding of the issue is needed. To do so an investigation of the estimated total amount of pulp produced by the biorefineries and how much pulp that was needed as feed for cattle. As well its current economical value on a national scale. The team, therefore, looked into the plans around the biorefineries in Denmark, with combinations with the dialog from Ausumsgaard (WS 1.5).

Based on estimations, the current production for biorefineries are 10 million tons yearly, based on the collaboration work of Aarhus and Copenhagen University with Dong energy (Gylling, Jørgensen and Bentsen, 2012). The biomass that is estimated, is divided into 5 categories of biomass.

Ill 2 Green biomass

Green biomass

Consist of green produce and grass (Gylling, Jørgensen and Bentsen, 2012).



Ill 3 Brown biomass

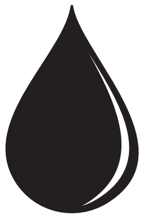
Brown biomass

Woody plant materials, such as willow or cottonwood (Gylling, Jørgensen and Bentsen, 2012).

Ill 4 Yellow biomass

Yellow biomass

Is straw from different cereal plants (Future farming: White paper Bioraffinering, 2018)..



Ill 5 Black biomass

Black biomass

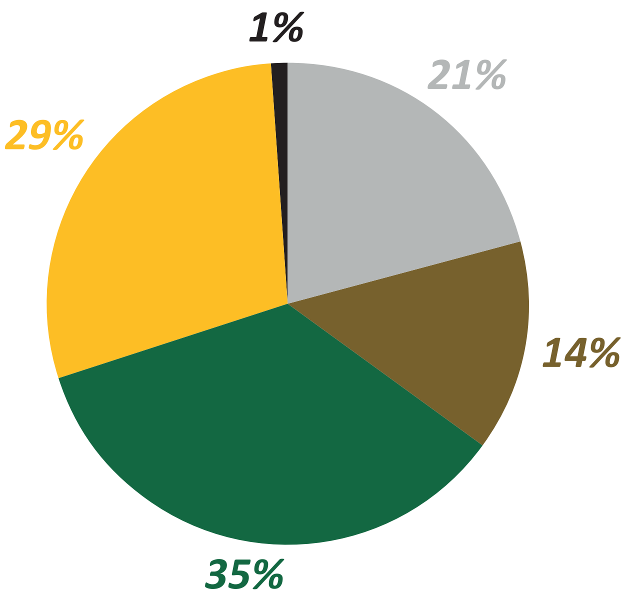
Black biomass is wording for rasp oil (Gylling, Jørgensen and Bentsen, 2012).

Ill 6 Grey biomass

Grey biomass

Manure derived from animal waste in agriculture (Gylling, Jørgensen and Bentsen, 2012).

From these 10 million tons, it is estimated that green biomass accounts approximately for 35 percent of the total mass (Gylling, Jørgensen and Bentsen, 2012). These are based on the environmental scenario from the 10 million plan, where the industry is targeted toward a sustainable solution, where the discard of nutrients is reduced, and increase toward biodiversity. The scenario for biomass optimization is estimated to produce close to 14 million tons of biomass (Gylling, Jørgensen and Bentsen, 2012).



Ill 7 Biomass graph

Information gained from Ausumsgaard, 80 percent of the weight that is pressed via the process of biorefineries, is pulp. Using these numbers the estimated weight of grass pulp to be produced, is 2,8 million tons. Indication of this results in that there would be an abundance of grass pulp.

"Estimated weight of grass pulp to be produced is 2.8 mio tons."

Via the dialogue with Asusmsgaard, it was indicated a strong drive for the other way to utilize the pulp itself, as it was the product with the lowest economical value from the process of biorefineries. As stated previously, the highest value they could derive from the grass pulp was around 0,25-0,50 DKK per kilo, it would be 250-500 DKK per ton of grass pulp. With these calculations, the value that the Ausumsgaard can derive from the pulp per hour is 3.250-6.500 DKK.

"Estimation of the current value of grass pulp is 700-1400 mio Dkk"

So all in all with the estimated 2.8 mio tons of grass pulp, the value is between 700-1400 mio Dkk. These numbers indicate the lowest value the grass pulp is able to gain, therefore if a product that can be produced out of the grass pulp and increase its value, there seem to be presidents that would be an market potential of developing it.

Potential of creating a product from the abundance of grass pulp that is produced **!**

Economical value prospect for a market potential. **!**

Drive for utilization of grass pulp, as necessity for the coping strategies to be dismissed. **!**

1.3 | Core design framework

As the team had established that there is a substantial amount of pulp and economic potential to develop a product from the grass. A product created from the pulp was viewed by the team to align with the trend of sustainability and circular. As the team had a basic understanding of the trend sustainability and circular economy, an investigation of what trends are. The purpose is to understand in depth these trends and to derive a baseline of what criteria for a product made from grass pulp should have. This is reached via desk research and the Core design framework (Ries, 2009) (WS 1.6 , WS 1.7).

“Megatrend’’ is a term that was made by John Naisbitt (1982), that describes the social, economical, political, and technological movements around the world that affect our everyday lives (Mittelstaedt, Shultz II, Kilbourne and Peterson1, 2014). Megatrends are less subtle in nature, longer in duration, and their effects are deeper integrated into our society than normal trends. Naisbitt says:
‘’Megatrends do not come and go readily. These large social, economic, political, and technological changes are slow to form, and once in place, they influence us for some time ...’’ (Mittelstaedt, Shultz II, Kilbourne and Peterson1, 2014)

1982 is almost 40 years behind us, and one expression that definitely is a megatrend in 2020 is sustainability and circular design. We consume resources 50% faster than they can be replaced and within 10-20 years we’ll need more than two of the same planet to meet demand (Ec.Europa.Eu, 2020). A solution would be to progressively move from a linear economy (take – make – dispose) towards a circular economy with continuous cycles.

Ellen MacArthur Foundation points to four distinct ways in which companies can create value in the circular economy. These are based on an improvement of material and production (Eleen Macathur Foundation, 2013).

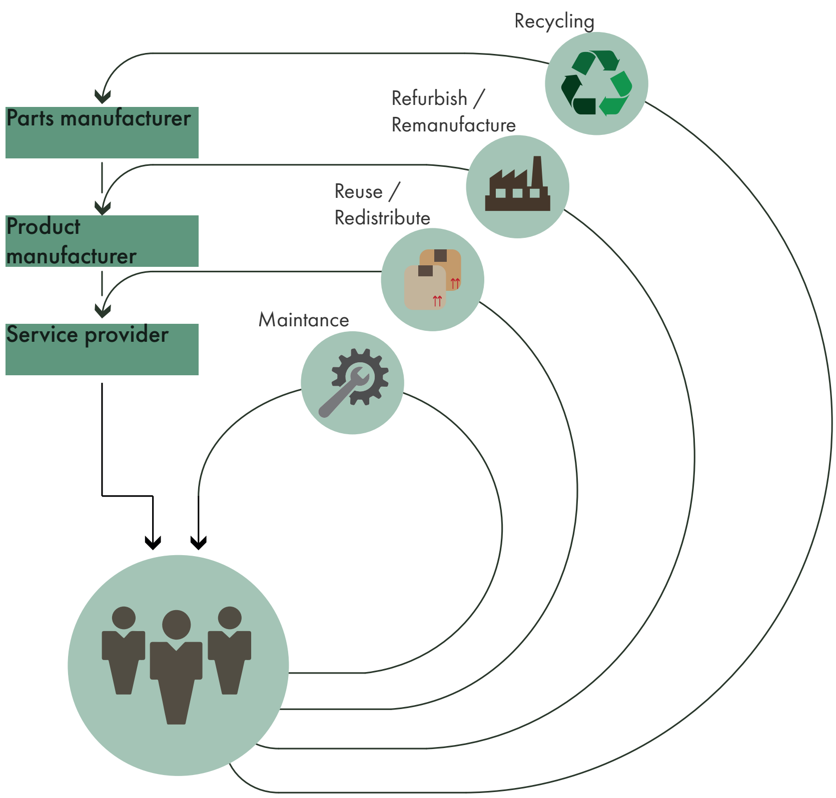
First is the ‘power of the inner circle’. This is about keeping products alive and operating them for as long as possible. The principle behind this relates to maintenance. Product design and supportive business models play a vital role in taking advantage of this opportunity (Eleen Macathur Foundation, 2013).

Second is the ‘power of circling longer’. This refers to keeping a product in as many consecutive cycles as possible and in this way prolonging the time of each cycle. For example with durable goods of cars, manufacturers could work towards circling their goods longer. This could be done by offering a high product quality, easy repairs and upgrades (Eleen Macathur Foundation, 2013).

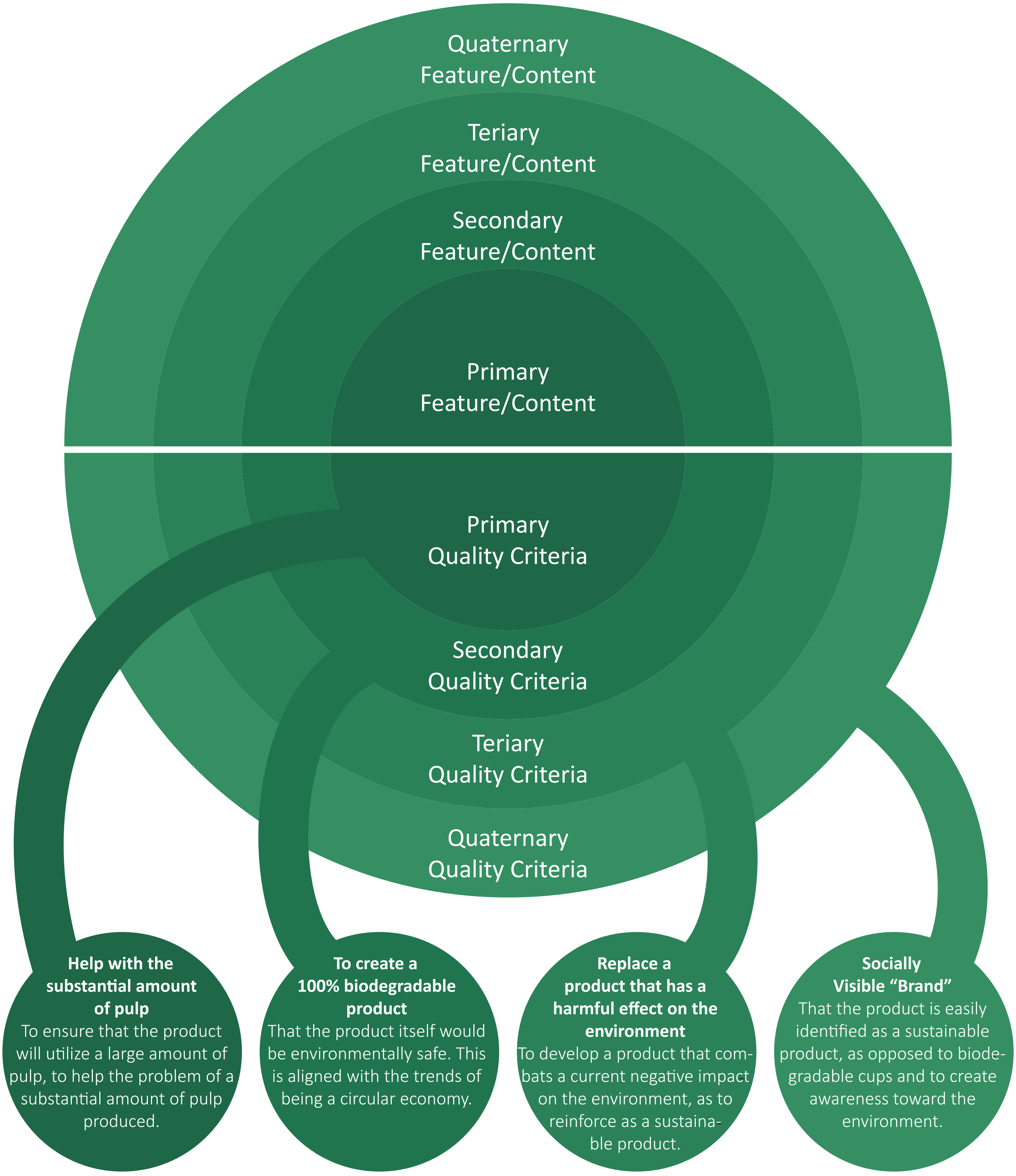
The ‘power of cascaded use’ is the third value principle. The idea is to reuse products and materials, within and between industries. An example of this is the textile industry. Clothing can first be reused as second-hand apparel, then be utilized in the furniture industry and end as part of insulation material for construction. In each case, the reused products and materials substitute a material (Eleen Macathur Foundation, 2013).

At the end is the ‘power of pure circles’. This principle highlights the importance of an uncontaminated material since this is a valuable key in order to maintain the quality of material for many consecutive cycles (Eleen Macathur Foundation, 2013).

From these principles, the team can get an understanding of how the core design criteria should focus, with the insight of sustainability and circular economy.



Ill 8 Circular economy layout



Ill 9 Core design frame

A product made from grass pulp, would aligns with the ideology of circular economy. !

The product need to be made out of 100% biodegradable materials made from grass.

1.4 Areas of interest

Identification of the core criteria, the team needed to find a suitable product to make from the grass pulp, and that aligned with the core criteria. Therefore a mapping of products of interest was done, to diverge the project. The team created a brainstorm, to select three products associated with an area of interest, where the team saw a potential. With the three identified areas, desk research was conducted to understand the products, and their respected context, to determine which upheld the largest potential and interest (WS 1.8, WS 1.9, WS 1.10, WS 1.11).

Brainstorm.

From the brainstorm conducted, three areas were chosen: Traffic cones, Picnic tables in urban public space, and Chairs at festivals. These were chosen based on the team's interest, of the contexts, and visualize if the products would be if made from a grass material. There were also other areas that had potential but were dismissed based on different parameters, such as lack of interest, issue to introduce grass pulp variance, and where there were already biodegradable products, such as the cutlery industry or construction.

Traffic cones in traffic

Traffic cones is a product that is used to warn people of hazardous situations or off-limit areas. They are mostly used in traffic or construction. They are in a rough environment that can either be humid or dry, and dirty (https://thenewswheel.com, 2020). They come in different shapes and sizes and are often made from one or few materials, with the most iconic color being orange and with UV reflectors (What Are the Different Types of Traffic Cones?, 2020). Traffic cones are built in such a way that they can be stacked on each other, and have a weighted bottom, to ensure they don't tip over.

Problems that are identified with traffic cones are mostly associated with human error, in terms of wrongful placement, visibility (https://www.expertinstitute.com, 2013). As traffic cones are so simple they are easily recycled into new ones, when damaged (Where Road Cones Go To Die, 2014).

Based on how they are recycled, the environment they are placed in, and the different product needs, and the teams fall in interest after investigating it, the traffic cone was not chosen to investigate further (WS 1.9).

Picnic tables in urban public space

Picnic tables are outdoor furniture that functions both as a place for seating and eating while having social interactions. They are often located in public spaces, such as parks or rest stops. As such the environment they are in is humid, and dirty, thereby being a rough environment for products. They are typically constructed in such a way that it is a table where a backless bench is attached at the legs. Most often they are constructed in wood, or either in combination or entirely out of metal such as steel (econation.co.nz, 2020).

Public spaces have proven to have a positive effect on its communities by establishing a place for social engagement, and events (Jagannath, 2016). The issue in public spaces is if they lack either place to sit or the lack of gathering point (https://www.pps.org, 2009).

The team viewed the picnic tables in the urban public as an interesting direction, with both in terms of user interactions and a problem. However, the question is if the municipalities, the owners of the public areas, see these issues as important. As well if the urban architecture is done correctly, these issues are non-existent (WS 1.10).

Lounge chairs at festivals

Lounge chairs are reclined chairs that are used for relaxing, where they come in a variety from indoor and outdoor, where outdoor versions are used for social gathering points, such as bars or at festivals. The context can be rough and dirty as you have many people who are at festivals resulting in a lot of dirt and mud. The context of festivals are also in the warmer seasons of the year (Momondo.dk, 2018).

Festivals are gatherings of people to celebrate cultural, social or traditional events. As such they have an important impact on social connections and communities engagement, as they present the opportunity for stress relief and an escape from the normal everyday life (Zalmay K, 2017)

Another issue that is viewed at multiple festivals is the waste generated. At Roskilde festival in 2018 there was generated 2217 tons of trash (Richardt M, 2019)

The team viewed festivals as an interesting direction to work with, as the issues with waste generated. It was also indicated that there was a good synergy with grass material and a festival context. (WS 1.11)

Ill 10 Traffic cone

Ill 11 Urban park

Ill 12 Festival ground

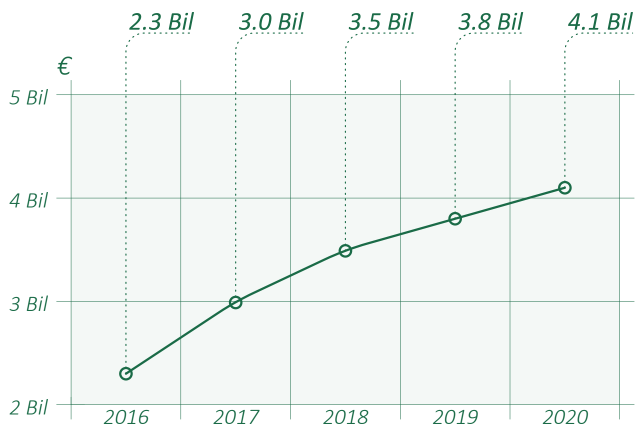
After the research of the areas of interest, it was clear to the team that the direction of festivals had the potential of working further with. The reasoning being the team's personal interest, but also that the team could see a clear synergy between the festivals and a grass pulp lounge chair.

Festival directions chosen as staging ground for a grass pulp product. !

1.5 | Festival drivers

With the identification of festivals as the direction for developing a grass pulp product, an understanding of the market and drives of the festival was needed. The reasoning for this was to have an insight of what market the festival is, and if there was a need for a product made from grass pulp. Therefore desk research was conducted to identify the size of the festival market, its growth, and what drivers they have. Along with desk research, an interview was made with a person of interest, in this case, Rie Berggren, sustainability coordinator, from Nibe Festival. This was done to understand theses drivers of the market (WS 1.12, WS 1.13)

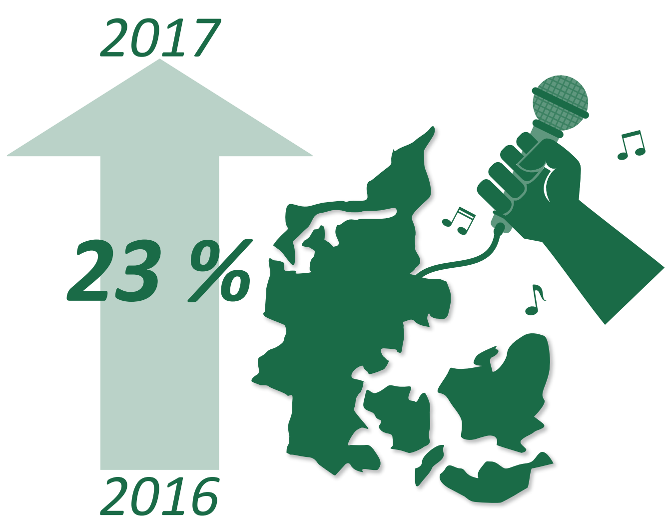
Denmark is a country with a substantial amount of festivals per capita, with an amount of around 61 festivals (www.festivalkits.dk, 2020). Statistics from "Danmarks Statestik" estimate that in 2018 one out of sixth Danes was at a music festival, where up to 40% of all students were at one (Engmann, T.S, 2019). The reason for this attendance to the festivals is that there is such a variety of festivals, with a different genre of music and experiences, therefore there is something for each persons taste (Afzal, 2018).
It can also be seen that there is growth with festivals, not just in Denmark but in all of Europe. Based on statistics from Festicket, that is a company located in England, where one can buy tickets



Ill 13 Festival market estimation graph

online to festivals around the world. Based on their data, they forecast a rise in the market of festivals, from 2,3 billion euro in 2016 to 4,1 billion euro in 2020 (Festticket, 2018). It has also been noted that there is an increase of 29 % of travelers, from abroad to festivals within Europe. This presents one of the reasons for the growth of the market (Festticket, 2018).

This growth is also visible alone in Denmark, as there has been an increase in the revenue of the music industry of 23% from 2016 to 2017, as a result of live concerts and music festivals (Lingren, 2018)



Ill 14 Denmarks festival growth

A growth that is also associated with music festivals is their agenda of becoming circular. Roskilde Festival together with 19 other festivals from 7 countries around Europe, has together signed and agreed, at the ADF Green, a "Green Deal Circular Festivals", to reach the goal of being circular at the year 2025 (greenevents.nl, 2019).

Ill 15 Green Deal Circular Festivals

Interview
Nibe Festival has in coalition with other festivals in Denmark though Dansk Live, striving to become sustainable, by helping each other, with information and initiatives. An example is the introduction of cardboard tents Kartent, such as Smukfest had introduced. This is also to help each other to solve the main issue of becoming sustainable, which is the waste generated at the campsite, with tents and chairs being the main culprit of it (WS 1.13).

"Danish festival has gone into a coalition to become sustainable"

Currently, it is seen that Nibe Festival is behind, on the environmental agenda, but strives to be more sustainable, as it is seen that festival guests will opt out of going to a festival that is not sustainable (WS 1.13).

"Festival guests will opt to go to festivals that are not sustainable"

This is also visible in the youth that has a strong desire for sustainability but has difficulty doing initiatives themself while they are at the campsite and are inebriated (WS 1.13).

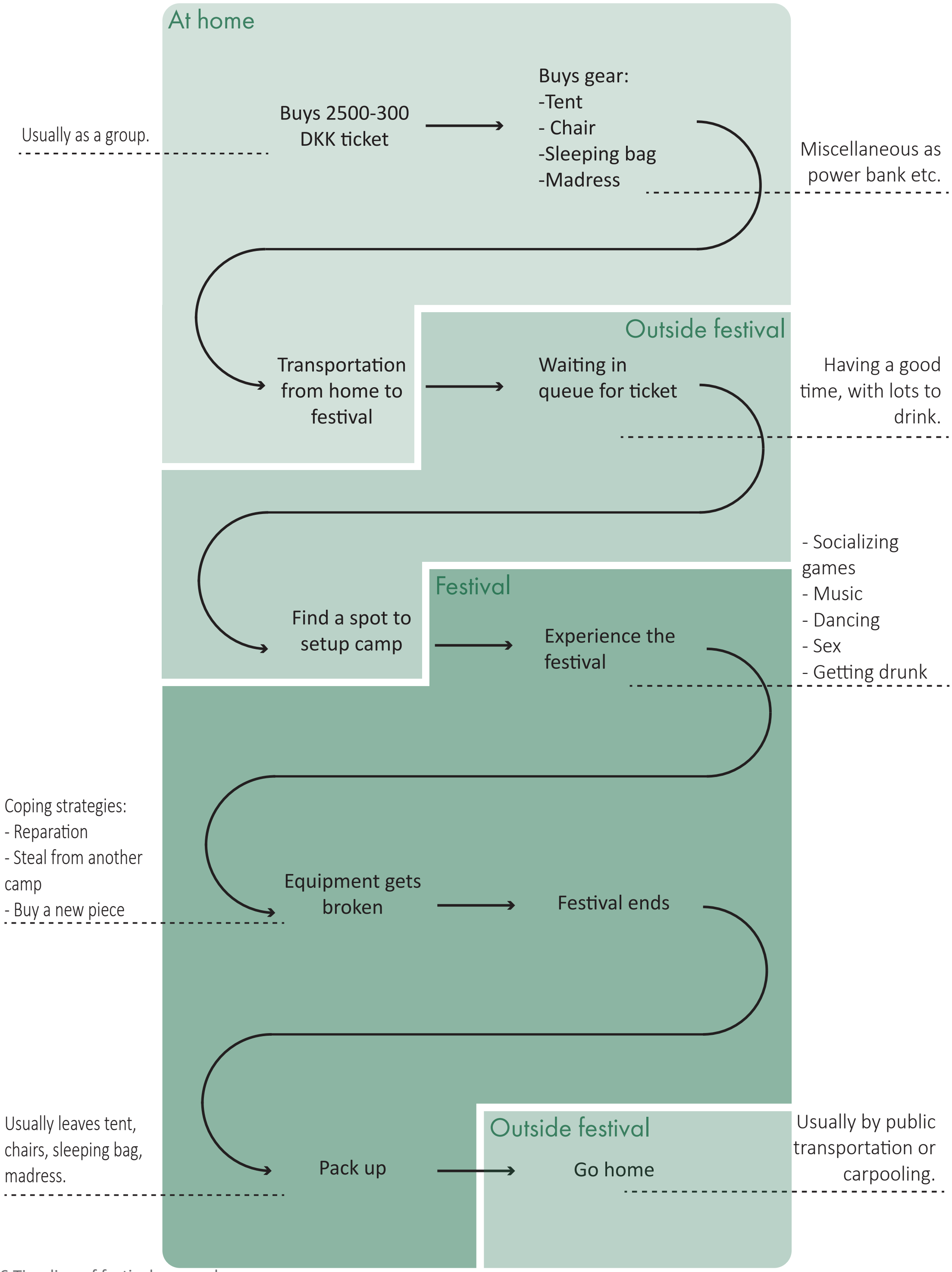
That the people, especially the youth, desire sustainability at festivals, but lack initiative to guide them. !

Festivals is a continuous growing industry both in Denmark and Europe.

There is a strong desire for sustainability at festivals, that organisation has been formed to advance it.

1.6 | Tracking of festival guest

From the first milestone it was identified, the team needed to dig into, how the setup of the festival i. This is directed towards what is the experience the festival guest has at the festival, and the steps they take when they come to, while they stay and when they leave the festival. This is to was for the team to get a better overview of what occurs at the festival. Therefore this was conducted by creating a mapping of the time line, based on own experience and experience from co students of the festivals guest who sleep at the camp site, as they are the ones who are present most at the festival (WS 1.14)



Ill 16 Timeline of festivals ground

The mapping showed difference occurrences at the festival. It was noticed that there is transported much equipment to the festival, and that items are thereafter not taken home. This is a result of the equipment breaking down, but also the mentality the guest has at the end of the festival, as they are exhausted.

Equipment is left at the festival based on there quality and the mentality of the festival guest. !

A high amount of equipment are to be transported to the festival site. Therefore the product needs to be light weighted for easy transport.

1.7 | Product at festivals

From the milestone the direction of developing a grass pulp product for festivals was positive, it was however pointed out why the direction was for the lounge chair. The meaning was if any other product were more optimal for creating a product out of grass pulp. Therefore the team investigated which products that were the major culprit toward the waste generated. This was conducted by interviewing people of interest, to understand the needs, trends, and issues they see with the products, and research propping of products that reflect does need trends, and issues (WS 1.15).

Interview

The people of interest who was interviewed were :
Jakob Thorup, Technical coordinator at Smukfest.
Michael Folmer Wessman, Member Responsible, for Dansk live.
Rie Berggren, Sustainability Coordinator for Nibe Festival.

Festivals are in total striving for sustainability, as identified from the previous interview with Rie Bergren (WS 1.15) The main issue is associated with the waste generated from tents and chairs, at the campsites. Therefore there has been done different initiatives from festivals, that has had variable degrees of success

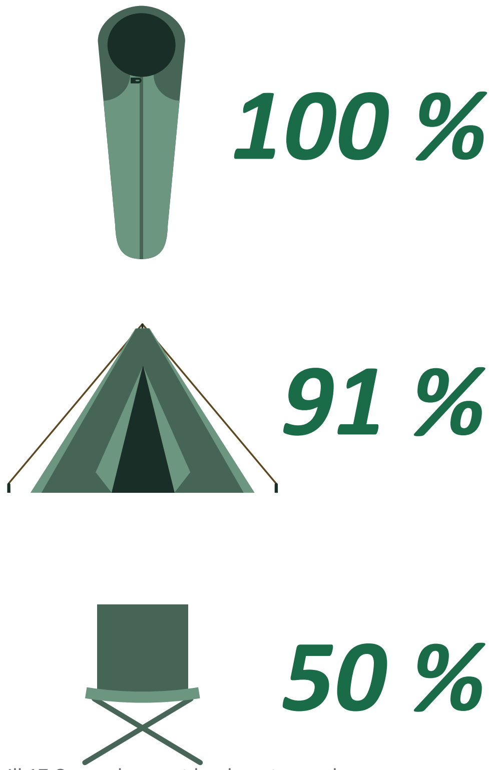
One of the initiatives that have been present is the sale of pre-pitched tents or camping solutions at festivals. It is identified that this approach is highly popular at Smukfest, which has a total of 20 camping options (Smukshop.dk, 2020). It has been identified that there is a growth of sales for these options, as the festival guests are seeking more comfort, based on the statement from Jakob Thorup. It was noted that guests are willing to pay a couple of thousand DKK, for such living conditions.

"Growth of sale of pre-pitched camping options - Jakob Thorup"

Here one of the more recent options was noted. Kartent, which is a tent made from cardboard, has had mixed feedback. Initially, people gravitated towards a sustainable tent that is also comfortable to sleep in. However at Smukfest in 2019, heavy rain resulted in the Kartents breaking down, and therefore the guest began having some dislike for the Kartents.
It was also noted that while there was growth for the pre-pitched tents, it was still far from the sales for the regular camping sites, stated by Michael Wessman. Also that the tents that were bought by the guests at the festival, only around 10 % take the tents home, stated by Rie Bergren (WS 1.15).

A different initiative of living at the campsite, are community campsites. The one that has presented positive results is the campsite "Clean Out Loud", stated by Michael Wessman. Here it is required by the festival guests who sleep here, that they clean up after them during the festival, and after the festival. It was viewed from Dansk Live, that this is the direction they are proposing for the different festivals across Denmark (WS 1.15).

"The communicate campsite such as "Clean Out Loud", is the direction Dansk Live proposing festivals follow - Jakob Thorup"



Ill 17 Camp clean out loud waste numbers

Based on numbers from Roskilde festival one of the community camps that is "Leave No Trace", the guest took back home 100% of there sleeping bags, 91% of there tents, and 50% of their chairs, while the rest was disposed of properly (Roskilde-festival.dk: WASTE & RECYCLING, 2020).

The community camp initiative is viewed positively by other festivals, as it places demands on festival guests to behave themself, as stated by Rie Bergren for Nibe festivals desire to have a similar system. Here it was identified that it is not always possible for a festival to do these initiatives, as a lack of manpower. Therefore, they need to hire people to handle such solutions, such as some of the pre-pitched tents at Smukfest (WS 1.15).

It was identified that from the waste that is generated, it is the tents themselves that are the largest mass. However, it was noted that while the tent amount to most mass, most tents were actually still functional, where camping chairs at the festival often were broken. This also supports the data from "Leave No Trace", from Roskilde festival (Roskilde-festival.dk: WASTE & RECYCLING, 2020).

"Festival chairs left are most often broken - Rie Bergren"

Pre pitched tents /camping offers

Looking at the different solutions the three largest festivals offers (WS 1.15) the following has been identified from them.

That the price of these solutions range between nothing as for the community-based campsite with rules for staying at them, toward to 4500 DKK for the luxurious pre-pitched tent, such as CanSleep where you sleep in a large "Beer can", with electricity, living room, and more (WS 1.15).

Most solutions are normal pre-pitched tents, with the exception of Smukfest that presented a multitude of camping options (WS 1.15).

They are focused on two or four people sleeping in each of the options (WS 1.13).

The more expensive options are renting units, where the cheaper ones are buying (WS 1.15).

Ill 18 Roskilde festival logo

Ill 19 Smukfest logo

Ill 20 Jelling festival logo

The product needs to be cost competitive with the current products.

Festival chairs

The current solution for the chairs is not present given from the side of the festival, however with the exception of the community-based campsites. The probing presented the following about the chairs themself (WS 1.15).

Festival chairs are priced between around 50 DKK for the most common and cheap chair, up to 750 DKK for a high-quality chair. Most of the chairs are still within 50-150 DKK (WS 1.15).
Based on personal experience the teams can assume that the most common chairs at festivals are the cheap models.

Most chairs that are offered are of similar design and construction. This includes function, where every one includes the ability to fold itself, for easier transport (WS 1.15).

Ill 21 Campingstol Haldbakken

Ill 22 Helinox campingstol

The product needs to withstand the environment that occurs at during festival.

There is growth of pre pitched tent / camping solution.

Community camping that demands the festival guest to clean and do proper waste disposal is growing. This is seen as a possible solution to the waste issue.

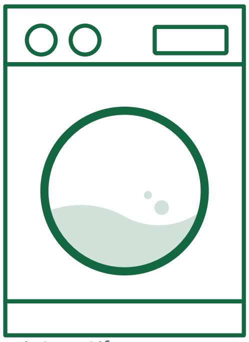
Chairs are the product that is broken the most, and therefore the least to be taken home again.

1.8 Business case

With both tent and chairs showing to be a potential product made from grass pulp, the team needed to choose which product should be worked with. Therefore an investigation into the business model and design strategies from a circular economy was made. This was to see which of the two products fits best with a circular business model, and design strategy. Research and understanding of the proposed business models, archetypes and design strategies are from the book Product To Last and Product To Flow, and a mapping of a business plan for each of the products.

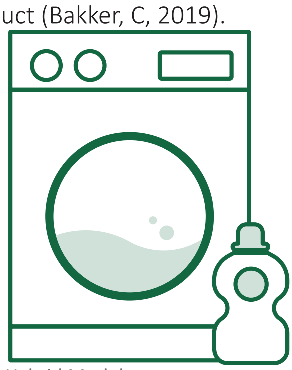
Business model archetypes

Classic Long Life.
A model where products have a long lifespan, where income comes from sales of the product. Here brands often have a reputation of good value for money, an example is Miele, where their household products are tested with life spans around 20 years (Bakker, C, 2019).



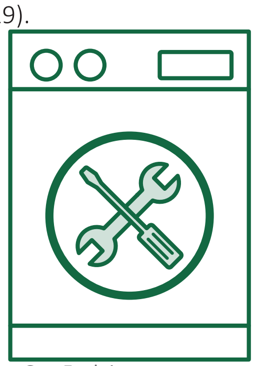
Ill 23 Classic Long Life

Hybrid Model.
This model is where quality products are sold cheap, that functions in conjunction with a short-lived product, that can be reused, where an example is printers and print cartridges. The profit is gained from continuous sales for the function of the long-lived product (Bakker, C, 2019).



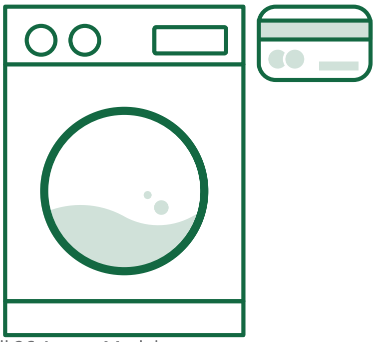
Ill 24 Hybrid Model

The Gap Exploiters.
The model is based on unidentified needs or value gaps in existing systems, that has yet been targeted at. Examples are the people who have repair shops of different products, such as smartphones like the iPhone, or the utilization of waste material (Bakker, C, 2019).



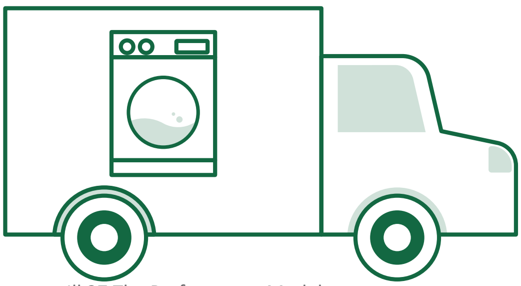
Ill 25 The Gap Exploiters

Access Model.
The following model provides access to products, while the ownership of the product is with the company. Here usage/service has a time limit and where it is used in turn (Product That Last), and profit is gained from the rent of the product/service. Example of a product that utilizes the access model is Lena, which is a fashion library in Amsterdam, where one has a subscription to borrow clothes (Haffmans, S., 2018).



Ill 26 Access Model

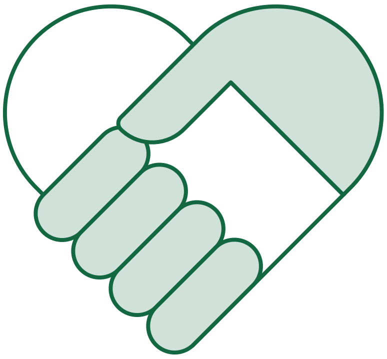
The Performance Model.
The model leaves all responsibility to the provider of the product/service, where the earnings are based on the performance itself. Here users are focusing on the service itself, and not the product. Examples of this model are Enviropac rentals, where they have higher quality moving boxes, and do the service of helping packing and moving one's home (Haffmans, S., 2018).



Ill 27 The Performance Model

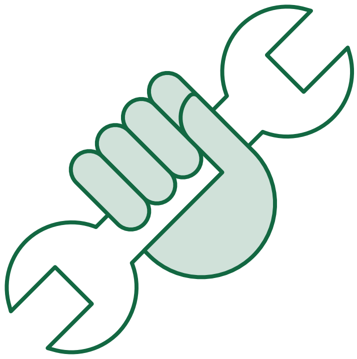
Circular Design Strategies.

Design for Product Attachment and Trust
Creating products that the user has a certain bond with, where they trust, or love them. Examples of design associated are watches, as we still have them, now that we have computers and smartphones to tell us the time. (Bakker, C, 2019.



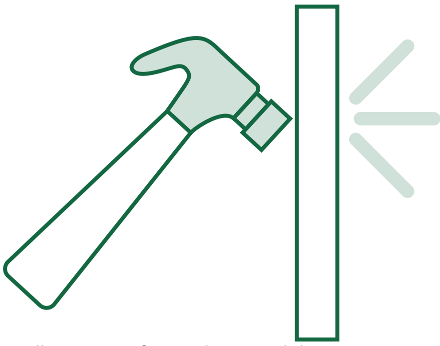
Ill 28 Design for Product Attachment and Trust

Design for Ease of Maintenance and Repair
Products where it is been built, to have its components switched out or have easy maintenance over it. Here a holy grail is self-repairing materials, such as an elastomer developed by researchers from Standford (Bakker, C, 2019).



Ill 31 Design for Ease of Maintenance and Repair

Design for Product Durability
Products that present optimum product reliability, in such that it can take wear or tear (Bakker, C, 2019). An example is Freitag (Circulardesigncases.nl, 2020), which produces bags out of recycled truck tarp. These are durable materials for outdoor usage, and they're durable for bags.

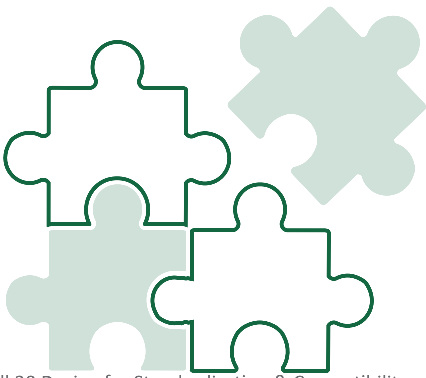


Ill 29 Design for Product Durability

Design for Upgradability & Adaptability
Products that are developed to be upgraded over time or have new modifications done to them (Bakker, C, 2019). This is often associated with computers, or smartphones, where new software is included in them.

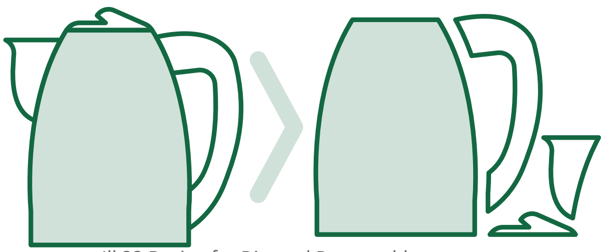
Ill 32 Design for Upgradability & Adaptability

Design for Standardization & Compatibility
Products that are made in such that they utilize components or parts that other users use in other products. One of the major users of the following design approach is Lego, as their interlocking system is used across almost all their products (Bakker, C, 2019).



Ill 30 Design for Standardization & Compatibility

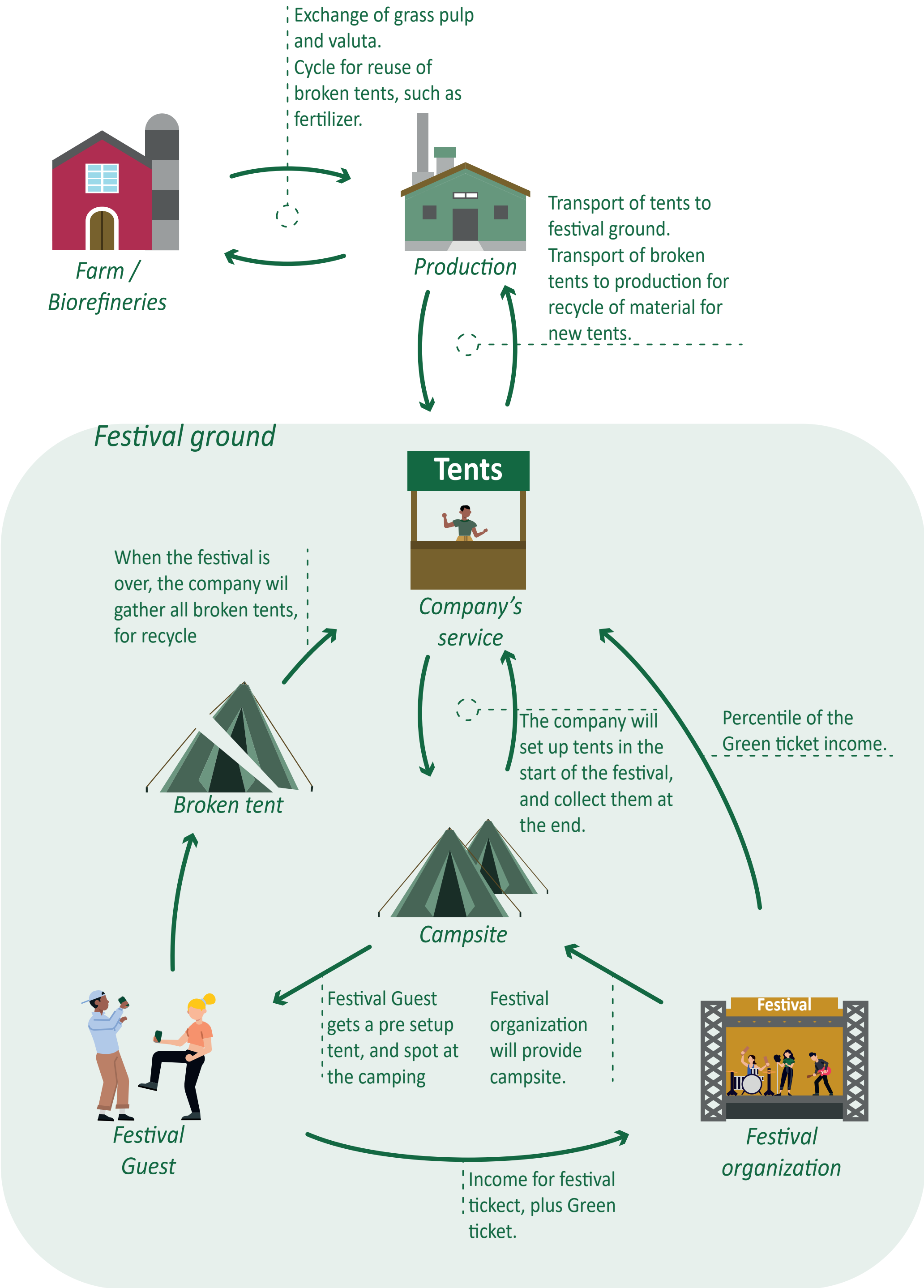
Design for Dis- and Reassembly
Products where dis- and reassembly are fast and easy. This is a newer approach compared to the others. Examples for this are in architecture where Better Shelter was made in collaboration between Ikea and United Nations High Commissioner for Refugees. It was built to be quickly assembled (Bakker, C, 2019)



Ill 33 Design for Dis- and Reassembly

Business plan: Tents

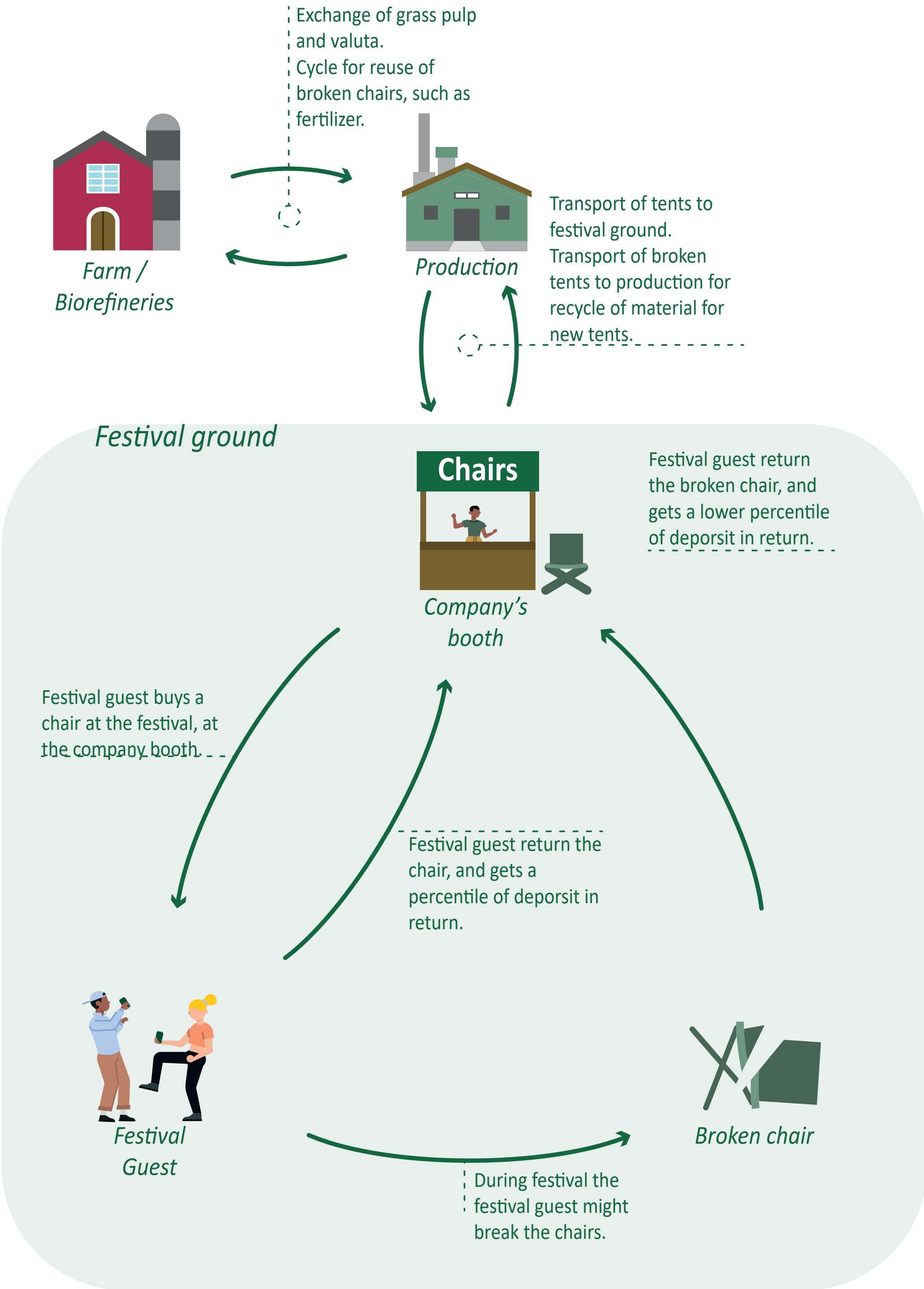
The business plan for Tents is based on two of the models. First is the Gap Exploiter, as that is the basis as the product would utilize grass pulp as the building material. The next is the performance model, as this would be a service that the festivals would hire. This business model is in alignment, with some of the other pre-pitched tents, currently in use at the festival, such as Smukfest.



Ill 34 Business Plan: Tents

Business plan: Chairs

The business plan for chairs are is also based on two models. First is the Gap Exploiter, as for the same seasons as the tents business plan. The next is the Access model. Here the business model is to be available to pay a deposit for a chair at the festival ground. Here they can then return the chair to get some of the deposit back or keep it. It aligns the deposit system there is in Denmark with bottles.



Ill 35 Business Plan: Chairs

Sum up.

After the business models were made, it was clear for the team that the tent's business plan was more complex compared to the chairs. Also, the team identified that the chair's business model could also be used for the tents. With this in mind, and with the trend of the community-based campsite, as "Clean Out Loud", from chapter 1.7, the team has chosen to focus on developing the chair. As for design strategies for the chairs, the basis should focus on "Design for Product Durability", as a direct counter to the high breakage that occurs with festival chairs, and "Design for Dis- and Reassembly", as this can be referenced to the mobility that is required for the chairs at the festival.

Festival chairs identified as the direction of the project. !

The chairs should be able to be reused, and therefore need withstand the rough handling, that occurs at a festival.

The chairs should be mobile and easy to setup.

1.9 | Project Brief

Project overview

Biorefineries are a growing industry in Denmark and Europe. It is a chemical method where you press fresh grass, the remaining grass juice, can through a chemical process be turned into proteins that can replace soya feeding to chickens and pigs. The main reason that Danish researchers want to replace soy feeding, is due to the harmful export of soy from the rainforest, where industries are burnings down a huge amount of hectares of forest in order to keep the production of soy up.
The technology of biorefineries is settled, it just needs to be implemented in order to logistics, politics, etc..
The team has found that a barrage for implementing the technology is the huge amount of residual grass pulp that is expelled from pressing the grass.
The objective of this thesis is to utilize the residual grass pulp and design a profitable and eco-friendly biocomposite used for the design, of products. for Danish festivals. This will be done as an initial starting point, with a scalable objective.

Business potential

With biorefineries growth and drive in the agricultural sector, there is a great business opportunity within utilizing the residual grass pulp that is produced in the process. It is estimated that the amount of just grass pulp in Denmark to be produced is around 2,8 Mio tons and with the current price of around 0.25 DKK per kg. Therefore it is a material where there is potential to develop a biocomposite, that can be used for a variety of products, and benefit most of the stakeholder's biorefineries. Furthermore, the direction of targeting the festivals as a starting point to enter the market with a grass pulp product is smart, as one-sixth of each Dane goes to festivals during the summer. Festivals are also a good possibility to brand a product, through word of mouth and for the festivals themselves, to enhance their own image.

Scope

To help scope the direction of what the mechanical properties of the biocomposite should strive toward, it was chosen that it should be able to be used for a festival chair at the campsites. This was chosen firstly due to the good symbiosis of green festival initiatives and the qualities of the grass composite material. Secondary based on the current directions of green initiatives at festivals is heading toward, such as the "Silent and Clean" camp, where people are urged to bring home whatever they bring to the campsite, where the chairs falters the most.
With the simplicity of the initial business plan, it is believed that the project can be scaled to various products at the festival, that follows the same structure.

Target Group / Market Strategy

The preparatory target group is festivals and festival guests at the camping sites. The festivals are as organizations currently undergoing different initiatives and solutions to improve their sustainability and environmental impact. This is due to the high trends of sustainability amongst the festival guests.
Furthermore, the direction of targeting the festivals as a starting point to enter the market with a grass pulp product is smart, as one-sixth of each Dane goes to festivals during the summer. Festivals are also a good possibility to brand a product, through word of mouth and for the festivals themselves, to enhance their own image.
In cooperation with these green agendas of festivals, the aim is headed towards the campsites, as this is where issues are seen the most.

Vision

Spriva aims is to be the first movers of grass pulp based biocomposite.

Mission

By designing a competitive and eco friendly festival chair for Danish festivals, made from the biocomposite. This will be done as an initial starting point, for scalable operation.

Criteria

The following criteria are based on the initial knowledge and findings resulting from the research conducted under the design phase. Through further conceptualization and testing of the material, and product, the criteria will be defined further:

Material criteria

• The material should be 100% biodegradable.	**Page.** 14
• The material should not have a harmful effect on the environment.	**Page.** 14
• The material must have a high availability, and have the possibility to be delivered in high quantities.	**Page.** 14
• The material must withstand water or other liquids.	**Page.** 19
• The material must be able to withstand high impact forces on a festival environment.	**Page.** 23

Product criteria

• The chair must be able to decompose down to simple organic matter.	**Page.** 14
• The chair must consist mostly of grass pulp composite.	**Page.** 14
• The chair should be light weighted for easy transport	**Page.** 17
• The chair should cost competitive to the current camping chair.	**Page.** 19

User criteria

• The user should be able to move the chair by hand, without restraint.	**Page.** 23
• The user should be able to easily understand and use the chair.	**Page.** 23

2 | Conceptualization

The chapter covers the development of a grass composite and initial ideation of a festival chair. This was done via analysis, dialogue with experts, and variations of material tests. These investigations resulted in a mycelium and grass composite, as well as design criteria for a festival chair. It was at the start of this process that the Covid-19 pandemic occurred.

2.1 | Bioproducts

With the direction of developing a biocomposite based on grass the team needed to research how to create such a material. Therefore research of different methods or binding material for a biocomposite, was done by located retailers or products made from composites. Here it was identified what material / method other current biocomposite product use. The activity will be conducted via desk research, where product/methods will be identified, and noting what materials, process, and function it has. The goal of the research is to identify certain binding material or methods, from the product or retailers (WS 2.1).

Storaenso.
Storaenso is a company located in Stockholm, Sweden, and Helsinki, Finland. It is a manufacturing company of a multitude of products, with biodegradable materials (Storaenso.com, Home page, 2020). The product range from packaging, fibers and biocomposite. With their biocomposite DuraSense™, they state it can be used for furniture (Storaenso.com, Biocomposites for furniture, 2020). It is a composite derived from tree fibers, and plastic, where one can get biodegradable plastic for it, such as PLA (Storaenso.com, DuraSense™, 2018).


Ill 36 Storaenso

The Flax chair.
The Flax Chair is made in a collaborative project with designer Christien Meindertsma and fiber specialists Enkev, initiated by Label/Breed (Labelbreed.nl, 2020). The chair is made of woven flax and PLA fibers that start as a cloth, and then heat pressed to the desired shape, to reduce waste generated (Meindertsma, C., 2015). Flax chair also won the Dutch design award' product category in 2016 (Tucker, E., 2016)


Ill 37 The Flax Chair

Forest Stool.
The Forest stool is a part of the final project done by Tamara Orjola, at Design Academy Eindhoven (KATHARINE SCHWAB, 2016). The project was made in response to the pine timber industry, where pine needles are wasted from it, and through research, it was around 30% of the mass (dip.ng, 2018). The result of the project was Forest wool, which can be made into textiles, or pressed to make the Forest Stool.(Tamara Orjola, 2020)


Ill 38 Forest Stool

Tresta Design
Tresta Design is a company that started based on a thesis project (Designmadeingermany, 2020). The project was about the waste material from the wine industry, of biomass from the grapes, vines, and stems, which is called pomace, wherein Germany there are produced 200.000 tons per year (Tresta-design). A material that is based on the pomace, and wax, such as beeswax and carnauba wax, was used for a binder, and it has been nominated for the Green Product award 2020 (Green product awards: Tresta, 2020). The product ranges from wine coolers and lamps that are made by compression (Designmadeingermany, 2020).


Ill 39 Tresta Design

Residue Chair.
The Residue chair is a chair that is made out of residue wood material from the wood furniture industry in combination with bone glue, as a binder for the wood, and is one of the nominated concept projects with Green Product Awards (Green product awards: Residue Chair, 2020. The project was a university project and made by the designer Hanna Carlsson (Carlsson, H. 2019).

Ill 40 Residue Chair

Ecovative Design.
Ecovative Design is a company located on Green Island, Ny, USA. It is a manufacturing company of multiple products, made from mycelium, that range from packaging, textiles, skincare, food and interior products (Ecovative Design, 2020). Here they grow their composites material themselves, with they also sell DIY bags, where one can grow the material themselves (Grow.bio, 2020). They manufacture the product MycoBoard, that resembles plywood, which is used in the Gunlockes Savor chairs, and made different products from wall tiles, and lamps (Interiors Ecovative Design, 2020).

Ill 41 Ecovative Design

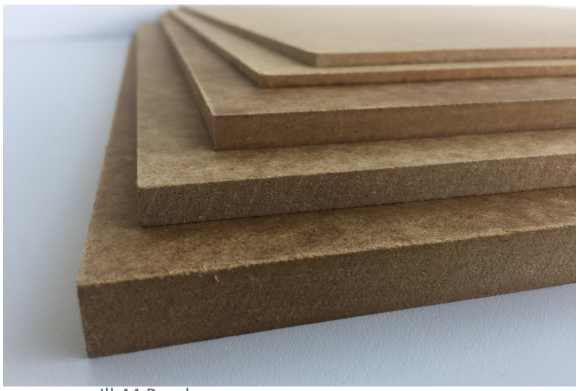
3dfuel
3dfuel is a 3d printing company that develops filament, where they have a filament with hemp and PLA (Flynt J., 2018). The company is located in Fargo, ND, USA (3dfuel, 2020). They have developed a line of composite filaments that is called C2renew, where they are 5 different filaments. They are: Buzzed, filament with beer waste material; Wound up, that has coffee ground in the filament; Landfillament, that is based on trash material; Entwined 2, filament with hemp fibers and a glass filled filament (3dfuel, 2020).

Ill 42 3dfuel

XYZAIDAN Paper mould
Paper clay is a clay body where cellulose fibers, either from blended paper or cardboard, are included (Wikipedia, Paper clay, 2019). Paper clay can be used to create different ceramic products, where it can substitute normal clay. It was identified as an alternative method, that was located via a youtube channel by XYZAidan, who had experimented with pressing the pulp, creating a product resembling a wood (XYZAidan, 2020). The molds used are 3d printed and have presented a guide of how to make them (XYZAidan, 2020).

Ill 43 XYZAUDAN Paper mould

Pond
Pond is a Danish company located in Aarhus (Pond, 2020). They have developed a biodegradable resin, that can be used in MDF boards (Jensen L.S.M, 2017). They state that this is the first biodegradable resin in the world (Jensen L.S.M, 2017). They sell currently 3 types of version of the product: Fibre, granulate and non woven (Pond, 2020).


Ill 44 Pond

Sebastian Cox
The designer Sebastian Cox has made products out of mycelium, which is two lamps and a stool, where the lamps are sold either for 300 £ for the larger one or 280 £ for the smaller one (SebastianCox.co.uk, 2020). The materials are based on waste materials that consist of hazel and goat wood (Hu G., 2017). The products are made via molds of the two lamps and the stool.


Ill 45 Sebastian Cox

Full cycle bioplastic
Full cycle bioplastic is a company that has developed a method of developing PHA plastic from agricultural waste (UPROXX, 2017). PHA is a biodegradable plastic. The company focuses on circular economy and therefore promotes the intake of old PHA to make new virgin material (Full Cycle Bio Plastics, 2020)..

FULL CYCLE
BIOPLASTICS

Ill 46 Full Cycle Bioplastic

Sum up
From the team's investigation of a variety of products and biocomposites, the team noticed a pattern occurring between the multiple products, and that is they use certain methods and material to make their biocomposite.

The first one we notice is bio-based plastic, such as PLA used in the Flax chair or hemp filament, Bio resin from Pond or PHA developed by Full cycle plastics.

The other was what the team defined is bioadhesive, which includes the Bone glue used in Residue chair, the carnauba wax, and beeswax usage in Tresta Design or the starch adhesive for the paper clay molds shown by XYZAIDAN.

Lastly, the final composite material was seen by Ecoactive Design and Sebastian Cox, with the mycelium based products, from packaging to chairs.

Even though there was no information gained about Forest stool production or other material used to create it, the information gave insight that creating a composite of grass was realistic, as the material used resembles grass.

Binding material /methods categories was identified as such: Bio plastics, Bio Adhesive and Mycelium

!

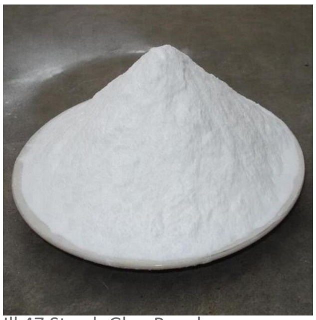
2.2 | Binding material / Methods

With the identified three categories of binding material/methods and the different varieties within each of the categories, the team saw a need to look more in-depth for each of them. This was to understand if there were early indicators for each of the materials to issues, that will result in the deselection of the spoken material. This was conducted via desktop research (WS 2.2, WS 2.3, WS 2.4), that looked into the basic information of the material.

Bio adhesive

Starch glue.

Starch glue is a glue made from different plant materials, such as roots, tubers, and plant seeds (LD davis, 2020). Starch-based glues are one of the most commonly used glues in industries, especially in the packaging industry, the primary use for bonding paper products (Adhesivesmag, 2015). Starch glue has many advantages for adhesive materials, such as good availability, low cost, stable quality, good adhesion to cellulose, and heat resistant (Adhesivesmag, 2015). As starch glue is widely available, it has a wide range of customization, such as viscosities, and there is continuous development with it. It is based on carbohydrate polymers, and starch is made up of amylose and amylopectin (Adhesivesmag, 2015). Starch glues were identified from the research of paper clay, and the making of hardening cardboard material from the YouTuber XYZAidan (XYZAidan, 2020). Indicators point towards that starch glue can be a potential binding agent for the use of composite material.



Ill 47 Starch Glue Powder

Animal glue.

Animal glue is a glue that is derived from different animal parts, primarily from collagenous material in hide, bones, or hooves (Wikipedia, Animal glue, 2020). The glue was identified by its usage in the Residue chair by Hanna Carlson. Animal glue is one of the oldest made by man, as it can be traced all the way back to ancient Rome (Gluehistory.com, 2020). With the introduction and use of chemical-based glues, animal-based glue almost collapsed (Gluehistory.com, 2020). Today animal-based glue is rarely used today and is the most used restoration work or specialized products such as violin or pipe organs (Wikipedia, Animal glue, 2020)). One of the reasons for its rarity of usage is that the glue itself is water-soluble (Wikipedia, Animal glue, 2020)). With the information identified it can be concluded that because of its rarity of usage today, that animal-based glue is not optimal for the composite material of the festival chair.

Ill 48 Animal Glue

Beeswax.

Beeswax is a natural wax, that is produced by honey bees with there honeycombs. This consists of around 284 different compounds, with the main components of long-chains of alkanes, acids, esters, polyesters, and hydroxy esters (Ahnert P., 2015). The composition wary from location to location, of the was itself. The melting point of beeswax is placed at around 60 °C (Ahnert P., 2015).

Beeswax is used mainly in three industries that are cosmetics, food, and pharmaceuticals (Wikipedia, Beeswax, 2020). The use of beeswax in composites was identified by Tresta Design, in their wine coolers and lamps. The process of developing the products is where the pomace and beeswax, has been compressed, into the shape of the products (Designmadeingermany, 2020). The current price of beeswax has increased over the last couple of year from around 33 DKK per kilo up to around 200 DKK per kilo, as a result in a collapse in bee populations by the varroa mites (Zhou N.,2018)

Ill 49 Bee Wax

Carnauba Wax

Carnauba wax is a natural wax that is derived from the Copernicia prunifera palm that grows in Brazil. The wax is the natural wax with the highest melting point of 82-86 °C, and also regarded as the hardest commercial wax, in that in its natural state it is harder than concrete (Helmenstine A.M., 2018). It is used in a variety of products, such as food, cosmetics, automotive wax, and furniture wax. It consists of 80-85% fatty acid esters, 10-16% fatty alcohols, 3-6% acids, and 1-3% hydrocarbons (Helmenstine A.M., 2018). The wax was identified by the research of Tresta Design, where they developed Wine coolers, lamps, and wall panels. The carnauba wax was used for creating wall panels and was stated to be precise, robust, dimensionally stable, and sound. absorbing (Designmadeingermany, 2020).

Ill 50 Carnauba Wax

Mycelium

Mycelium is the vegetative part of fungi, that is made of numerous amounts of weblike strands of fibers called hyphae (Study.com, 2020). It is from the mycelium that the fungi absorb nutrients, by a two-stage process, where it first releases enzymes to breakdown complex biological polymers, down to monomers (The Conscious Club, 2017). Thereafter the different monomers are absorbed via a combination of facilitated diffusion and active transport. From here there are different methods of processing the material, as the following segments will look further in. The use of mycelium was identified via Ecovative design, which is currently the leading developer of mycelium composites (Ecovative Design, 2020). The first stages of growing mycelium are by combining agricultural waste or wood waste, were it then is placed within a mold to grow over 4-5 days (Bloomberg, 2015).


Ill 51 Mycelium Growth on Ground

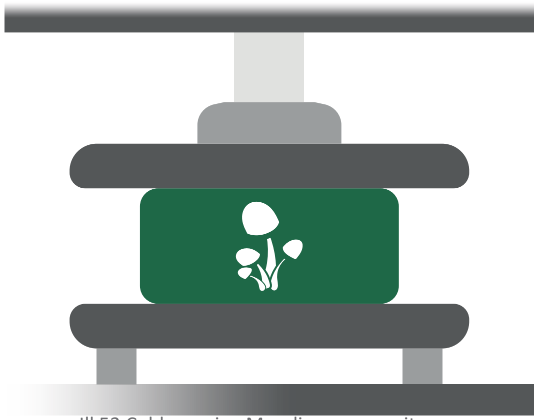
Drying

The first method of creating a mycelium composite is by drying the mycelium (Jones M. A. et al, 2020). This is done to neutralize the mycelium, and this is done either by air drying or placed within an oven (Jones M. A. et al, 2020). The material granted via this process resembles a foam-like material (Stowa, 2017). There have been different experiments with different agricultural materials that have resulted in different strengths (Jones M. A. et al, 2020). Based on a study these can range from 0,02 to 0,15 MPa in compression strength (Jones M. A. et al, 2020).


Ill 52 Drying Mycelium composite

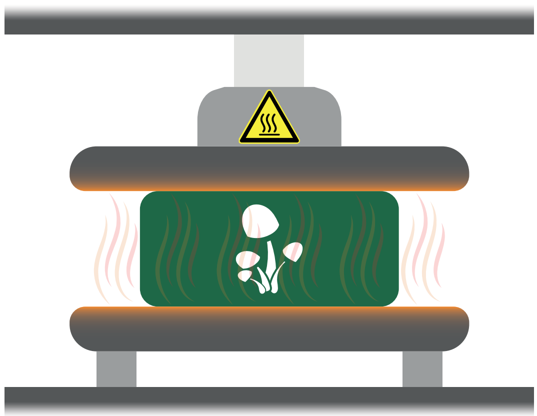
Cold press

Cold press is the method of pressing the material together, via a press (Jones M. A. et al, 2020), whereafter the process of drying of the material includes, as a normal drying method (Jones M. A. et al, 2020 Jones M. A. et al, 2020). This method results in a foam board like material (Stowa, 2017). It has been defined that the process of pressing the mycelium composite increases its strength (hJones M. A. et al, 2020). Based on a rapeseed straw composite the tensile strength increase to 0,01 MPa - 0,03 MPa and the elastic modulus to 2 MPa - 9 MPa (Jones M. A. et al, 2020). This improvement also includes flexural strength improvements to 0,06 MPa - 0.21 MPa) and moduli 1 MPa - 15 MPa (Jones M. A. et al, 2020).


Ill 53 Cold pressing Mycelium composite

Heat Press

Heat press varies from the cold press, in that you heat the materials while pressing it. This results in that there is no need for drying of the mycelium material afterward. The composite gathered from this process resembles a board like material (Stowa, 2017). As cold-pressed mycelium composites showed improvements compared to, the normal foam mycelium, via heat press this is significantly higher (Jones M. A. et al, 2020). Here the improvements of the rapeseed mycelium composite in regards to the dried mycelium composite, where the tensile strength increases to 0,01 - 0,24 MPa, and elastic moduli to 2 MPa - 97 MPa (Jones M. A. et al, 2020). This is also seen with flexural strength improvements of 0.06 MPa to 0.21 MPa and moduli 1 MPa to 15 MPa (Jones M. A. et al, 2020). This is the same with flexural strength and moduli to 0,06–0,87 MPa for flexural strength and to 1 MPa- 72 MPa for flexural moduli (Jones M. A. et al, 2020). There is however talk that the board material still needs development for usage in structural elements (Jones M. A. et al, 2020), but looking at Ecovative Design Mycoboard, they have developed board material for furniture (Shanesy L., 2016), and strength of 15 Mpa (McIntyre G., 2016).


Ill 54 Heat pressing Mycelium composite

Bio Plastics

PLA

Polylactic acid or PLA is a biodegradable plastic that is derived from the fermentation of carbohydrate sources, mainly corn or sugar canes (Rocío Jaimes Gutierrez R.J., 2020). PLA is a biodegradable plastic, as it is made from biological materials, meaning that it will decompose in nature (Rocío Jaimes Gutierrez R.J., 2020). However for it decomposed in a reasonable time manner, it needs to be placed in a commercial composting facility, where it takes around 3 months for it to decompose (Rocío Jaimes Gutierrez R.J., 2020). A benefit with PLA is that it is a thermoplastic, meaning that I can be re-melted, and reused for different applications. For its application, it's used in a variety of industries, and products, such as packaging, medical, textile, and 3d printing (Rocío Jaimes Gutierrez R.J., 2020). The material was registered, from the Flax Chair (Labelbreed.nl, 2020). PLA shows good mechanical properties compared to other plastics such as polypropylene, polystyrene, and polyurethane, however it does present a certain brittleness to it (Rocío Jaimes Gutierrez R.J., 2020). A positive note with PLA is that it is widely available and that it's economically feasible (Rocío Jaimes Gutierrez R.J., 2020).

Ill 55 Colored PLA Filament Pile

PHA

Polyhydroxyalkanoates or PHA is a biodegradable plastic that is made via the process of microorganisms that produces the plastic within their cells, by feeding them biomass (Hoeven D.V.D, 2016). PHA is viewed positively with its biodegradability even compared to other bioplastics, as it can degrade in the ocean environment within 6 months, and it does not require the need for industrial compost. (Tullo A.H., 2019). However, even for its benefits, companies have tried to market PHA since the nineties but did not succeed (Hoeven D.V.D, 2016). Based on a state from Jan Ravenstijn, a consultant in bioplastics, the bioplastic market is focused on quality and pricing, and that PHA is not there yet (Hoeven D.V.D, 2016). There is however traction for biodegradable plastic over the world, and therefore PHA is beginning to rise in popularity (Barrett A., 2019). The material was identified from Full Cycle Bioplastics, which has developed a method of creating plastic from agricultural waste, instead of direct agricultural materials (Bioplastics.guide, 2020).

Ill 56 PHA Plastic bottle degradation

BIO Resin

Pond Bio is a bio-resin that was developed by the company Pond located in Denmark. A collection of further information about the bio-resin developed by Pond was not successful, as contact with Pond was attempted, via phone or mail. However, the feedback was given back from Pond, that due to Covid-19, that they were currently in a state of crisis, and did not have the time to answer any question there, even though they stated that they normally do a collaboration with students. Therefore further investigation of BIO resin has not been taken further, as information associated could not be located through normal desktop research.

Ill 57 Pond Logo

Sum up

By researching the different materials that can be used as binding for the biocomposite, the team was able to get an insight into which should be investigated further and which delimited.

From the category of bioadhesive, animal glue and Beeswax was not taken further. Animal glue as stated is used rarely in industries, and beeswax there is some indication of an increase in prices and worries with production. Also as carnauba wax is already viewed to be stronger, the team did not see the point in proceeding further with beeswax.

With the mycelium composites, the team saw potential with material as a whole, but from the information gained it was noted that heat pressed mycelium is the strongest of the materials, and therefore the team chose not to further testing and work with dried and cold-pressed mycelium.

Lastly, with bioplastics, we chose to work further with PLA, as it indicated as a widely known bioplastic. As for bio-resin and PHA they were deselected, as PHA is not yet a commonly used bioplastic. Even though the team saw potential with the bio-resin, it was not possible to gain further information from Pond about the material. Therefore the team did not see any point of investigating further with this material.

Following binding agents where chosen for testing: Starch glue, Carnauba wax, Mycelium and PLA. !

2.3 | Composite test 1: Development

Now that the team had chosen four different binding agents, to jump-start the development of the composite, the team chose to initiate the test of creating the composite materials. This was to both note if any indicators from creating the material showed issues, and to understand what aspects within the process of creating the material, had an effect on the material. The objective was to create material samples, for each of the material, and try different varieties of the process/recipe to see any effects would occur, or indicators of issues with the material. (WS 2.4, WS 2.5, WS 2.6, WS 2.7, WS 2.8, WS 2.9, WS 2.10, WS 2.11, WS 2.12, WS 2.13, WS 2.14, WS 2.15).

Carnauba wax

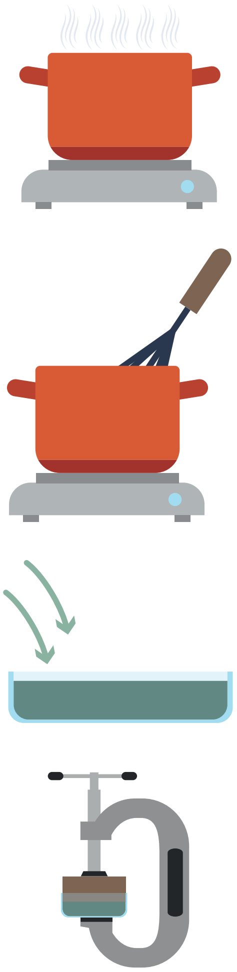
Ingredients
- 50 Grams Grass pulp (Dried)
- 35 Grams Carnauba wax

1|
Mix Dry grass pulp with Carnauba wax in a pot and heat it.

2|
Stir the mixture until the carnauba wax is melted, and its humongous.

3|
Place the mixture into a container, for the wished form.

4|
Press the mixture inside the container, with a clamp, until cooled off to take out.



Ill 58 Carnauba Wax recipe list

Sum up

The team viewed that reducing the amount of carnauba wax should not strife too far from the amount used in test 1, as reducing it by the amount seen in test 2 would result in failure in material strength. The creation of the material was viewed simply and did not show any indication of issues with the production of it. Overall the material with the proper ratio has a high material strength.

Ill 59 Carnauba Wax material test 1

Wax Test 1

The process of making the carnauba wax composite was quite simple and straightforward and proving no issues. The resulting material proved better than first expected, and was surprisingly strong and durable. The material could resemble a hard plastic or rock-like material and would require substantial strength to break with once bare hands. The team viewed the material highly positive but could see that the amount of carnauba wax used in the mixture was quite high, and saw reducing it would benefit, as to reduce the most expensive component in composite (WS 2.11).

Ill 60 Carnauba Wax material test 2

Wax Test 2

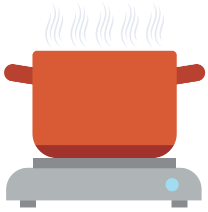
The second test changed the following ingredients:
- 15 Grams Carnauba wax

The process of making the material was similar to the first test, however, even at this stage, the material did seem porous. This was also verified when the material was made, as it was porous and broke easily when taking it out of the mold. The team could identify that the reduction of carnauba wax in the composite, reduces the strength quite substantial (2.12).

Starch adhesive

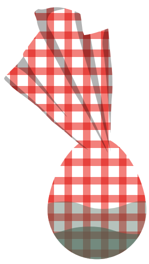
Ingredients
- 50 Grams Grass pulp
- 20 Grams Dry rice
- 20 Gram Cornstarch
- 200 ml water

1
Cook rise in water, until its a glue like consistency.



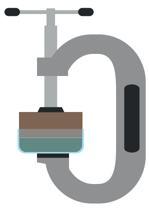
2
Place cooked rice, corn-starch, grass pulp and water in a blender. Blend until its a humongous.

3
Place mixture in a piece of cloth, and press as much water as possible out of the mixture.



4
Place the mixture into a container, for the wished form and dimension.

5
Press the mixture inside the container, with a clamp. Wait 24 hours, to take composite out, and air dry.



Ill 61 Starch adhesive recipe list

Sum up
From the different tests with adhesive, it can be concluded that a more humongous mix between all components improves the binding of the material seen in test 2, and higher pressure results in a stronger starch adhesive composite test 3 and 4. The material overall has a fine strength and a bit brittle.

Ill 62 Starch Adhesive material test 1

Starch Adhesive 1
The process of creating the starch composite included multiple factors to create, and the strength needed to press fluid out of the pulp was quite high. The material itself when first made resembled rubber, but after drying it became harder and more like wood. The material had a fine strength but also did show some brittleness to it (WS 2.4).

Ill 63 Starch Adhesive material test 2

Starch Adhesive 2
The second test changed the recipe in terms of not blending, but mixing the materials together. This was to see if upholding the length of the fibers would improve the material.

The process did present the same issues of pressing fluids out. The resulting material did not achieve the same binding as the first test, and therefore not as cohesive. This resulted in the material being easy to break apart even when dried (WS 2.7).

Ill 64 Starch Adhesive material test 3

Starch Adhesive 3
At the third test, the mold that was used to press the pulp was changed to one that was able to have increased pressure on it.

Same notifications on the process as the previous starch adhesive test. The material itself resembled rubber when pulled from the mold, however when dried it presented a higher strength compared to test 1, however, this was hard to perceive as the sample was so small (WS 2.9).

Ill 65 Starch Adhesive material test 4

Starch Adhesive 4
The fourth test used the same process as starch adhesive test 3 but utilized a larger 3D printed mold to validate the test.

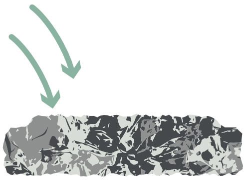
The process of pressing the pulp in the mold required more force compared to test 3. The resulting material was similar to test 3 in terms of strength. An accident that occurred including a team member falling, resulted in a breakage of the material. This however validated that its a brittle material and how the inner structure was (WS 2.14).

PLA

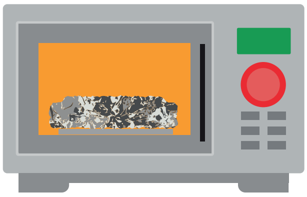
Ingredients
•50 Grams Grass pulp (Dried)
•20 Gram PLA

1
Blend the grass and PLA until fine.

2
Place the dry mixture in a tinfoil, for the wished form and dimension



3
Place tinfoil container into the oven, and bake at 250 Celsius for 20 minutes. Thereafter take out of oven and let it cool off, before taking composite out



Ill 66 PLA recipe list

Sum up
From the different tests it can be concluded that for a proper PLA composite, it is necessary to have a dry material when heated, from PLA test 4. Also that a prober and thoroughly mixed blend of PLA and grass improved the binding of the composite, noted from PLA test 3, and that ensuring that the material is heated for enough time for the PLA to melt to be able to bind with the grass, seen when comparing test 2 and 3. Overall the material can show promising strength and hardness, even if it does seem a bit brittle.

Ill 67 PLA material test 1

PLA test 1
The first test PLA was different from the main recipe used further on. Here the process was to first melt the PLA in the oven by itself and then mix the grass with it. This however proved not possible, and the PLA did not have enough viscosity to mix with the grass itself. This test then resulted in a new base recipe of making material, seen to the left (WS 2.6)

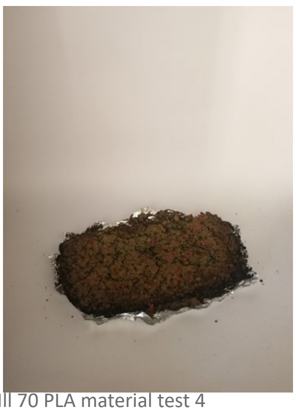
Ill 68 PLA material test 2

PLA test 2
Test two followed the recipe seen to the right and was successful in making a PLA composite. The process was easier than first anticipated, as it was initially thought to blend the PLA would be difficult. The material itself resembled a mix of wood or plastic. It was quite a strong material, along with fine hardness. it was however noted that the material did seem to be brittle, and snap if enough force was applied (WS 2.8).

Ill 69 PLA material test 3

PLA test 3
Test 3 variates the recipe by having a reduced cooking time from 20 minutes to 10 minutes.

The process was similar to test 2. The resulting PLA composite resembled more like wood than plastic, and also presented some considerable strength and hardness. However, it was not as strong as the material from PLA test 2. The reasoning is estimated to be that the materials were not as fine mixed, and the PLA did not melt thought out the mixture (WS 2.10)



Ill 70 PLA material test 4

PLA test 4
Test 4 changed the recipe to include:
•40 ml Water.
This was to ensure that the PLA and grass were mixed more humongously, before heating.

The process took longer than the other tests, as the material began to stick to each other during the blending process. The material itself was a failed material and did not melt the PLA. This resulted in a crumbly matter that broke easily. The reasoning for this is that the water conducted heat away from the mixture when it evaporated, and therefore the PLA did not melt (WS 2.13)

Mycelium

Ingredients
- 50 Grams Grass pulp
- 1-2 Tea spoons Oyster Mushroom

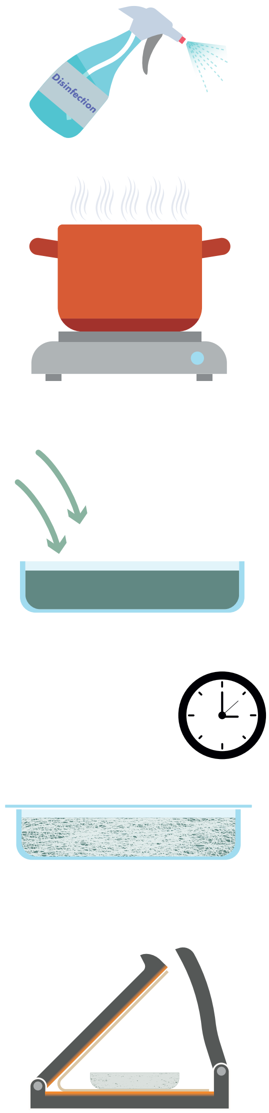
1
Sterilize all equipment used for recipe.

2
Cook grass at high heat for 20-30 min, to sterilize the grass

3
When grass is cooled down, place in a container with mushrooms. Cover container, allowing minimal airflow.

4
Wait for the mycelium to growth throughout the grass before taking out of container. Around 4-7 days growth time.

5
Place mycelium grass composite in tortilla press that been heated to 250 Celsius. Press the composite for 10 Min, with substantial force.



Ill 71 Mycelium recipe list

Ill 72 Mycelium material test 1

Mycelium test 1
The process of making the mycelium took quite some time to be conducted as the material required a couple of days to grow. It was also noted that pressing the material, the force applied was too quickly, as this resulted in a steam explosion in the material, as the moisture in the material could not escape. There was still a fragment of the mycelium composite after the test. The material itself was presented with quite a strong strength and durability for such thin material. The material could resemble strong veneer sheets (WS 2.5).

Ill 73 Mycelium material test 2

Mycelium test 2
The recipe for mycelium test 2 was the same as for test 1, however, the pressing of the material was done more controlled. However, the process of pressing the mycelium composite was done to lighten this time, resulting in it still being quite damp after 10 min. Therefore ten minutes more of pressing was done with more pressure reaching the same amount as test 1, but more controlled. The material itself resembled a woodlike material. It had resembled the same strength and durability as test one, however, it did seem a higher amount of force would require to break it, as it was thicker than test 1 (WS 2.15)

Sum up
The process of making the mycelium requires some fine-tuning to reach the right condition, such as growing it and pressing. The material was viewed positively as it presented quite a strength. It was also a material that was solely based on grass, which the team saw as an important factor.

2.4 | Material parameters

With the creation of the different composite materials, the team saw a need to define the parameters the composites would be upheld too. These parameters would look into overall information on the binding material, and what the mechanical properties of them would be, to determine which composite material show the most economical and mechanical potential. The following segment will look into what different parameters that have been chosen and why, as well research does parameters that do not require testing of the materials, such as mechanical properties (WS 2.16, WS 2.17, WS 2.18, WS 2.19, WS 2.20, WS 2.21).

The different parameters that were chosen were split into two groups being principled and mechanical.

Principled

Accessibility
The parameters looked into the access and abundance of the material. This was to determine how the global production, export, and production or harvest of the material is done. Understanding these aspects of the material would be crucial from a logistical standpoint when developing the composite material

Price
The understatement of what the pricing of the material needed to create the different composite, excluding the known pricing of grass. The parameter would give insight to the team, into creating an economical competitive composite.

Environmental impact
Another principled parameter was to see what the environmental impact of the material used for the composite. As the composite material should be sustainable and biodegradable, it was important to understand what effects on the environment the binding material had in terms of acquisition and disposal.

Simplicity of Production
The last parameter of the principled looks into the simplicity of the production of the composite in terms of ingredients, requirements, and equipment needed. This gives an insight into how the economical effect of the composite would be.

All the parameters will be pointed from 1 to 5, and each of the parameters will be weighted between 1 to 5 in ratio. The ratio is then multiplied to what the parameter is pointed

Ratio value	Multiplication factor
1	0.2
2	0.4
3	0.6
4	0.8
5	1

The team investigated first the principled parameters, as these would require desktop research, and not testing. This is done to reduce overall time, as if there were indicators of issues with any of the composites, these would then be excluded from further testing. Therefore the pointing of the parameters will be done in two sets.

Mechanical

Strength
The main parameter is the strength of the composite, in terms of its ability to resist deformation and breakage from external forces (Freelancer.com, 2017). It is important for the composite material to be strong enough for its intended purpose as a chair.

Toughness
The composite's ability to absorb energy and withstand not getting deformation from impact forces (Freelancer.com, 2017). To handle certain impacts is an important factor for the material, for the handling the festival chair at the festival.

Thermal resilience.
The composites resistance to withstand deformation from thermal change, especially heat (Freelancer.com, 2017). This to understand how the composite will react under the environmental condition at a festival.

Moisture absorption
The moisture absorption is the amount of water the composite would absorb. This would give insight to how the composite would act in the environment of a festival, both in terms of biodegradability, and if it loses strength.

Density
As a composite, the density would present the mass of the material per volume. This is an important parameter toward how the users interact with the chair when moving it around.

Accessibility

The team gave accessibility a weight of 5 in the point system. Reasoning for this is that the team viewed that being able to acquire the material for the biocomposite is necessary, due to the quantities of grass pulp.

Starch glue

Starch glue is a commonly used adhesive and is the main binding agent in the paper industry (adhesivemag.com, 2015). Also, the starch adhesive can be derived from a readily available variety of raw materials such as corn, wheat, potato, rice, tapioca, and sago (adhesivemag.com, 2015). An example is that there is produced 75.900.000 tons starch, where 44% is corn, 24% tapioca, 5% potato, 4% wheat and 22% dextrin or other starch types (www.who,at 2018)

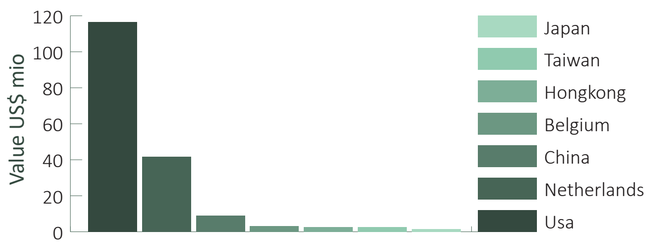
Carnauba wax

Carnauba wax is mainly derived from Brazil, where it was estimated in 2017 exported 15,652 tons (www.factmr.com, 2020), where the harvest is concentrated in the northeast of Brazil where the Carnauba palm tree originates from (Wikipedia: Copernicia prunifera, 2020). Carnauba wax is mainly exported to Usa 25%, Germany 10-15%, Japan 15-25%, and 5% each for Holland and Italy (Studyres.com, 2011). The main producers of carnauba wax are Brasil Ceras, Carnauba do Brasil, Foncepi, and Pontes (Grandviewresearch.com, 2016).

PLA

PLA is derived from biomass material such as corn and etc. Leading manufactures of PLA are as following (www.plasticsinsight.com, 2020):

The main exporters of PLA are USA, Netherlands, China, and etc, as seen in illustration 73 (www.plasticsinsight.com, 2020).



Ill 74 PLA top exporters chart

The global production of bioplastics in 2019 was at 2,11 million tons, where PLA was for 13.9% of it being 151800 tons PLA (www.european-bioplastics.org,2020). There are however moral issues in the productions of PLA, as it competes with food crops over land used (www.filamentive.com, 2019). The other issue gained from Zuzana Weberova from Aage Vestergaard Larsen A/S is that the amount of tailings collected from PLA is only at 2-3%.

Mycelium

With the method of making the mycelium composite, the necessity of resupplying mycelium such as oyster mushrooms is almost non-essential, as it can easily be grown as a starter. As the mycelium itself grows to be the binding agent in the composite, by the use of grass as a growing medium. However, looking into the global production of mushrooms, it has increased by 18-fold over the last 32 years, from 350,000 tons in 1965 to 6,160,800 tons in 1997 (Extension.psu.edu, 2016), and this would indicate a higher increase in recent years.

Price

Price was given a weight of 4 in the point system. Price is an important parameter, however as the grass pulp is already a low-cost material, it was given a 4.

Starch glue

As the starch adhesive is so widely available and used in a multitude of industries such as the paper industry as a binding agent, it is identified as a low-cost product sold in high-volume orders (LD Davis: Natural Starch-Based Glues, 2020). This is backed as the starch adhesive can be derived from a multitude of natural crops (adhesivemag.com, 2015). The pricing for industrial use of rice starch powder is currently around 2,7 Dkk per kg (www.persistencemarketresearch.com, 2020), and corn starch around 2,0 DK per kg (www.fortunebusinessinsights.com, 2019).

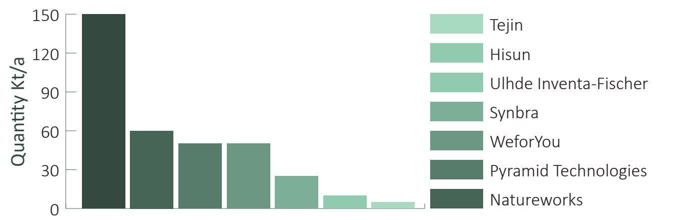
Carnauba wax

Via mail exchange with the company, Carnauba do Brazil, an exact number of the pricing was not given, however what influence the prices were (WS 2.19). Carnauba wax was indicated to be a comity item, and that its prices fluctuate year to year due to different factors, as weather or politics (WS 2.19). Via contact with Tresta Design the team was able to get knowledge of the carnauba wax they have used for their product (WS 2.19), which is from Amazon and the pricing is 190 Dkk per kilo (Amazon, 2020)..

PLA

Global trade prices of PLA from main producers USA, China, Germany and Japan can be seen in the illustration 74 (www.plasticsinsight.com, 2020) .

China: 4770 US$/tons, Germany: 2642 US$/tons, Japan: 2160 US$/tons, USA: 1910 US$/tons



Ill 75 PLA top producer chart

The average price of PLA per kg is 2,8705 US$/kg or 19,80 DKK per kg.

Mycelium

The pricing of the mycelium would be relatively low, as stated before as the required material is mainly grass itself, and the manufacturing of the composite. Based on the research paper the cost of mycelium material is around 0,48-1,17 Dkk per kilo mycelium composite (Jones M. A. et al, 2020)

Environmental impact

The parameter environmental impact was given a weight of 3. The reasoning for the weight given was that though sustainable is an important factor for the branding and image of the composite, all binding agents investigated are biodegradable and already viewed as sustainable solutions.

Starch glue

Starch glue is derived from natural ingredients and is water-soluble, it is used as the main sustainable glue within packaging (LD Davis:he Role of Eco-Friendly Glues in Sustainable Food

Packaging, 2018). If looking at normal cardboard it is able to degrade in normal garden conditions within three months (www.planetpaper.com, 2017).

Carnauba wax

The harvesting of carnauba wax has presented issues that were both social and environmental. Here the social issues has been associated with working conditions for the workers in the fields, and the environmental effect is the poor harvesting practice and deforestation (Ethicalbiotrade.org, 2020). These poor practices have led to imbalance of biodiversity, invasive species and drought (Ethicalbiotrade.org, 2020). However, Ethical Biotrade has started "Initiative for Responsible Carnauba", in collaboration with the Brazilian government, to improve the social and environmental impact of the harvest of carnauba wax (Ethicalbiotrade.org, 2020). The initiative has included the major producers of carnauba wax (Ethicalbiotrade.org, 2020).

PLA

As a biodegradable plastic it is able to decompose, however to achieve this PLA needs certain conditions and time. To decompose it needs to be within industrial composting facilities, where it takes up to 90 days (www.filamentive.com, 2019). If not and if placed in normal landfills this process can go up to 1000 years (www.filamentive.com, 2019), as it requires UV light and oxygen to decompose (www.scientificamerican.com, 2008). This issue is also seen when PLA is in seawater, where it will not even decompose when submerged for 6 to 12 months (Syke.fi, 2019).

Mycelium

The environmental impact of mycelium is relatively low as the material needs to be grown and not fabricated as many other materials. A quote from the paper Engineered mycelium composite construction materials from fungal biorefineries: A critical review it states (Jones M. A. et al, 2020)

"Mycelial growth provides a unique low energy bio-fabrication method to upcycle abundant agricultural by-products and wastes into cheap and environmentally sustainable alternatives to synthetic construction materials " (Jones M. A. et al, 2020)

Simplicity of Production

The team gave a weight of 1 for the simplicity of production. Even though the production of the composite is important, the following answers are estimations of the production. This is due to the team already made the different composite materials and had an indication of how the production would be. The team had discussed including the parameter for its low ratio, however, it did aid the team in the understanding of the materials.

Starch glue

Production of the starch composite is estimated that it would not require the use of high energy, as it would not require high heat usage. For the production, it would require thorough mixing of grass and starch glue powder, to a humongous mass, where it would be pressed in a high-pressure mold. There are however various steps required to manufacture the composite, such as blending the material, and letting it dry when it is pressed.

Carnauba wax

The team estimated the production of carnauba wax composite would be simple since it would only require mixing the grass and wax in a heated container, where it is then placed in a mold with pressure.

PLA

The production of PLA the team estimated would require quite an amount of energy, as it would need to be heated to the melting point of PLA that is around 180 degrees. If the material could reach a substantial viscosity it could be extruded or injection molded, however, more research would be required to validate this.

Mycelium

The production of the mycelium is estimated to be a bit complicated due to its biological nature, though it is low in energy consumption. As the mycelium needs to grow, having full control of how dense or fast it grows, would require more research before finding all the right conditions. However, the production is low in energy, as it only needs to be steam for sanitation and heat pressed at the end.

Parameter	Importance	Mycelium	Starch glue	PLA	Carnauba wax
Accessibility	5	5	5	3	2
Price	4	5	4	2	3
Environmental impact	3	5	5	1	4
Simplicity of production	1	3	4	2	4
Result		12,6	12,0	5,6	7,6

Sum up

From the points given it is clear to see that there are two distinct composite materials that have an overall lead, compared to the other two. Mycelium scored high in the categories of accessibility, price, and environmental impact. However, as the production required a bit of fine-tuning the simplicity of production was placed at 3. Starch glue was also given a 5 rating inaccessibility and environmental impact, as the material is so widely available, however price was given 4 as there is still a need to buy starch glue powder. The simplicity of production is given a 4 as it does not require energy for heat, and the process is straight forward. PLA was given its lower score as it presented issues in different parameters. This is especially true for its environmental impact, as it needs proper disposal to even degrade. With the Carnauba wax, the team had viewed it positively from the result of composite test 1, however, issues with access and price of the material presented less than ideal values.

Therefore the team has decided to remove PLA and Carnauba wax from further testing, as the values they present were substantially lower compared to mycelium and starch glue, which were quite close to each other.

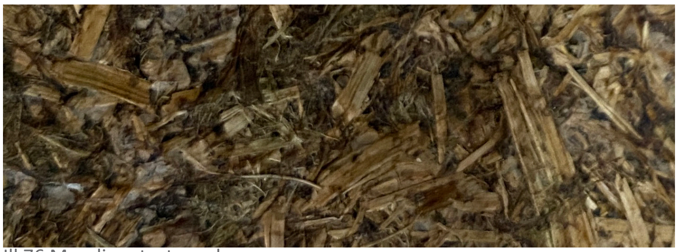
PLA and carnauba wax removed from further mechanical testing. !

2.5 | Composite test 2: Mechanical

Starch adhesive and mycelium composite were chosen to do mechanical testing. These tests will be based on the mechanical parameters that the team identified. These tests that have been conducted are based on already known mechanical properties test that have been validated on a PLA sample. (WS 2.21, WS 2.22, WS 2.23, WS 2.24, WS 2.25, WS 2.26, WS 2.27, WS 2.28).

Mycelium

The grass composite with mycelium as a binding agent is one of the two materials that are to be tested. On the first glimpse the appearance of this composite, is a bit dark, due to the heating press production method. This composite is an orthotropic material, due to the fact that it has the same properties in all directions in the plan, but others in the thickness, perpendicular to the plan (Wikipedia: Orthotropic material, 2019).



Ill 76 Mycelium texture close up

Starch Adhesive

The grass composite with starch adhesive as a binding agent is the second of the two materials that are to be tested. Opposite to the mycelium composite, the appearance hereof is a bit lighter. Just like the mycelium, this is considered an orthotropic material.

Ill 77 Starch Adhesive texture close up

Before conducting the different test, the team decided that the different calculation of the biocomposite will be done as if it was an isotropic material, even though the material is an orthotropic material. Materials such as steel or aluminum are isotropic materials because they have the same mechanical properties independent in all directions, orientations, and points in the material (Matmatch.com: Isotropy vs Anisotropy, 2020).

To find the different mechanical properties of an orthotropic, it would require a multitude of tests, in its different orientations. The team did not see this a problem since it was initially directed to find an indication of a possible working biocomposite, and not fully mature it. Therefore it was viewed that handling the material as an isotropic material would be sufficient.

Via dialogue with the project's technical supervisor, it was decided that there were two more mechanical parameters that needed to be included, stiffness and shear strength. Stiffness is the material ability while under load to resist elastic deformation (Freelancer.com, 2017). Shear strength is a mechanical property of strength, in the materials ability to resist shear forces, that is stresses coplanar to the cross-section of the material (Matmatch.com: What is Shear Strength?, 2020)

Below shows a table of content of the rating of weight given to each parameter and reason for them.

Parameter	Importance	Reasoning
Strength	5	The reason for this rating is that the strength of the material is what defines the materials, the ability to handle a certain load.
Toughness	4	Due to the environment of festivals where impacts are likely to occur, it is an important parameter to consider.
Stiffness	4	The rating is based on the materials ability to resist elastic deformations, when subjected to certain loads.
Shear	4	The rating is there to present the material ability to resist failure in term of shearing.
Density	3	The rating is due to that the usage for a chair, it should be possible to move it around.
Thermal resilience	2	As a material that is placed outside during the summer, high-temperature UV light might heat up the product. Therefore, thermal resilience is important to consider.
Moisture absorption	1	The material needs to be able to handle the outdoor environment, in the time period of a festival. Also as a biodegradable material, some moisture absorption would aid in this.

Strength

To test flexural strength, modulus of rupture was tested. The reason for this is that testing only compressive or tensile strength requires more advanced equipment, where the modulus of rupture can be tested via 3 points bending test (www.testresources.net, 2020). This test was chosen as the test is simple, and while it does not present the fundamental true value of compression, tensile or shear, as all of them are in play, it gives a proper estimation. Also by looking at how the material specimen breaks, you can state what strength is weakest, such as if it starts breaking in the bottom side, its tensile. The parameter strength was given 5 in weight as the team viewed that this was a high priority mechanical property, since the material is to be used for a chair, and therefore needs to have a strength to handle the load from an adult human.

The test was made via a 3D printed frame. The specimen was placed on top of the frame, and where force was applied then after. It was monitored at what force the specimen broke. With the flexural strength formula beneath, we were able to calculate the modulus of rupture.

The modulus of rupture is calculated by the formula:

$\sigma max = 3*F*L/2*h*t2$

Where

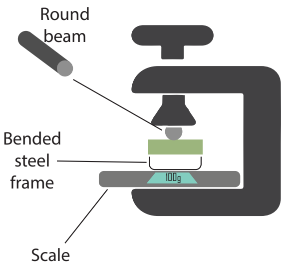
I: Moment of inertia: $I=(b*h3)/12$

h: Specimen height

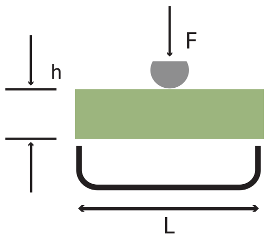
b: Specimen width

L: Specimen length

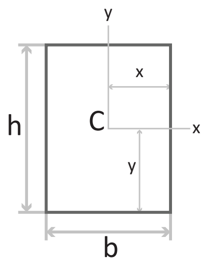
F: Force



Ill 78 Graphic flexural strength test setup



Ill 79 Graphic flexural strength diagram of force



Ill 80 Graphic flexural strength diagram of dimension

Ill 81 Flexural strength test setup

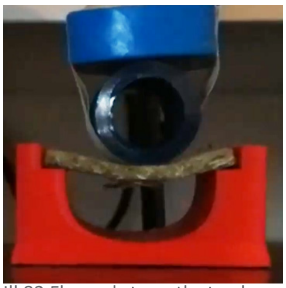
PLA

$$\sigma max = \frac{3 * 133N * 75\ mm}{2 * 40\ mm * 3^2} = 41{,}6\ MPa$$

To identify that the flexural strength test works, a well-known material was tested at first. As for the well-known material PLA was chosen. The PLA material gave a result of 41,6 MPa. Compared to the known mechanical properties, that say 43.6 MPa, the test is identified as successful (A Nugroho et al, 2018).

STARCH ADHESIVE

$$\sigma max = \frac{3 * 22{,}4N * 40\ mm}{2 * 35\ mm * 3^2} = 4{,}3\ MPa$$


Ill 82 Flexural strength starch adhesive during


Ill 83 Flexural strength starch adhesive after

MYCELIUM

$$\sigma max = \frac{3 * 29{,}3N * 40\ mm}{2 * 40\ mm * 3^2} = 4{,}9\ MPa$$


Ill 84 Flexural strength mycelium during


Ill 85 Flexural strength mycelium after

Reflection

Overall the test indicates a slightly higher flexural strength with the mycelium. It was observed with both material specimens that the fracture occurred at the bottom of the specimen. This is an indication that the material is better at compressive strength, rather than tensile strength. The flexural test is a tool to evaluate the tensile strength of the composite material in an indirect way. Sources of error for this setup is the method for adding pressure, as it was difficult to add a linear pressure. Also, the method for measuring the exact pressure of failure is questionable. However, the team saw the test still give valid information on the mechanical strength of the material.

Toughness

To test the toughness of the materials the team chose to work with the pendulum impact strength test (www.mtm.kuleuven.be, 2013). The test functions by having a hammer on a pendulum, that is raised to a given position height H0, and then strikes the fixed specimen. When the pendulum fractures the specimen, a part of its energy will be consumed. After the pendulum will swing up to height H, depending on the toughness of the material. For the test to show true data all specimens must have the same geometry, this is due to the fact that the load will be a mixture of shear and bending. The parameter toughness was given 4 in rating. This was chosen as an impact is likely to happen at a festival. However, it was not seen as important as the strength parameter.

A homemade pendulum test equipment was made and set up in one of our home offices. The setup was made via a hammer attached to a bolt, in a ball bearing to work as the rotation joint. The specimens were fastened in a clamp, where the hammer would then strike the specimen.

The impact toughness of the specimen is calculated by the formula:

a = A/ S

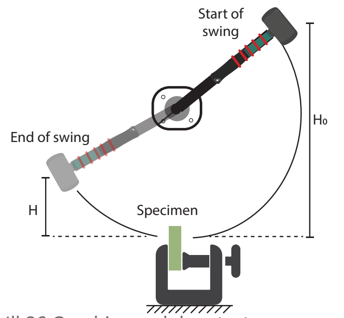
Where

a: Impact toughness,

A: Impact meter Strength = A = M*g*H0–M*g*H

M: The pendulum mass,

S: Cross-section area of the specimen.



Ill 86 Graphic pendulum test setup


Ill 87 Pendulum test setup


Ill 88 Pendulum test equipment

PLA

A = (1,85Kg * 9,82m/s^2 * 0,35m) - (1,85Kg * 9,82m/s^2 * 0,27m)
= 0,001453 KJ

0,001453 KJ / 0,00012 m^2
= 12,11 KJ/m^2

To identify that the test worked as intended a control sample was conducted, with PLA. The PLA material gave a result of 12,1 KJ/m2. Compared to the known mechanical properties, this was an indication that the test worked, which says an average result of 13,7 KJ/m2 (Kandasamy J., 2018).

STARCH ADHESIVE

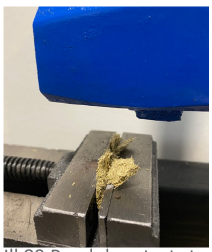
A = (1,85Kg * 9,82m/s^2 * 0,35m)- (1,85Kg * 9,82m/s^2 * 0,305m)
= 0.000817 KJ

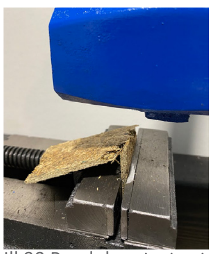
0.000817KJ / 0,00012 m^2
= 6,80 KJ/m^2

MYCELIUM

A = (1,85Kg * 9,82m/s^2 * 0,35m)- (1,85Kg * 9,82m/s^2 * 0,29m)
= 0,001090 KJ

0,001090KJ / 0,00012 m^2
= 9,08 KJ/m^2


Ill 89 Pendulum test starch adhesive after


Ill 90 Pendulum test setup mycelium after

Reflection

Overall the mycelium composite has a 33,5% higher impact strength than the starch adhesive.

Since this was tested via homemade equipment there are of course some sources of error. One of them being the height after impact. This is due to the precision of the measured height of H0 and h, as the test equipment did not show at what height it was exactly. The height was noticed by using a slow motion camera. At the rotation hinge, a ball bearing was installed that does have certain friction, however, the effect of this is minimal.

Stiffness

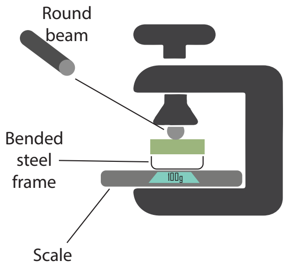
Stiffness of a material is its ability to resist deformation, in response to an applied force. This is identified via Youngs modulus (E), which measures the stiffness of a material, with the relationship between stress and strain. Young modulus can be identified via the same setup from the 3 point test, however only applying a certain force, and measuring the deflection that occurs. Youngs modulus is derived from the formula that describes the deflection of a beam from a given force (Gere, J.M., Goodno, B.J., 2014). Stiffness was given 4 in rating. The reasoning for this was that as a material used for a festival chair, the material needs to have a certain stiffness to not have too high deflection when under load, however not the same rating as strength.

For this test, a 3D printed frame was made. The specimen was placed on top of the frame. Next up, a press applied a certain amount of amount of force, where the deflection of the material was measured at that given force

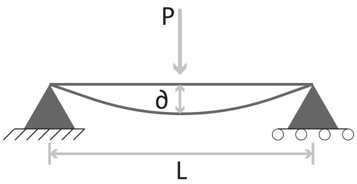
The stiffness of the specimen is calculated by the formula:

$$\partial = \frac{PL^3}{48EI} \qquad E = \frac{PL^3}{\partial 48EI}$$

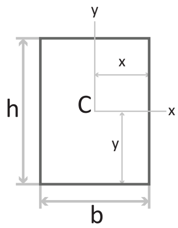
Where
E = Youngs Modulus
I = Second Moment of Area
P = Point Load
L = Length of Beam
∂ = Maximum Deflection.



Ill 91 Graphic stiffness test setup



Ill 92 Graphic stiffness diagram of force



Ill 93 Graphic stiffness diagram of dimension


Ill 94 Stiffness test setup

PLA

$$E = \frac{41{,}2\text{ N} * 74\text{mm}^3}{3{,}5\text{ mm} * 48 * \frac{20\text{mm}*3\text{mm}^3}{12}} = 2207{,}8\text{ MPa}$$

To identify the calculation and the test worked, PLA was used as a control test specimen again. The PLA material gave Young's modulus of 2207,8 MPa. Based on information gathered it was identified that the Youngs modulus for PLA can range from 0,09 - 13,8 GPa and the average is 2,80 GPA or 2800 MPa (www.matweb.com, 2020). As for our result, we are not that far from the average, and therefore the team can state the test valid.

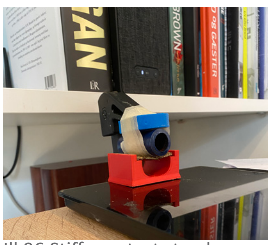
Starch adhesive

$$E = \frac{16{,}7\text{ N} * 40\text{mm}^3}{1\text{ mm} * 48 * \frac{35\text{mm}*4\text{mm}^3}{12}} = 119{,}1\text{ MPa}$$

MYCELIUM

$$E = \frac{9{,}81\text{ N} * 40\text{mm}^3}{0{,}5\text{ mm} * 48 * \frac{35\text{mm}*3\text{mm}^3}{12}} = 332{,}2\text{ MPa}$$


Ill 95 Stiffness test starch adhesive during


Ill 96 Stiffness test starch adhesive during

Reflection

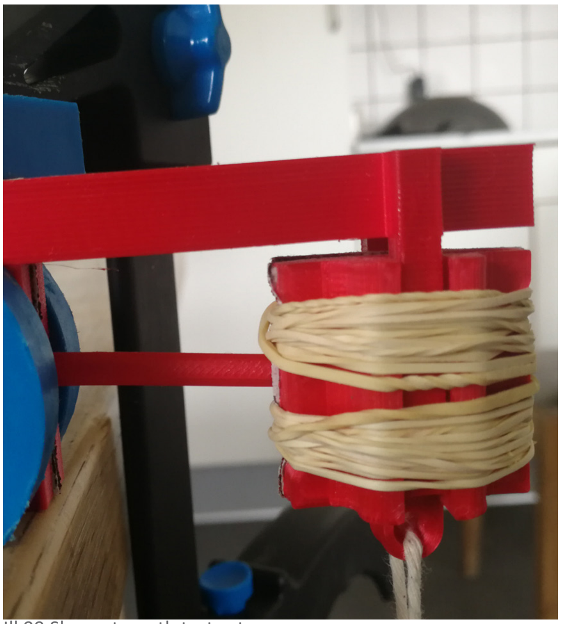
From the test, we can determine that mycelium has a Young's Modulus of 332,2 MPa and Starch adhesive has a Young's Modulus of 119,1 MPa. To compare to another material, Cork has a Young's Modulus of 20 MPa (www.makeitfrom.com, Cork, 2020).

One of the major sources of error is the measuring of the deflection, as this was done without high precision measuring tools, however when compared to the PLA deflection, the results are deemed trustworthy. A setup that would have made the tests easier for us, would have been to use longer specimens that would have made a larger deflection.

Shear strength

As previously indicated the following test was a result of a dialogue with the project technical supervisor. It was gained from the dialogue that to find the shear modulus of the material, would be difficult. The test is based on the Shear modulus formula, and Illustration 96 (Gere, J.M., Goodno, B.J., 2014). Shear strength is the material's ability to resist shear stress. As such the shear strength of the material is based on shears modulus (G), and is the rigidity of the material, and is defined by shear stress divided by shear strain. Shear modulus will be identified via a shear test, and derive Shear modulus from the formula. Shear strength was given a rating of 4, as it is an important factor in the strength of the material, as the flexural strength is a combination of tensile, compressive, and shear.

For this test, two 3D printed clamps were made. Here the specimen will be clamped in each of them. Next, a force will be applied via weight, hanging in a string, where guides built-in will insure that the shear stress would occur to the material. To test if the setup worked, PLA was used as a validation test as with the previous tests.

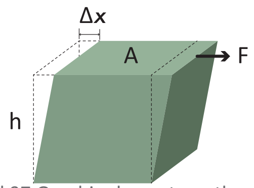


Ill 99 Shear strength test setup

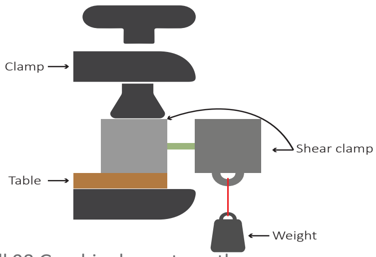
The shear strength of the specimen is calculated by the formula:

$$\frac{\text{Shear Stress}}{\text{Shear Strain}} = \frac{F / A}{\Delta x / h} = \text{Shear Module}$$

F = Force
A = Areal
Δx = Deformation
h = Hight
G = Maximum Deflection



Ill 97 Graphic shear strength diagram of dimension



Ill 98 Graphic shear strength test setup

PLA

F = 4.4032 N
A = (1mm*4mm)=30 mm²
Δx = 3mm
h = 30mm

$$\frac{4{,}4\ \text{N} * 30\text{mm}}{4\ \text{mm} * 3\text{mm}} = 11{,}0\ \text{MPa}$$

Initial test results did not achieve the same Shear modulus that PLA has, which is 2,4 Gpa (www.makeitfrom.com, Polylactic Acid (PLA, Polylactide), 2020). The value gotten from the test presented a significantly lower value. Indication for this is estimated because there is occurring a beam deflection of the sample, and not a shearing of the material, therefore it is not testing the shear strength of the material.

PLA version #2

F = 77.47 N
A = (0.5mm*14mm)=7mm²
Δx = 1.5mm
h = 10mm

$$\frac{77{,}5\ \text{N} * 10\text{mm}}{(0{,}5\ \text{mm} * 14\text{mm}) * 1{,}5\ \text{mm}} = 73{,}8\ \text{MPa}$$

Ill 100 Failure of equipment of shear strength

The second test was more successful, however, was still far from the values the team was seeking. Here the model was enlarged and made stronger. However when applying the weights with the force of 77,8 newtons, after a few seconds of holding the guiding rails of the setup broke. What we learned from this is that in theory, the test could present the shear modulus, however, too many variables come into play, such as the 3d printed test equipment not being strong enough for such a test. Other are the clamps could not hold tight enough for the test material to ensure it did not slide within the clamps. Lastly that the equipment is not precise enough to be able to read the deflection occurring.

Work around

As the test could not be validated with the control test, the team saw no need to try with the biocomposites, and a workaround was done. Here research into different materials, that resembles the biocomposite, in terms of the other properties that have been noted, and derive the shear modulus from these.

Looking at different materials, our material could resemble a material between cork and MDF. The shear modulus was derived from Shear modulus formula (Gere, J.M., Goodno, B.J., 2014), based on Youngs modulus and poison ratio, where we have taken a median of poison ratio, of the cork (www.engineeringtoolbox.com, 2020) and MDF (www.makeitfrom.com, Medium Density Fiberboard (MDF), 2020).

The Poison's ratio for Cork and MDF are as followed:
Cork: 0
MDF: 0,25
Median: 0,125

$$G = \frac{E}{2(1+v)}$$

G = Shear modulus
E = Youngs Modulus
v = Poison's ratio

MYCELIUM

$$G = \frac{332{,}2\ \text{MPa}}{2(1+0{,}125)} = 147{,}6\ \text{MPa}$$

STARCH ADHESIVE

$$G = \frac{119{,}1\ \text{MPa}}{2(1+0.125)} = 52{,}9\ \text{MPa}$$

Density

The test of density required only to measure the specimen and measure its mass. From these the density can be calculated. It was also notified to see what percentage of the density was grass, as one of the important factors is to utilize as much grass in the composite as possible. Density was given a rating of 3 as it is considered important, for ease of transportation of a festival chair, however, the team viewed it should not be weighted more than the structural mechanical properties of the material.

The density of the specimen is calculated by the formula:
p = density = m/v
m = mass
v = volume

MYCELIUM

$$p = \frac{1{,}62\ g}{3{,}96\ cm^3} = 0{,}42\ g/cm^3 \sim 420\ kg/m^3$$

50 gram grass
5 gram mycelium
55 g total

100 / 55 g = 1,1 * 50 gram grass
= 90,9 % grass

STARCH ADHESIVE

$$p = \frac{1{,}55\ g}{3{,}96\ cm^3} = 0{,}39\ g/cm^3 \sim 390\ kg/m^3$$

50 gram grass
20 gram rice starch
20 gram corn starch
90 g total

100 / 90 g = 1,1 * 50 gram grass
= 55,5 % grass

Reflection

The calculations indicated that the mycelium composite has a density that is 30 kg/m3 higher than the starch adhesive - an increase of close to 8 %. Furthermore, it was noted that mycelium has a substantial percentage of grass, within its mixture.

Moisture absorption

Testing of moisture absorption of the material is based on ASTM D570 (Omnexus.specialchem.com, 2020), where the specimens are completely dry before they are submerged into water for 24 hours and let dried again, where measurement of their mass is done before and after. The test is done as festival chairs are often exposed to a wet environment. Also with a dialogue with the technical supervisor, a test of the materials flexural strength was conducted again, to see if any changes to the strength of the material have occurred. This is to simulate different conditions the festival could be presented to such as heavy rain.

	Mycelium (gram)	Starch Adhsive (gram)	Mycelium (MPa)	Starch Adhesive (MPa)
Original state	0,54 g	0,44 g	4,9 MPa	4,3 MPa
Immersed in water 24 hours	1,43 g +164 %	1,75 g +298 %	$\sigma_{max} = \frac{3 * 9{,}8N * 40\ mm}{2 * 35\ mm * 32} = 1{,}2\ MPa$	Deliminated
Surface dry	1,05 g +94 %	1,10 g +150 %	$\sigma_{max} = \frac{3 * 8{,}5N * 35\ mm}{2 * 12\ mm * 32} = 4{,}1\ MPa$	$\sigma_{max} = \frac{3 * 6{,}6N * 35\ mm}{2 * 12\ mm * 32} = 3{,}2\ MPa$
Complety dry - after immersion	0,55 g +1,9 %	0,46 g +4,5 %	$\sigma_{max} = \frac{3 * 9{,}5N * 35\ mm}{2 * 12\ mm * 32} = 4{,}6\ MPa$	$\sigma_{max} = \frac{3 * 7{,}5N * 35\ mm}{2 * 12\ mm * 32} = 3{,}6\ MPa$


Ill 101 Moisture absorption measurement of specimens

A precision weight was acquired, due to the expectation of decimal measurements.


Ill 102 Moisture absorption test emerged in water

Immersion in water for 24 hours. Due to a density lower than the water, the object would flow.


Ill 103 Moisture absorption atmosphere drying

Expose the specimens to some atmosphere to get a dry surface.


Ill 104 Moisture absorption hot air drying

Expose the specimens to hot air, in order to get them completely dry

Reflection

An interesting observation was how the starch adhesive reacted after the water immersion. During the flexural strength test, the specimen simply deliminated, due to its softness. Other than this the decrease of the flexural strength of the two specimens is very much the same, however, the mycelium upholds most of its strength continuously.

Parameter	Importance	Reasoning	Mycelium		Starch adhesive	
			Value	Rating	Value	Rating
Strength The ability of withstanding high flexural strength.	5	The reason for this rating is that the strength of the material is what defines the materials, the ability to handle a certain load.	4,9 MPa	5	4,3 MPa	4
Toughness The ability of withstanding high impact force.	4	Due to the environment of festivals where impacts are likely to occur, it is an important parameter to consider.	9,08 KJ/m²	5	6,80 KJ/m²	4
Stiffness	4	The rating is based on the materials ability to resist elastic deformations, when subjected to certain loads.	332,2 MPa	5	119,1 MPa	2
Shear	4	The rating is there to present the material ability to resist failure in term of shearing.	147.64 MPa	5	52.92045 MPa	2
Density The weight of the material combined with the volume. Grass ratio, compared to binding.	3	The rating is due to that the usage for a chair, it should be possible to move it around.	420 kg/m³	5	390 kg/m³	3
Thermal resilience The ability of withstanding high flexural strength, in a heated environment.	2	As a material that is placed outside during the summer, high-temperature UV light might heat up the product. Therefore, thermal resilience is important to consider.	xxx	xxx	xxx	xxx
Moisture absorption The ability of withstanding high flexural strength.	1	The material needs to be able to handle the outdoor environment, in the time period of a festival. Also as a biodegradable material, some moisture absorption would aid in this.	164 %	4	+298 %	1

From the different testing of mycelium and starch adhesive, the team can clearly see an indication that overall that the mycelium composite performed better than the starch adhesive. Looking at the strength and toughness tests, mycelium is performing better by some margin. However, looking at some of the different parameters a different picture is formed. With the Stiffness and Shear values, mycelium outperforms starch adhesive by almost three times as much. Even though it was one of the lower-rated parameters the result of the Moisture Absorption test, was when the team noticed a drawback, with starch adhesive. Here starch adhesive lost a substantial amount of its strength. As the materials are biodegradable some degree of water absorption is necessary, however, these values, of starch adhesive, are not suitable for biocomposite, within the environment at a music festival.

The testing of heat deflection was not conducted, due to issues that resulted in cultivation of new mycelium grass batches, where they went bad. However the team viewed that the team had enough data, from the other test a choice could be made.

Therefore with the data collected from the different tests, it can be concluded that the mycelium is the best binder for a grass pulp biocomposite.

As previously mentioned, the biocomposite that the team seeks to develop is to be an early indication material, and the biocomposite would require further maturing. Areas that need further investigation, would be regarding the manufacturing of the material, such as the optimal growth condition as temperature, humidity, growth time, and proper initial fungi culture. The other aspect is to the process of heat pressing the mycelium composite, in terms of temperature, time of pressing, the force it is pressed with, and what shapes are possible via heat-press. The other subject needed to mature the composite is more validated, and precise material testing, since testing different orientations of the material due to it being an orthotropic material. These would further improve the material.

Mycelium composite

Yield strength:	4,9 MPa
Compression strength:	4,9 MPa
Young's modulus:	332,2 MPa
Shear modulus:	147.64 MPa
Poison's ratio:	0.125
Density	420 kg/m³
Moisture Absorption:	164 %

The chosen composite material is a heat pressed mycelium grass composite.

2.6 | Composite testing

With the mechanical properties of the material now identified, it was needed to see what the material was able to withstand, in real conditions. Now when the mechanical properties are known, it was possible to test the material within a finite element analysis in Solidworks. This would not give a true picture, but a defined estimation of what would occur. The analysis was done on a sample of known design chairs, already in the market (WS 2.29). By doing this the team had an idea of the capabilities of the material.

There were chosen four chairs. Two of the chairs are designed by Verner Panton. These are Vitra Panton from 1967 and Vitra Amoebe from 1970. The third chair is the Shell Chair by Hans J. Wegner from 1963. The last is the Bengthålan Stool from Ikea. These chairs were chosen as they include different design parameters, and it was possible for the team to locate 3D models of them for testing. All of the finite element analyses had a load of a person of 80 kg.

Vitra Panton chair - Werner Panton.

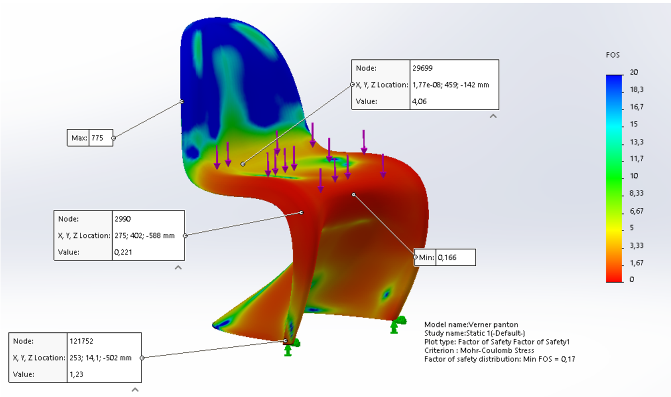
The first chair was the Panton chair. Here it was clear to see that with mycelium composite, it could not hold a person of 80 kg, as the lowest Factor of safety was 0,16. This was in the middle of the bend, at the front of the seat. This was estimated would happen, as it is here an overhang was, and the shell thickness is 8 mm. However, the team was surprised that the legs of the chairs upheld with a FOS of 1,7. The weight of the total chair goes up to 3,0 kg, which indicates that it would be possible to create a lightweight chair, but as this is still not strong enough it would weigh more.

- Shell thickness needs to be larger than 8 mm.
- Large overhangs would be prone to high stresses

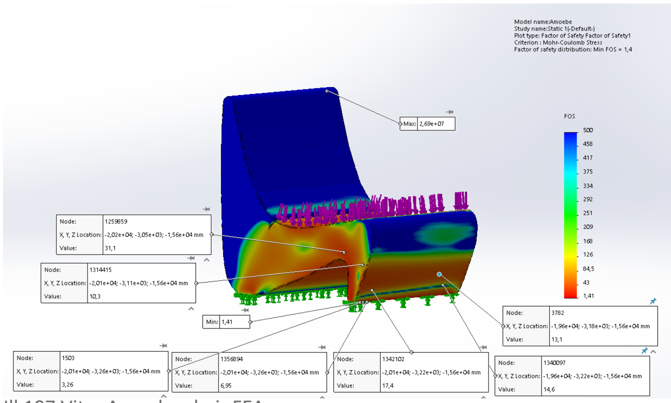
Vitra Amoebe - Werner Panton

The following chair is the Amoebe chair. Here the chair had a massive weight to its design, rounding up to a weight of 78 kg with the mycelium composite. This is far from ideal in terms of weight for the chair. Also, the lowest FOS in the analysis was 1,4, which is located at the corner of the front leg, this is however highly estimated to be because of the 3D model itself. This can also be indicated as propping beside the minimum FOS reads a FOS 3,3 and 6,9. Because of the mass, the chair has there occurs a maximum displacement of only 0,7 mm.

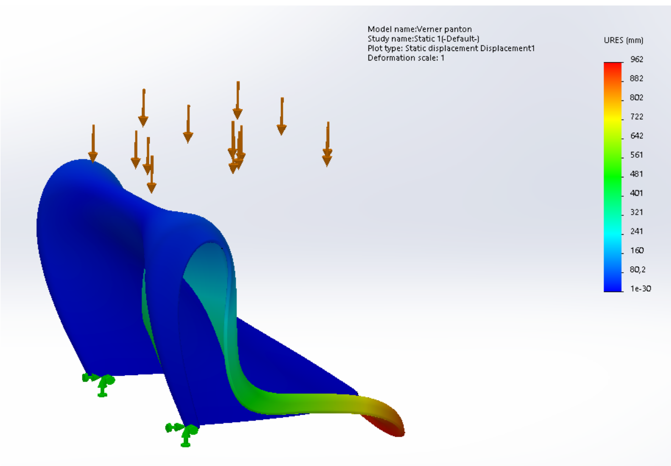
- High mass chairs are unnecessary and impractical for a festival chair.
- Ensuring a proper 3D model when conducting an FEA to get valid data.



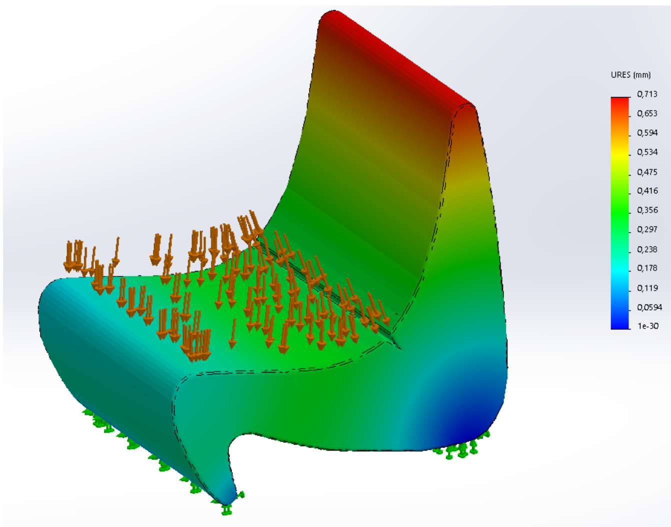
Ill 105 Vitra Panton chair FEA



Ill 107 Vitra Amoebe chair FEA



Ill 106 Vitra Panton chair displacement



Ill 108 VItra Amoebe chair displacement

Shell Chair - Hans J. Wegner

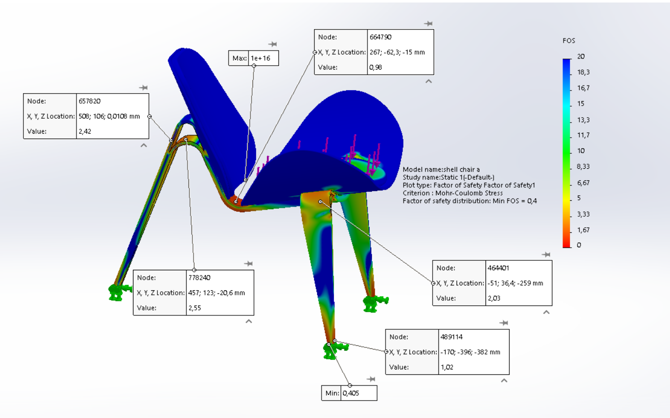
The third chair used in an FEA was the Shell Chair. The lowest FOS from the FEA was at the bottom of the two front legs with a FOS of 0,4, however, this could indicate an issue with the model, as propping right beside shows a FOS of 1,0. However, despite the issue with the model, small contact areas with the ground indicate areas of high stress. Another failure within the model can be seen at the support structure between the seat and backrest. Here there occurs a failure with a FOS of 0,9. Even if the thickness is 24 mm the most of the forces from the person are concentrated here. The total weight of the chair is 21 kg.

- Small contact areas to the ground results in stress points.
- Single support areas would result in high stress.

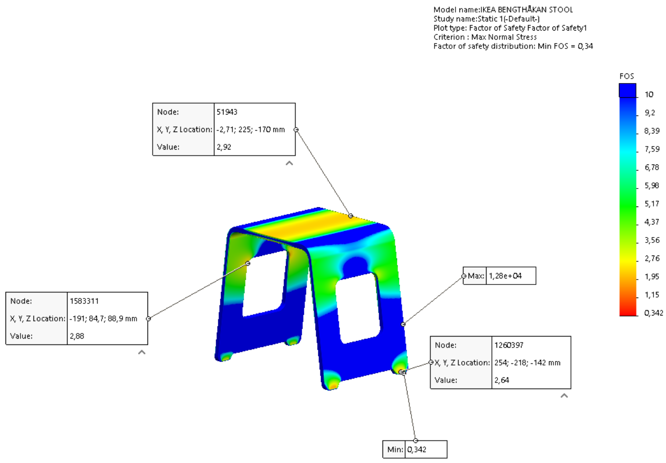
Bengthålan Stool - Ikea

The last chair is Bengthålan Stool from Ikea. The chair is a simple design, which is the chair that performed overall the best. A similar issue of small areas of contact between the feet ground, with a FOS of 0.342, however, this can be seen with the model as propping beside the point shows a 2.64. The seating presented with a FOS of 2.92, showing that the chair would handle a person of 80 kg. The thickness of the chair is 17 mm, which indicates what thickness the festival chair should be around. The weight of the chair is 2.5 kg, which is in competitive weight with the common festival chairs.

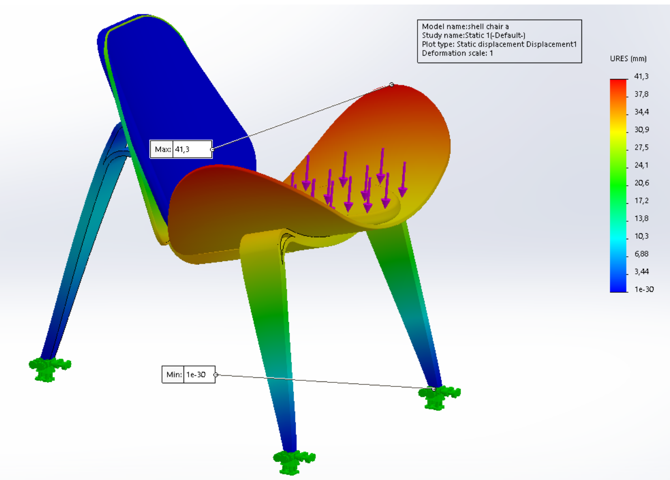
- Upholding a simplistic design indicates success in upholding the load.
- The thickness of 17 or more would be needed to uphold a proper FOS for the festival chair.



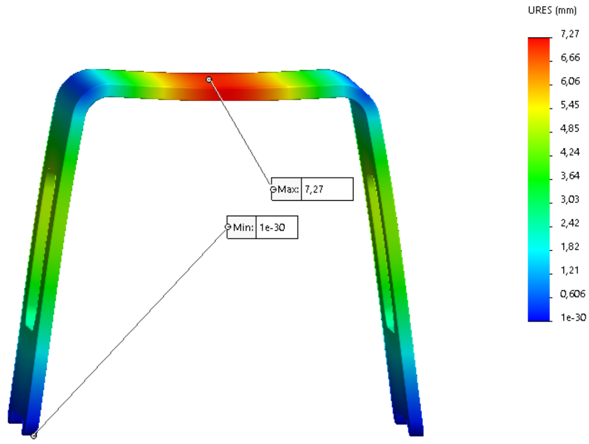
Ill 109 Shell chair FEA



Ill 111 Bengthålan Stool FEA



Ill 110 Shell chair displacement



Ill 112 Bengthålan Stool displacement

Sum up

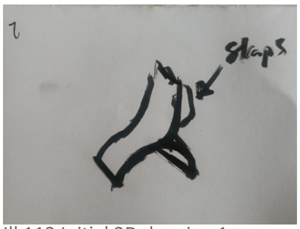
From the FEA the team could indicate that it is possible to design a festival chair, out of the mycelium composite. This needs however some certain guidelines, such as simplicity seen with the Bengthålan Stool, and how not to design such as the Panton chair. With the conclusion that a chair is possible to be made from the developed mycelium composite, the team can see that there is a possibility to ideate on different ideas for the festival chair.

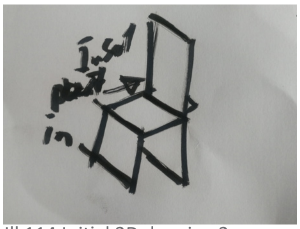
The thickness of the material need to be a minimal of 20 mm.

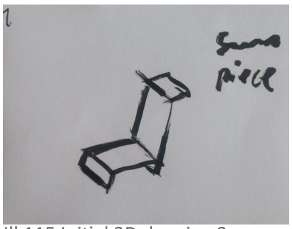
2.7 | Initial ideation

As the composite had been developed, and with the FEA analysis showing its possibilities, the team viewed that an initial drawing round was needed. This was to get all ideas and thoughts out of the team members head, down on paper. There was no restriction to any idea, however, they would still be directed based on the knowledge already gathered. The following sketching round is based on utilizing the drawing method, of small paper format and large drawing medium, and thereafter adjusting these sizes, to large paper format and small drawing medium (WS 2.30).

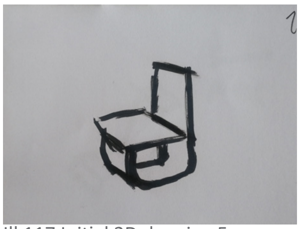
The first drawing phase included the following parameters:
Paper format- Notepad
Drawing medium- Thick pen
30 sec for each idea
20 min total.


Ill 113 Initial 2D drawing 1

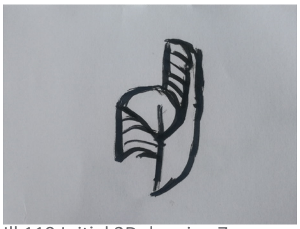

Ill 114 Initial 2D drawing 2

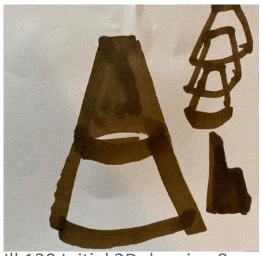

Ill 115 Initial 2D drawing 3


Ill 116 Initial 2D drawing 4

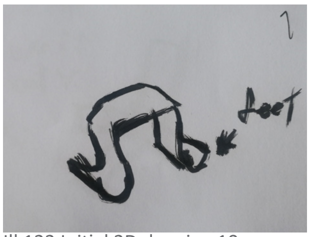

Ill 117 Initial 2D drawing 5


Ill 118 Initial 2D drawing 6


Ill 119 Initial 2D drawing 7


Ill 120 Initial 2D drawing 8


Ill 121 Initial 2D drawing 9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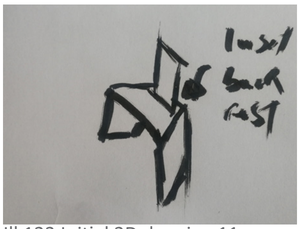
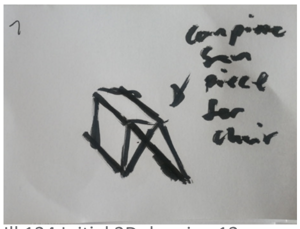
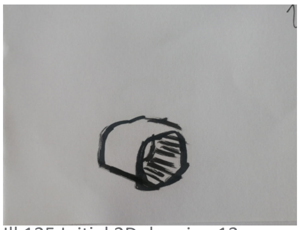

Ill 123 Initial 2D drawing 11


Ill 124 Initial 2D drawing 12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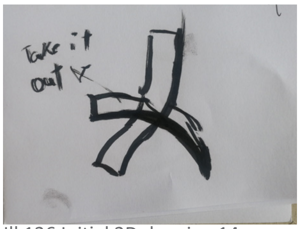
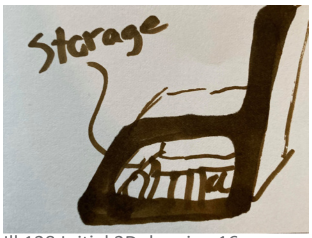
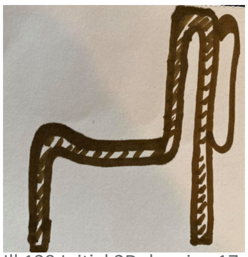

Ill 126 Initial 2D drawing 14


Ill 127 Initial 2D drawing 15



Ill 128 Initial 2D drawing 16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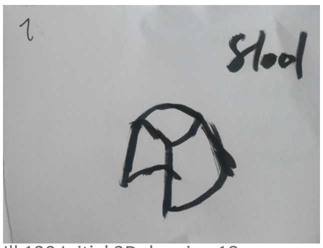


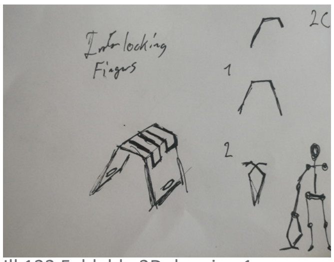
Ill 130 Initial 2D drawing 18


Ill 131 Initial 2D drawing 19

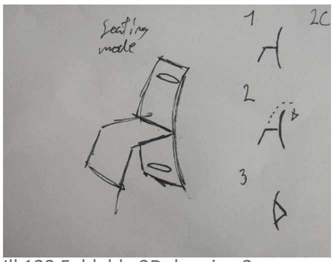
From the initial drawing phase, the team saw 3 groups emerging. These 3 groups were Storage, Transportable and Foldable. Storage was focusing on the chairs can stack on each other, the transport was focused on being able to transport the chair itself, and foldable focused on the chair could be folded to a smaller size. These groupings were made, as the team felt that the initial drawing round did not present any distinctive ideas, from one or more of the drawings. This resulted in the team looking for similarities that resulted in the groups.

Second drawing phase included the following parameters:
Paper format- A6 paper size
Drawing medium- medium size pen
3 min for each idea.
20 min for each group.

Foldable

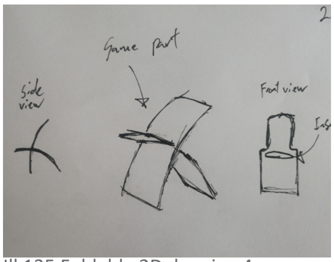


Ill 132 Foldable 2D drawing 1

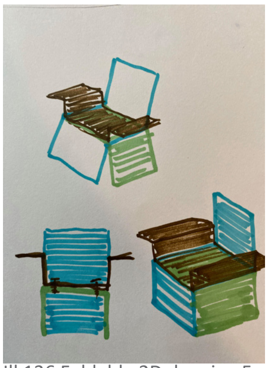


Ill 133 Foldable 2D drawing 2

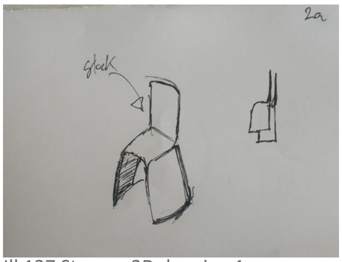

Ill 134 Foldable 2D drawing 3



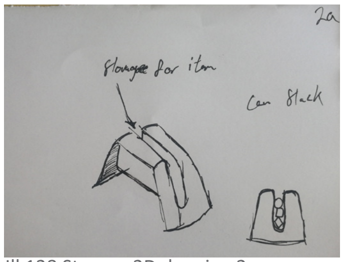
Ill 135 Foldable 2D drawing 4


Ill 136 Foldable 2D drawing 5

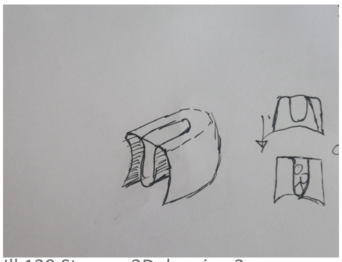
Storage

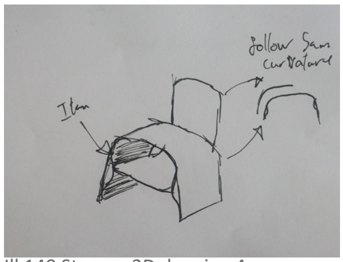


Ill 137 Storage 2D drawing 1

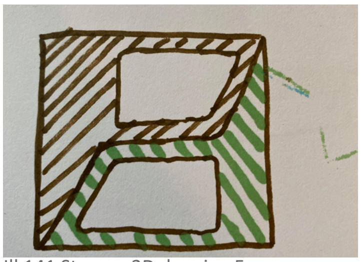


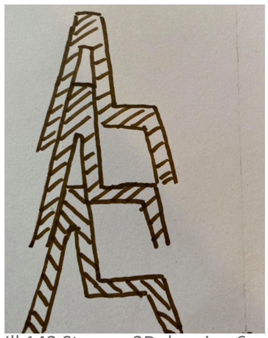
Ill 138 Storage 2D drawing 2

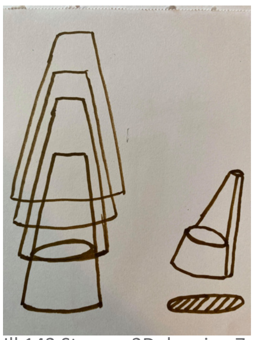

Ill 139 Storage 2D drawing 3



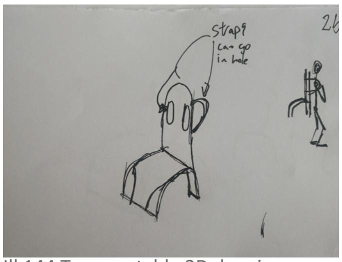
Ill 140 Storage 2D drawing 4


Ill 141 Storage 2D drawing 5

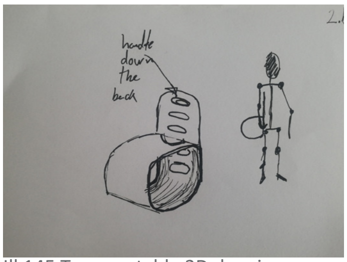

Ill 142 Storage 2D drawing 6


Ill 143 Storage 2D drawing 7

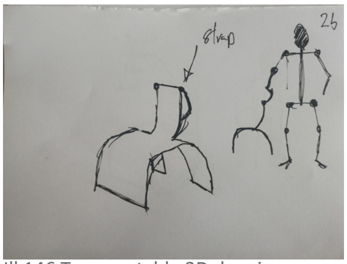
Transportable



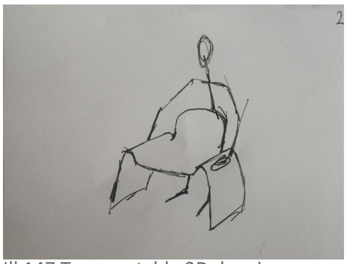
Ill 144 Transportable 2D drawing 1



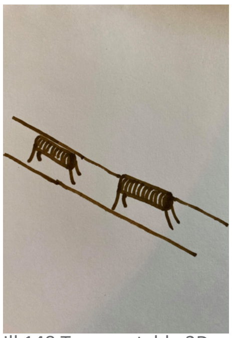
Ill 145 Transportable 2D drawing 2



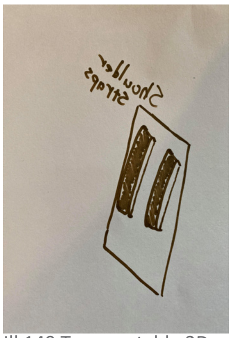
Ill 146 Transportable 2D drawing 3



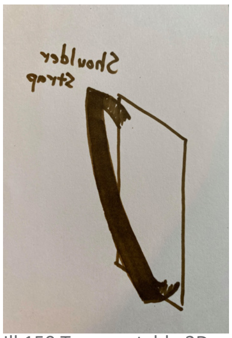
Ill 147 Transportable 2D drawing 4



Ill 148 Transportable 2D drawing 5



Ill 149 Transportable 2D drawing 6



Ill 150 Transportable 2D drawing 7

From the second round, a revaluation of the groupings based on the ideas and areas of interest came from the drawing phase. There were however issues that occurred, which was that the team had a hard time dictating what direction the concepts should strive towards, as there was disagreement on how to proceed further. The issue was that the level of details in the sketches, as the team had a difficulty of deriving information from the sketches. Also, it was noted that some user-related information would be beneficial. This lead to an ending of the initial drawing round. Nonetheless, it was decided that the keywords Stackable and Foldable would be worked further. Reasoning that the grouping of Transportable did not continue as a keyword is that the team viewed this as an essential part of the chair itself, and should at always be included.

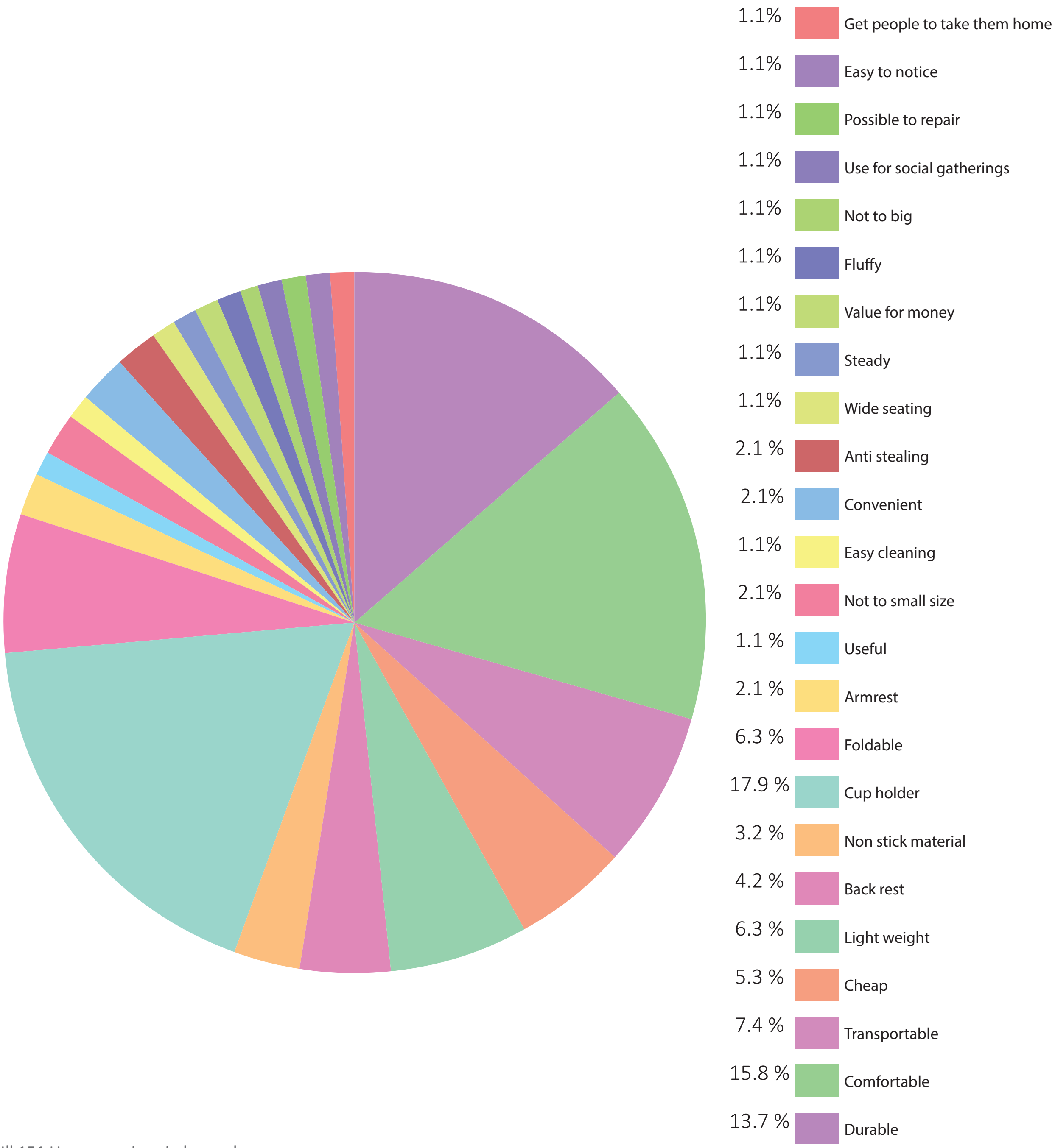
From this, the team viewed they needed to get a more in-depth understanding of the needs of a festival chair.

2.8 | User propping

To direct the ideation of the festival chairs design, the team saw a need to locate and do a probing of users on their view of the festival chair. This was to get a better understanding of what the users defined as the most important factors for a good festival chair. The propping was conducted on the people who live at Aalborghus college dorm, from door to door as one of the team members live there. The objective is to identify keywords about the festival chair, from a users perspective (WS 2.31).

The propping conducted had a series of three questions that were asked to the users. In total 32 people were able to answer the questions in full. The questions are as follows:

Question 1: Have you been to a music festival?
-The following question was asked, to identify which of the residents at Aalborghus College dorm were users, and who was not. This was to ensure that the answers gotten were valid.
Question 2: What is your view of the three most important factors for a good festival chair.
-The question was asked to identify what the users viewed as what makes a good festival chair.
Question 3: If you have any last comment about the classic festival chair, this can both be positive, negative or none, what are they?
-This was to get a final insight of the user's opinion of the festival chair itself.



Ill 151 User propping circle graph

Data given from question 2, indicates certain main keywords about what defines a good festival chair. Looking at the graph the keywords that were said most were Durable, Comfort, Transportable, Cup holders, and cheap. The keyword Durable is probably associated with the dissatisfaction with the current durability of the classic festival chair. The keyword Comfortable is wide and hard to pinpoint what they mean with comfortable. However looking at some of the other keywords, we can notice a specified trend for what comfort means. These words were Non-stick material, where when it is warm outside, the material doesn't stick to one's skin. Comfort could also indicate to the body of a chair, such as Armrest, Backrest, Wide seating, Not to Small size, and Not to big size. Another important keyword was transportable, as this indicated easy transport of the chair. This keyword has close relation with lightweight and foldable, and the ability to actually carry the chair via handle or straps. Cupholder was the keyword most people used. This can be related to the age demographic of the interviewees as they are around 20-30 years of age, however, it does indicate that including a cup holder in the festival chair is an important function of it. One of the main key points was Cheap, this can be said for a multitude of things, however the keyword "Value for money" can be associated with the definition of cheap. Other keywords such as easy cleaning, as there occurs a lot of spillage of drinks or rain at a festival. Along with the word Steady while seated in the chair one would not tip over.

Room number	Comment
153	The chairs break
148	No one takes them home again
145	The chairs break
140	The current chairs a pleasant to sit-in
134	The small feet stick into the ground
136	The current chairs do there job
135	N.C
127	Current festival chairs are to long when folded
157	N.C
104	They are essential for the festival experience
112	They all look the same
109	The current chairs do what they supposed to do
110	Its a shame they are left behind
113	N.C
200	They are important for the social experience
119	You forget to bring them to the festival

Room number	Comment
19	N.C
23	N.C
18	N.C
52	That you can move them around
42	The design is boring
39	N.C
30	N.C
54	If they get wet, it's not pleasant to sit on them
31	N.C
7	The current chairs function as they should
11	The current chairs you sit fine in them
4	N.C
6	N.C
20	They break and a left at the site
126	N.C
120	Smart that you can bring them with you all over the place

From the data of the last comment, some parallels could be seen. If the comment was negative, it was often associated with the current chairs breaking or people leaving them at the site as trash. The other comment that was a bit of a surprise was that the person in room 42, commented that the design was boring, and room 112 said they all looked the same. The comments from room 42 and 112 were critics about the classic festival chair, which the team saw as positive as it shows that there is a drive for a change of the aesthetics. As for positive comments, most were associated that they function well for their purpose and they are an essential part of the festival experience. There were also plenty of people who did not have an ending comment, feeling that presented what they wanted to point out from the second question.

Sum up

From the probing we can sum up the following based on that the users said are as following:
Users wish for a durable chair.

Users wish for an easy transportable chair.

Users wish for cup holders in their chairs.

Users wish value for there money for a relatively cheap chair.

Users wish for comfort, that can be given via armrest, backrest, Wide seating, and the material not sticking to them.

Users wish for a chair that can be cleaned easily.

Users wish for a chair that is steady.

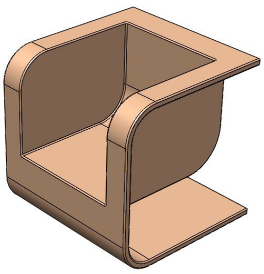
Users wish for a aesthetic pleasing chair.

With the identification of the keywords, the team is able to direct the ideation of the festival chair.

2.9 | 3D Ideation

Both in terms of the identification of the keywords from the user propping and with the issues of the idea development from initial sketching round, the team viewed that doing the ideation via 3d models would be more efficient as it will allow for a higher amount of detail in the ideas. These concepts will follow the groupings of Foldable and Stackable, and the ideation will be conducted via Solidworks, a 3D cad modeling program (WS 2.32, WS 2.34)

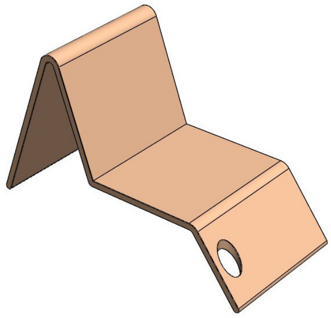
Stackable



Ill 152 3D ideation Stackable Solrig

Solrig

A one-part chair that utilizes contrasting shapes, dynamic curves. The chair can be stacked on each other when you tip the chair on its back. Through dialogue, the team viewed that Solrig present challenges for the material to be made in such a form, as it has quite drastic angles

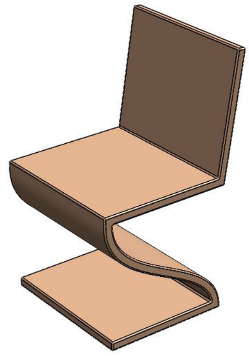


Ill 153 3D ideation Stackable Iceberg

Iceberg

Iceberg is a simplistic chair that is defined by oblique lines, where they are able to be stacked on one and other. The chair includes cup holders that were viewed as an important part of the user propping. Dialogue in the team did enjoy the simple lines, but concerns that loads could result in high deformations.

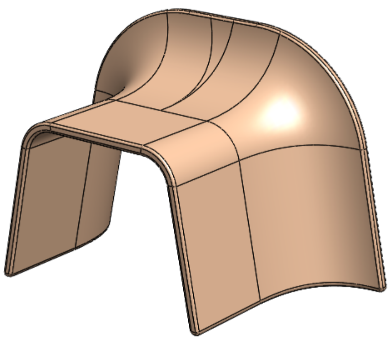
Inclusion of cupholders



Ill 154 3D ideation Stackable Hawewe

Hawewe

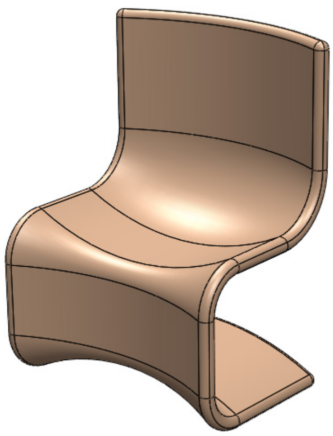
The curve under the seating had interesting lines, however, the team viewed that the overall design resembled too much as a dining chair and not a festival chair. Also, there were concerns as Solrig, that the angles would be too drastic to produce such a chair via heat press /deep draw.



Ill 155 3D ideation Stackable Maya

Maya

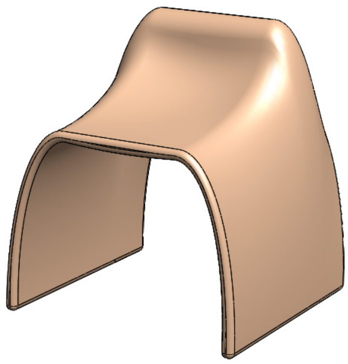
The team though the transition from the seat to the backrest was quite interesting, and how the backrest followed down to the legs. There was still a concern in producing the chair via press mold.



Ill 156 3D ideation Stackable Slim in

Slim in

The team viewed slim in to be too similar to common everyday chairs, that they used indoors, and that it was a boring version of Verner Panton chairs. Also as Hawewe the concern of molding it out of the mycelium composite.

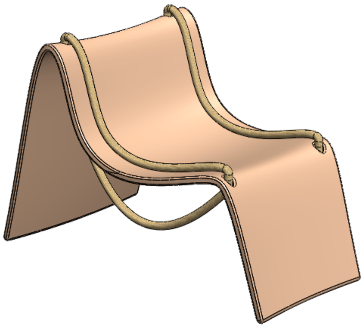


Ill 157 3D ideation Stackable Bumb

Bumb

The team disliked how the transition between the seat to the backrest, as it felt out of place. Also, the same concerns about the possibility of production with the material came into play

Foldable

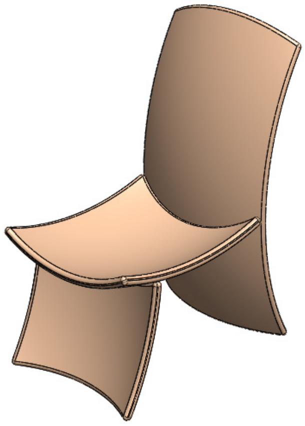


Ill 158 3D ideation Stackable The Wave

The Wave

Inspired by Iceberg, the wave did achieve the over same aesthetics as Iceberg, but not as dynamic. However the addition of the rope, to be used as handles, was a principle the team viewed quite positively, as it introduced contrasting lines to the overall design.

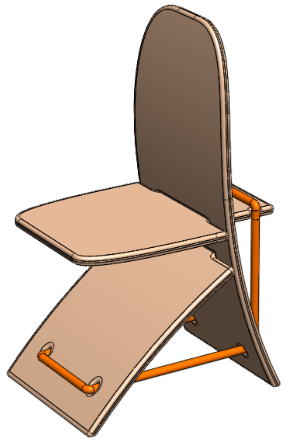
The addition of rope, as a handle, introduces dynamic and interesting curvature to the design.



Ill 159 3D ideation Foldable The Bend

The Bend

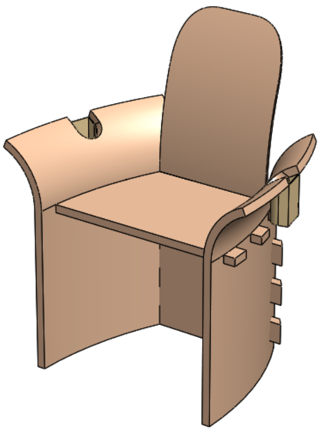
The bend utilized the same curvature to make the seating, front leg, and backrest. Even though it utilized the same part for the production of the chair, it presented a certain level of discomfort to it.



Ill 160 3D ideation Foldable Rope

Rope

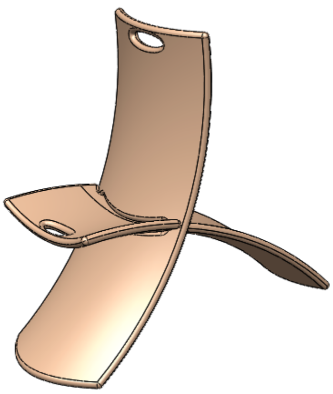
The idea of utilizing rope as the structural element clashed with what the team wished the design of the chair should strive toward. Also, the angle between the seat and backrest presented a discomfort. Also, there was a concern with the displacement that would occur with the seating.



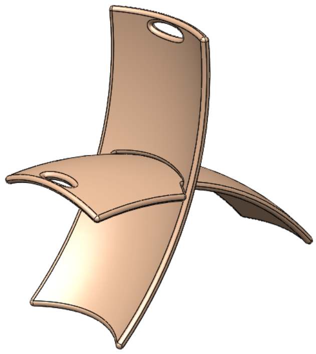
Ill 161 3D ideation Foldable Throne

Throne

The opening in the front was seen as welcoming, however, the team did feel that the curved top of the sides clashed with the seating and backrest. Also, the taps used to interlock the sides broke the surface of the sides.



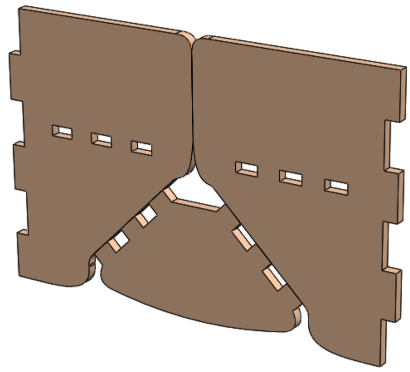
Ill 162 3D ideation Foldable Stargazer 1



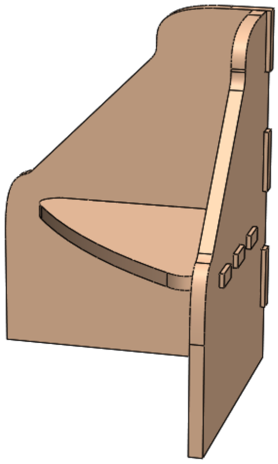
Ill 163 3D ideation Foldable Stargazer 2

Stargazer 1 & 2

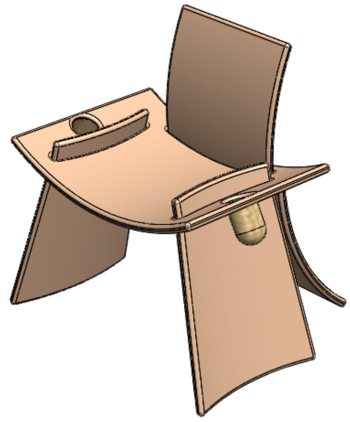
The team viewed both stargazer 1 & 2, as positive, in the simplicity of its design. However, there was quite a concern with the displacement that would occur under load, with the seat. The team however did see that including handles would be beneficial.



Ill 164 3D ideation Foldable Tri One B 1



Ill 165 3D ideation Foldable Tri One B 2



Ill 166 3D ideation Foldable 4 Plates

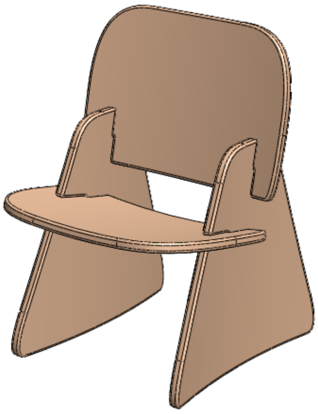
Tri One B

The end design of Tri One B was not seen as dynamic or interesting and did feel it would be uncomfortable to sit in. However, the idea that the chair itself was cut out via Laser-cutting, from a single board, was viewed positively. This idea of making the chair matched in synergy with how the mycelium composite was made, in-plane board material.

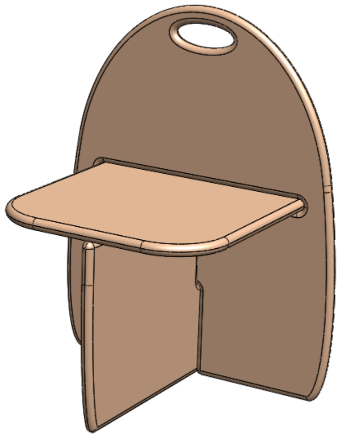
4 Plates

The placement of the sides, seat, and backrest was viewed as interesting, however, the curvature of the plates was too drastic overall, and clashed with the overall design.

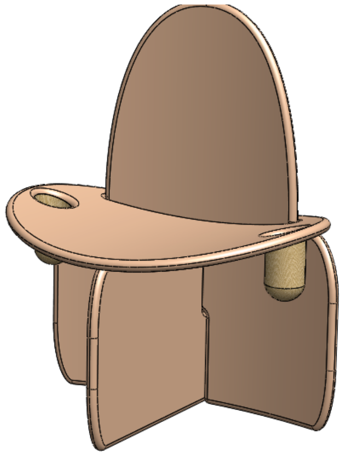
Utilizing laser cutting as the production method for the chair itself.



Ill 167 3D ideation Foldable Angle



Ill 168 3D ideation Foldable Interlock 1



Ill 169 3D ideation Foldable Interlock 2

Angle

The overall design of Angle was viewed highly by the team. The simplicity of the chair of each part, and how the gap between the seat and backrest creates a certain lightness to the chair itself. The team also saw positive in how the chair parts interlocked with each other.

The interlocking of the parts was seen as simple and elegant with the concept of Angle, and the overall aesthetics did fit well with the team.

Interlock 1 & 2

The team disliked the connection of how the bottom part of the chairs was. Interlock 2 seen below was viewed more positively, as the shaping of the seat and backrest played better together, however, there was an overall unsatisfactory for the concept.

Sum up

After the sketching round, it was clear from the team that the grouping of stackables clashed too much with the possibilities of production of the mycelium composite. The idea from Iceberg of including cup holders was seen as an important inclusion that can be easily implemented. Seen in The Wave the team was positive about the inclusion of rope as a handle, in that it would create a functional dynamic contrast to the design. Angle was the concept that the team saw as having the strongest aesthetics, in both simplicity and elegance. However, the idea of working with simple plates, instead of curved ones seen in Tri One B, where the idea was laser cut, is a method the team viewed is the right direction for what the team should strive toward. This is due to the already known material of Mycoboard by Ecovactive, that is a board material, that is similar to the grass mycelium composite, developed by the team (S. W. Angus, 2016). As both materials are toward a board material, laser cutting is seen in the right direction. On that note, the concept parts should be made via laser cut, as this will help narrow down the direction of how the final product should be. Overall the aesthetic direction the team would follow is in terms of angle, with the production method of Tri One B. The inclusion of rope as handle and cup holders would be helping functions to make a festival chair. Therefore the concept changed from foldable chairs to Laser Cut chairs.

2.10 Design criteria

It was identified that defining what design criteria the chair should be directed towards, would help the teams progress the concept further. This in terms of what defines the essentials of what a festival chairs functions. These criteria has been based on the work that the team has conducted throughout the project. (WS 2.33)

Number	Criteria	Unit	Marginal value	Ideal value	Reference
1	The chair should withstand the weight of 85 kg person sitting on the chair.	FOS	4	5	WS 2.34
2	Chairs should not exceed a certain weight.	Kg	<7kg	<5kg	WS 1.15
3	The chair shall have interaction areas for ease of carrying.	Binary	Pass	Pass	WS 2.32 WS 2.34
4	The chair should include cup holder, that can have 330ml beverage can.	mm	Diameter: 70 mm	Diameter: 70 mm	WS 2.32 WS 2.34
5	The chair should highest consist of x different materials.	Binary	>5	>3	WS 2.32 Ws 2.34
6	The chair shall include a backrest	Binary	Pass	Pass	WS 2.32 WS 2.34
7	The chair shall include a armrest	Binary	Non	Pass	WS 2.32 WS 2.34
8	The chair shall have a wide seat	mm	420 mm	560 mm	WS 2.32 WS 2.34
9	The chair should have easy to clean in corners or notches.	Binary	Difficult	Pass	WS 2.32 Ws 2.34
10	The chair should be steady	XYZ coordinates Center of gravity	< Half of total height < 30% from XY center	< 40% of height < 20% from XY center	WS 2.32 Ws 2.34
11	The chairs thickness of part should withstand the physical requirements from it.	mm	30 mm	20 mm	WS 2.30 Ws 2.34
12	The chairs feet surface area should not be focused on small areas	Binary	Pass	Pass	WS 2.30 Ws 2.34
13	The chair shall be made via a sheet manufacturing process	Binary	Pass	Pass	WS 2.33

3 Detailing

In this chapter, the team investigated the overall design of the chair, through desktop and FEA analysis, 3D modeling, systematic work approach, and prototyping. The work with these tools and approaches resulted in the product solution, which is a biodegradable festival chair, made from grass composite laser cut plates.

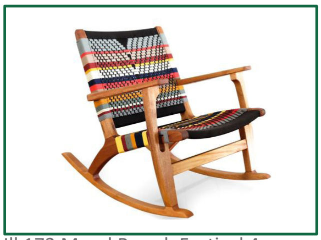
3.1 | Moodboard: Festivals

As the team had identified a design direction of the chair, that held potential, the team saw a need to understand the aesthetic context of the festival. This was to get a better understanding of the festival and help direct the development of the concept. This was conducted via a mood board, with photos of festivals or design reference to the chair (WS 3.1).

Ill 170 Mood Board: Festival 1

Ill 171 Mood Board: Festival 2

Ill 172 Mood Board: Festival 3



Ill 173 Mood Board: Festival 4

Ill 174 Mood Board: Festival 5

Ill 175 Mood Board: Festival 6

Ill 176 Mood Board: Festival 7

Ill 177 Mood Board: Festival 8

Ill 178 Mood Board: Festival 9

Ill 179 Mood Board: Festival 10

Rustic.
The keyword rustic is a reference to the overall context that occurs at the festivals, as there is rough exposed material, such as industrial pallets. This is also associated, with the furniture and materials being in close contact with the outdoor environment.

Colours.
The keyword colour is pointing at how there is an element of colour in association with rustic elements. The addition of bright and strong colours creates a contrast to the rustic aesthetics of the material seen at festivals. The coloured elements are seen as the details for the overall rustic context. An old concept had ropes included, and with the identification of the colours, the team looked at coloured ropes, as an aesthetic reference.

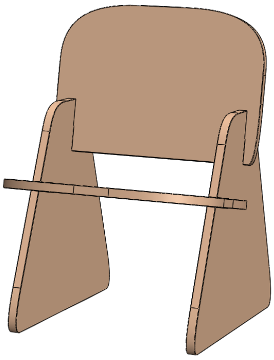
Geometric shape.
The overall form of products at the festivals are geometric in their shapes. These are associated with more simple shapes and are not toward organic forms and curvatures. The only objects that present a certain level of organic curvature are tents.

Design of the chair follows a rustic geometric design, with coloured detail. !

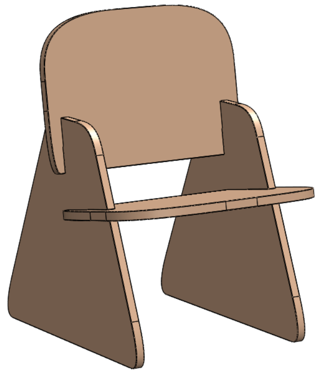
3.2 | 3D Detailing: Round 1

With the main idea chosen from the first 3d modelling, detailing the concept was the next step. As the third milestone closely approaching the team saw that creating a more completed concept, to present to the milestone, would give more constructive feedback, that would help improve the concept further. The activity was conducted in Solidworks, with inspiration from the festival mood board, with analyses of the feedback given from the third milestone (WS 3.2, WS 3.3)

The team had chosen to work further with the concept idea angle as the base for the chair concept. The team had chosen to utilize laser cut board elements, based on the manufacturing of the grass mycelium composite. Therefore the first change was to create a version of angle with board elements seen on illustration 180 and 181. This change follows the principals with the concept while staying true to the manufacturing method.

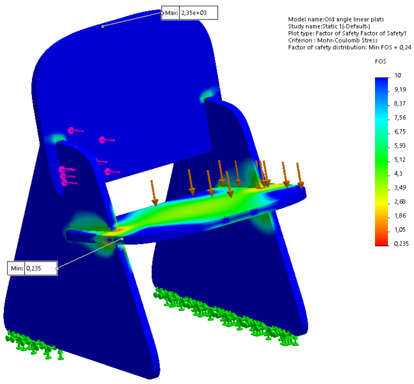


Ill 180 3d Detailing Round 1: 1A

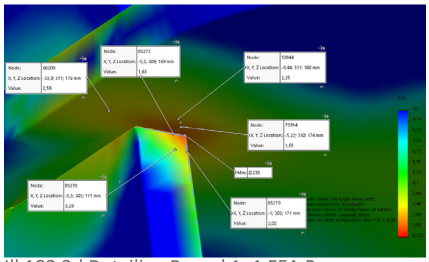


Ill 181 3d Detailing Round 1: 1B

As a first step, there was made an FEA analysis of the concept, to get an understanding of its capacities, and changes needed to the design. From FEA analysis the team could identify an issue with the seat. The overhang of the seat resulted in too high stresses occurring at the side panes seen in illustration 183. Here the FOS range from 1-2, with the exception of the lowest FOS at 0,235, where this FOS is a result of the nature of 3d cad models simplicity to reality. It was viewed that to handle the following issues, the side panel should support the entire length of the chair itself.



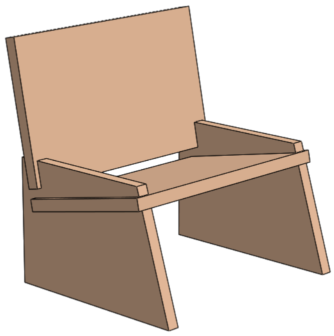
Ill 183 3d Detailing Round 1: 1 FEA A



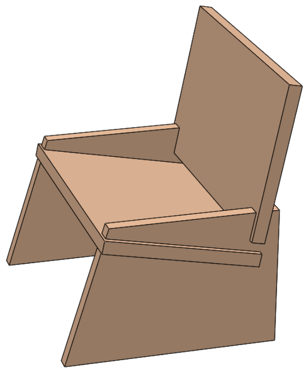
Ill 182 3d Detailing Round 1: 1 FEA B

Here the team changed the concept by extending the sides, so they supported the seat. Also while doing this the team discussed the design of the side, which led them from a triangular shape to a rectangular, seen in illustration 184 and 185. This was as the shape aligned more with the purpose of the sides supporting the seat. Also, the team saw that the concept should align more toward a geometrical design, to align with the festival mood board.

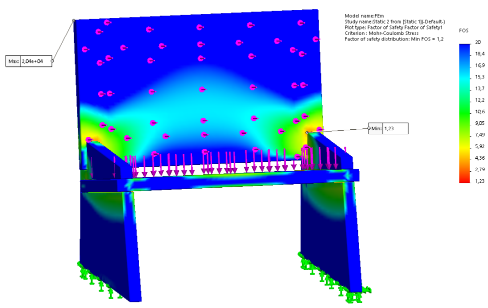
Here a new FEA was made. The FEA showed vast improvement, with the seating removing previous issues. There were still issues with high-stress points, however, the team had a discussion with the technical supervisor about the reasoning for these, and that reason they are there is the simplicity of the cad model compared to real life, and the material in the FEA does not react in truth to how the material would really react. The compressive strength is set as the same as the tensile, where in truth it might be higher. Therefore the FEA is only used as a tool, to give a reliable estimate. From the FEA it could be seen that there were issues with the backrest, similar to the same issue with the seating. Therefore increasing the amount of support for the seating is estimated to fix the issues.



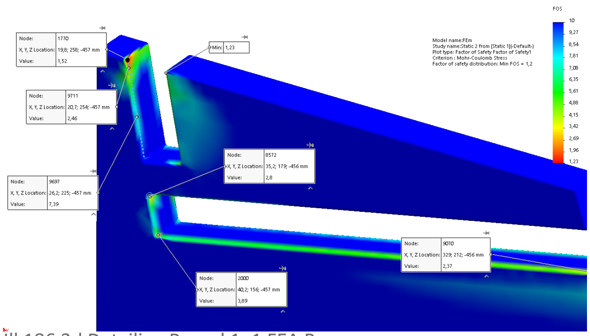
Ill 184 3d Detailing Round 2: 1A



Ill 185 3d Detailing Round 2: 1B

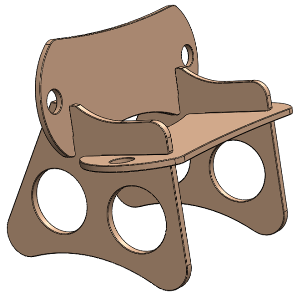


Ill 187 3d Detailing Round 1: 1 FEA A



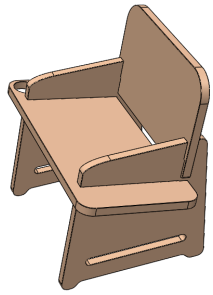
Ill 186 3d Detailing Round 1: 1 FEA B

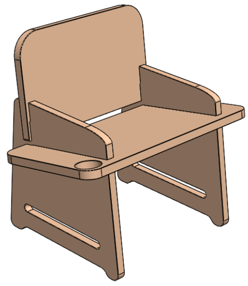
Here the team decided to make some individual versions, from the last version, to try some variation, while including the knowledge of supporting the seat and backrest.


Ill 188 3d Detailing Round 1: 3

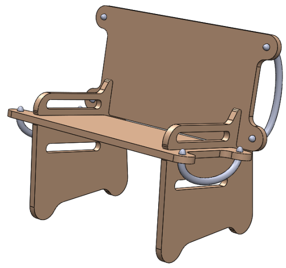
The concept seen in illustration 188 was to challenge the current design, with bringing more curvature and organic form language. The team however felt that the idea strayed too far from the current design direction the team envisioned and clashed with what rustic context of the festival. Also that the design strayed away from a chair and more towards a bench.

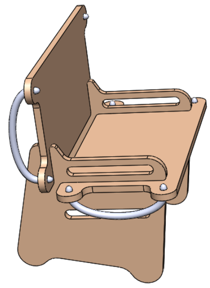
Illustration 189 and 190 shows a concept that is more true to the design direction. Here the radius was given to the corners, making the design less intimidating. Also widening the seating area for the inclusion of a cup holder. The team were more aligned with the following concept and felt that the design overall was what the team was seeking. Issues were with the large spacing between the seat and backrest in width.


Ill 189 3d Detailing Round 4: 1A

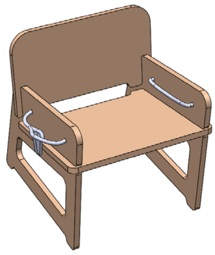

Ill 190 3d Detailing Round 4: 1B

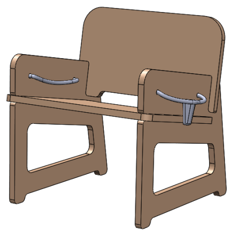
The next concept is seen in illustration 191, and 192 included the aesthetic reference of rope, as a functional element, in term of handles. The overall form of language was inspired by the previous concept. The team felt however that the extrusion segment where the rope was mounted in clashed with the simplicity of the lines of the chair. However, it was via this concept here the idea of utilizing the rope not just as handles but also the cup holder, resulting in the final concept that would be presented, to the third milestone.

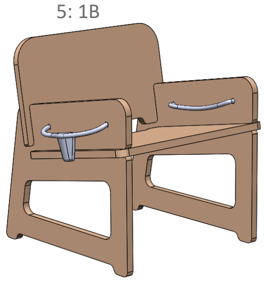

Ill 191 3d Detailing Round 5: 1A


Ill 192 3d Detailing Round 5: 1B

This led to the concept that the team named Sprout 001. The chair itself upheld the simplicity of the original design while introducing an element of contrast with the inclusion of the rope handle/cup-holder seen in the simple rendering of the chair. The sides were made more structural than before to both make the chair lighter in weight and appearance.


Ill 193 Sprout 001 A


Ill 194 Sprout 001 B


Ill 195 Sprout 001 C


Ill 196 Milestone rendering of concept

Milestone 3 feedback

The feedback overall given from Milestone 3 was quite positive. The feedback was given from supervisors to other teams. The supervisors saw the framing and direction of the project as intriguing, and the combination between the grass pulp material and the festivals was a positive synergy. The constructive feedback was focused toward the aesthetics of the chair itself. The feedback on the chair based on board material made sense for the supervisors in terms of the material. They did, however, feel the chair overall was a bit boring in its design. This was associated with the lines being too simplistic, and it could be made more dynamic. It was advised to see variations of laser cut furniture, to get an aesthetic reference.

Sum up.

With the feedback, the team saw themselves on the right patch. However, it was also visible that the base of the concept of Spout 001 was quite simplistic overall, and could be seen as boring. Therefore improvements were needed with a focus on the aesthetics.

3.3 | Aesthetic redesign

With the feedback given associated with the aesthetics of the chair, it was viewed that further work associated with the aesthetics was needed. This was to solidify the concept in a direction that would result in a concept that would be stronger and more compelling. A mood board was conducted with different designs of furniture that utilize the principle of laser cutting elements, where a new round of 3D modeling was conducted based on inspiration from the mood board. This was done for the team to see different opportunities and improve the design (WS 3.4, WS 3.5)


Ill 197 Laser cut mood board 1


Ill 198 Laser cut mood board 2


Ill 199 Laser cut mood board 3


Ill 200 Laser cut mood board 4


Ill 201 Laser cut mood board 5


Ill 202 Laser cut mood board 6


Ill 203 Laser cut mood board 7


Ill 204 Laser cut mood board 8


Ill 205 Laser cut mood board 9

Ill 207 Laser cut mood board 10


Ill 206 Laser cut mood board 11


Ill 208 Laser cut mood board 12


Ill 209 Laser cut mood board 13


Ill 210 Laser cut mood board 14


Ill 212 Laser cut mood board 15


Ill 211 Laser cut mood board 16


Ill 213 Laser cut mood board 17


Ill 214 Laser cut mood board 18


Ill 215 Laser cut mood board 19


Ill 216 Laser cut mood board 20


Ill 217 Laser cut mood board 21


Ill 218 Laser cut mood board 22


Ill 219 Laser cut mood board 23


Ill 220 Laser cut mood board 24


Ill 221 Laser cut mood board 25


Ill 222 Laser cut mood board 26


Ill 223 Laser cut mood board 27


Ill 224 Laser cut mood board 28

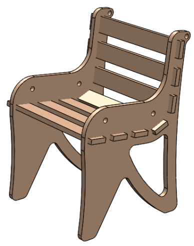

Ill 225 Laser cut mood board 29


Ill 226 Laser cut mood board 30


Ill 227 Laser cut mood board 31

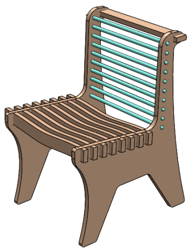
Via the mood board, the team initiated a new 3D modeling round. Here the team decided to not limit inspiration, and create variation aesthetic approaches. This was to both challenge Sprout, and see if any ideas could amplify the form language of Sprout. What the team sought was to identify key aesthetic factors, to work further with.

A



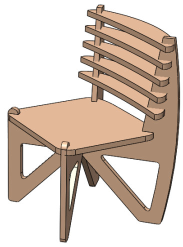
Ill 228 Laser cut 3D concept A

B



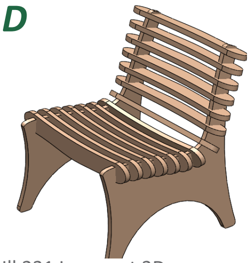
Ill 229 Laser cut 3D concept B

C



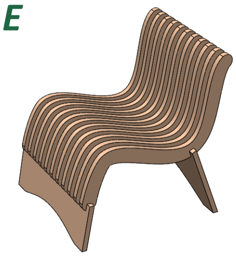
Ill 230 Laser cut 3D concept C

D



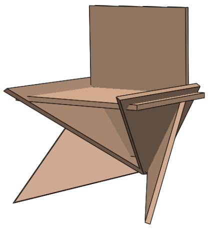
Ill 231 Laser cut 3D concept D

E



Ill 232 Laser cut 3D concept E

F

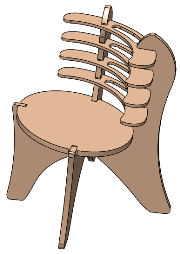


Ill 233 Laser cut 3D concept F

G

Ill 234 Laser cut 3D concept G

H

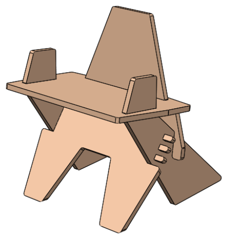


Ill 235 Laser cut 3D concept H

I

Ill 236 Laser cut 3D concept I

J

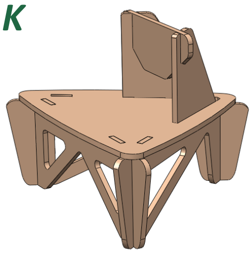


Ill 237 Laser cut 3D concept J

Dialogue

The ideas utilized different inspirations and references from the mood board. A multitude of the first ideas utilized the use of slats, such as concept A, B, C, D, E, H, and I. The use of slats were used differently, where some utilized them for a segment of the chair such as the backrest of the seat or both, seen in A, B, C, D and H. Two of them utilized the concept of slats to create the entirety of the chair seen in E and I.

K



Ill 238 Laser cut 3D concept K

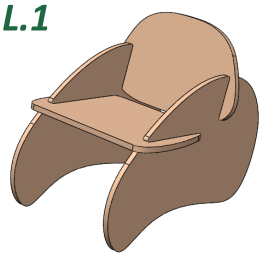
The team had concerns with the amount of slant needed for some of the concepts, as these would increase the amount of time needed for the users to assemble and disassemble the festival chair. This was especially for ideas D, E, and I, as these would utilize a substantial amount of slats to function. Also, another issue that was presented, was even though the slant created gaps in their concept that made the chair look lighter, that would in truth utilize quite a large amount of material. Another note is idea B, that utilized rope as the seating, which the team saw did not function, as it would still need a constructional supporting element to work.

Two ideas utilized slats that the team saw interesting were idea C and H. These were seen as interesting as the legs were crossed with each other in the middle. Here it was H that was seen as the stronger variant, as it slanted seat. It was discussed that these models resemble dining chairs rather than festival chairs.

Another batch of the ideas utilized the constructional principle of the triangle, as it is a fundamental shape in terms of stability and strength, seen in F, G, J and K. The team saw the idea of utilizing the triangle in terms of constructional integrity, however, the concept aesthetically did not reach a level the team saw fit. This was true for concepts F, J, and K, as these concepts felt unwelcoming for the users, as they were sharp angles and complex. The one that was seen better was Concept G, but the concept resembled too much a stool and did not hit the essence of what a festival chair would look like.

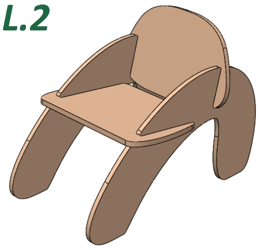
The team looked back at the concept presented at milestone 3, and why the team gravitated to it from the start. It was the simplicity in its construct, and elegance of its lines. The ideas from here resemble more towards the original concept of Sprout 001.

L.1



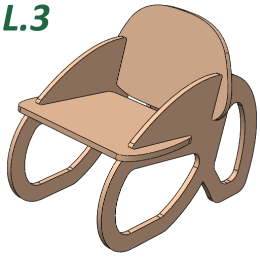
Ill 239 Laser cut 3D concept L1

L.2



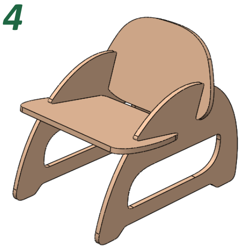
Ill 240 Laser cut 3D concept L2

L.3



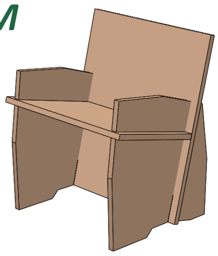
Ill 241 Laser cut 3D concept L3

L.4



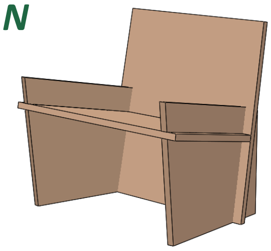
Ill 242 Laser cut 3D concept L4

M



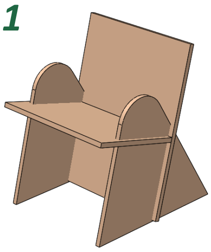
Ill 243 Laser cut 3D concept M

N



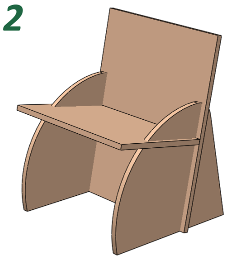
Ill 244 Laser cut 3D concept N

O.1



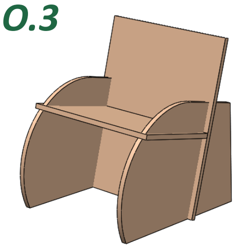
Ill 245 Laser cut 3D concept O1

O.2



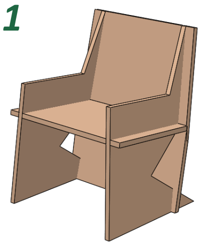
Ill 246 Laser cut 3D concept O2

O.3



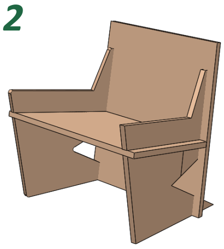
Ill 247 Laser cut 3D concept O3

P.1



Ill 248 Laser cut 3D concept P1

P.2



Ill 249 Laser cut 3D concept P2

Here one of the concepts that challenged the more geometric shape of sprout 001 was L1, L2, L3, and L4. These worked with a more organic form language, and the team saw that they were too playful, and resembled furniture for kids. This also includes concept O1, O2, and O3, even though the organic form language was dialed quite below fore these. The concepts that were more intriguing were N, P1, and P2. N in its base shape is almost identical to Spout 001, the change here is that the backrest instead of stopping at the seat, it continues down to the bottom. The team saw this both as changing contrast to the sides, and that created stability for the overall design. The other ideas of P1 and P2 are what the team viewed as the most influential of the concepts. It was not the form of the cutout, as the team saw the armrest not as a positive, but the angle of the sides. The previous Sprout 001, had its side with an angle perpendicular with both the backrest and seat, however not with P1 and P2. Especially for P2 where it opens in the front, resulting in the chair welcoming the user to sit in it. Also with the inclusion of slant lines a result of the sides, the team felt it resulting in a more compelling form language, and not as plain as the original Sprout 001.

Sum up.

An aesthetic direction was gained to improve the concept Sprout 001, to make the concept more dynamic and compelling while being true to its original concept.

Side plates should be inclined with the seat and backrest. **!**

Backrest should extend the ground. **!**

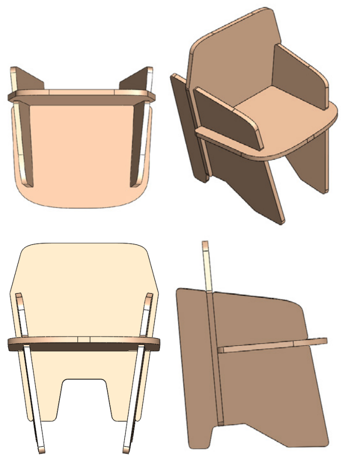
3.4 | 3D Detailing: Round 2

The team had identified what details should be changed with Sprout. It was from here chosen to work with a systematic approach of working with the details, trying different variations of them to see which fits best with the concept. The systematic approach was conducted by working on one certain detail and then processed further to the next as the variant was found. The activity was conducted together in Solidworks via screen share on Skype. Here a constant dialogue took place within each detail and repeated until a final concept was placed (WS 3.6).

The team first made a simplistic variation of the original concept from the third milestone, with changes that resulted from the aesthetic redesign discoveries.

Side plates orientation

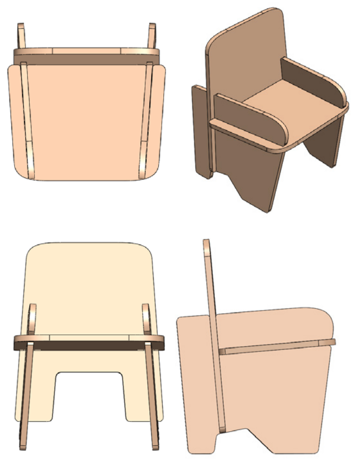
The first round was focused on the orientation of the side panels. This was to see what orientation of the sides the team saw had the overall strongest dynamic form language.



Ill 250 Diverge top - Converge front group

Diverge top, Converge front.

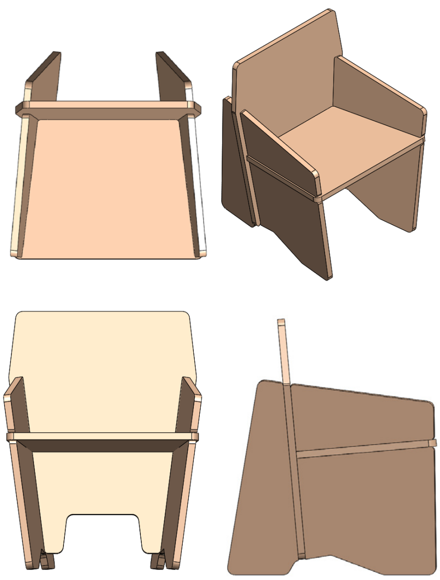
The team did not see the following concept as positive, as the converging of the front results in "push away" from the chair to not sit in it. However diverging the top does help "opening the chair up".



Ill 252 Converge top - Converge front group

Converge top, Converge front.

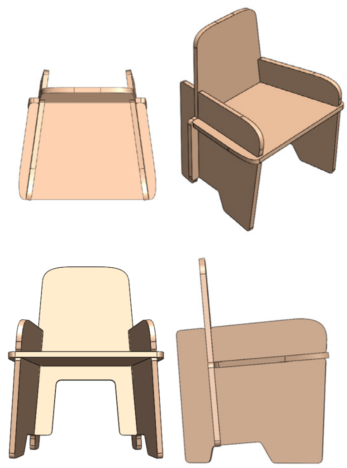
The following version did not feel unwelcoming, for the users to sit in. This is due that it converges both at the top and front of the chair, resulting in a narrow path for the seating of the chair.



Ill 251 Diverge top - Diverge front group

Diverge top, Diverge front.

It was quickly viewed by the team that this was the clear favorite, from the round of orientation. Here the team felt that the diverging of the top and front of the side plate results in the chair opening itself for the users, and is spacious to sit in. Therefore it was clear that the team chose to work further with this orientation.



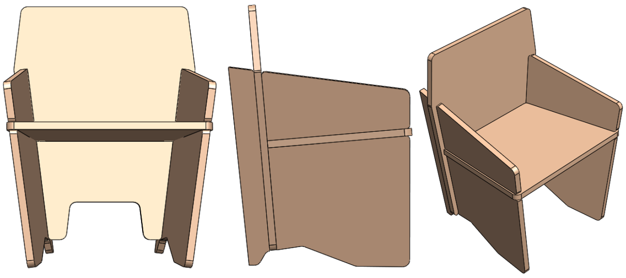
Ill 253 Converge top - Diverge front group

Converge top, Diverge front.

The team thought the following concept had potential. The opening of the front results in a welcoming feeling to sit in the chair, and that the converge to the top creates a stable footing. However, it does seem that while seated the user pushed by the sides.

Form variation process

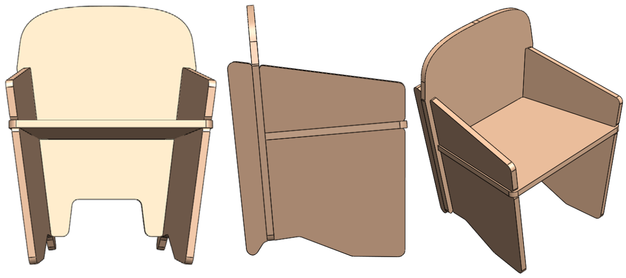
Here the team further proceed with the design of the chair from orientation. The team together used the same strategy as previously and worked step by step, trying different variations, and designs. Here it is presented with the steps and variations that followed.



Ill 254 Form variation step A

Step A

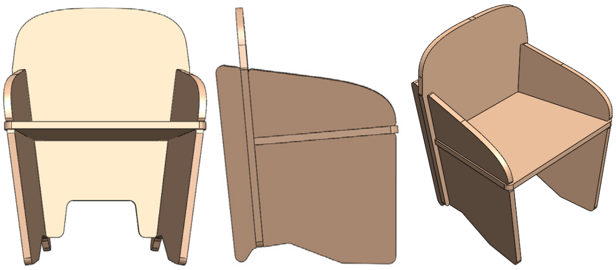
The first change the team did was to change the angle of the cut out in the back, so it was parallel with the seat. The change was done as the team viewed that parallel lines were compelling and had balance overall.



Ill 255 Form variation step B

Step B

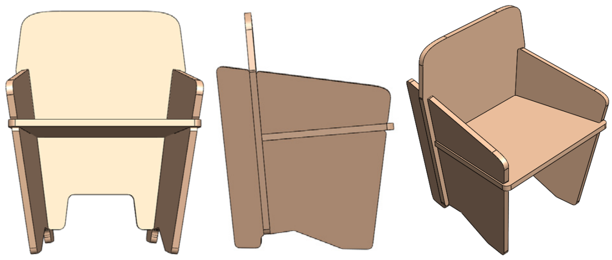
The next change was to dramatically increase the radius of the top of the backrest. This was to create a smoother and more relaxed backrest. The team was a bit split if such a radius clashed with the geometric shaping of the concept.



Ill 256 Form variation step C

Step C

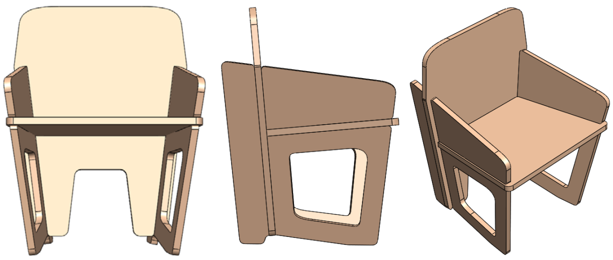
The team changed the radius of the armrest. This change was viewed by the team as too dramatic and clashed with the geometrical form language. Here the team viewed that the lost geometrical lines, from both the armrest and backrest, did not archive the same driven curve.



Ill 257 Form variation step D

Step D

While reverting back to a more geometrical form, it was seen that the back end footing was too small. Therefore the line parallel with the backrest was moved further. The team viewed that the change improved the stability. As of now the team viewed that the chair overall was on the heavy side, this was also viewed with the weight of the chair as it was 8,1 kg.



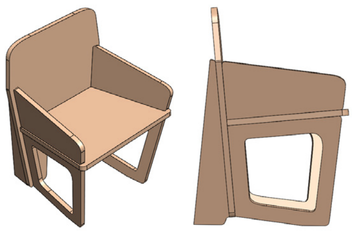
Ill 258 Form variation step E

Step E

As such the team made a cut in the side panes below the seating. The cut lines were parallel with the seat, backrest, front, and bottom lines. Also, the cut out at the bottom of the backrest was made higher.

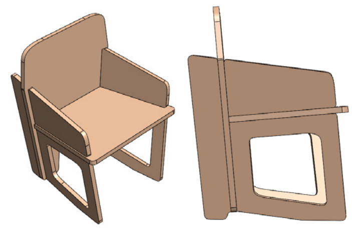
Sides cutout angle

After the last change, the team had a dialogue to see what effect the angle of the sides, with the lines of the front, back, and armrest. This was to see different variations of the chair and see if any was viewed by the team, to have a stronger form of language.



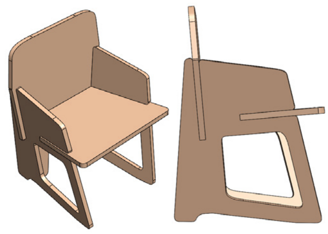
Ill 259 Downward armrest A

Downward armrest: A



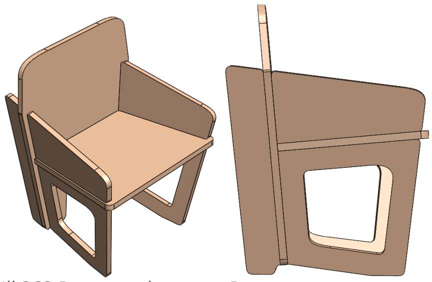
Ill 260 Downward armrest B

Downward armrest: B



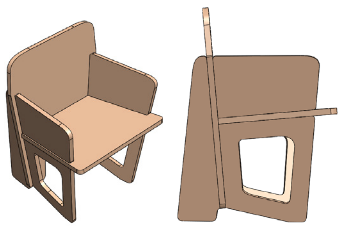
Ill 261 Downward armrest C

Downward armrest: C



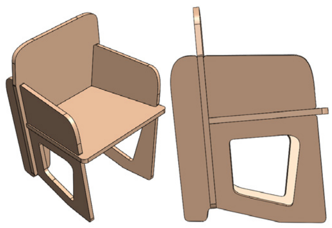
Ill 262 Downward armrest D

Downward armrest: D



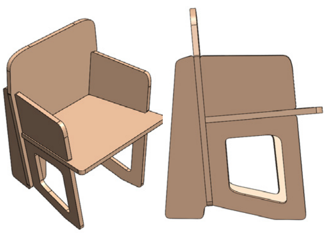
Ill 263 Horizontal armrest A

Horizontal armrest: A



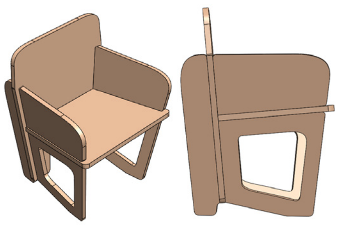
Ill 264 Horizontal armrest B

Horizontal armrest: B



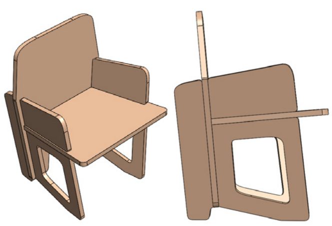
Ill 265 Horizontal armrest C

Horizontal armrest: C



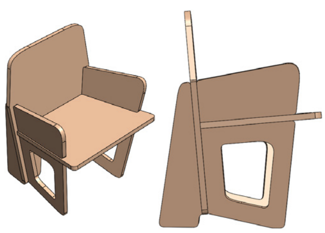
Ill 266 Horizontal armrest D

Horizontal armrest: D



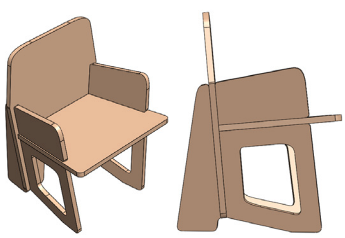
Ill 267 Upward armrest A

Upward armrest: A



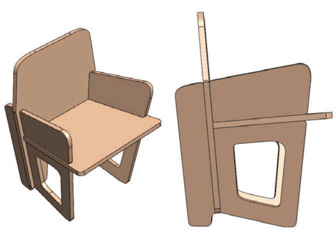
Ill 268 Upward armrest B

Upward armrest: B



Ill 269 Upward armrest C

Upward armrest: C

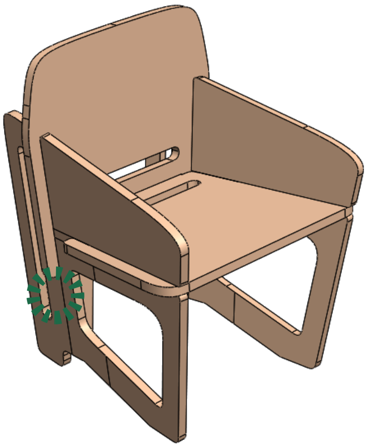


Ill 270 Upward armrest D

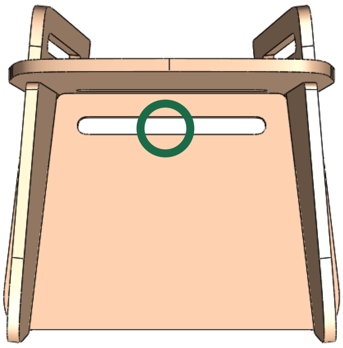
Upward armrest: D

From the variations, it was clear that all of the variations that included a horizontal armrest did not have a compelling design, in the sense that the horizontal line was bland. This was also seen when the sides were parallel with each other. Even though the concept with an upward armrest had powerful lines, the team saw it as too aggressive. By that definition, the strongest variation was seen as Downward C and D, however variation D, was the one the team saw as the strongest design, as it upheld a welcoming and appealing form language.

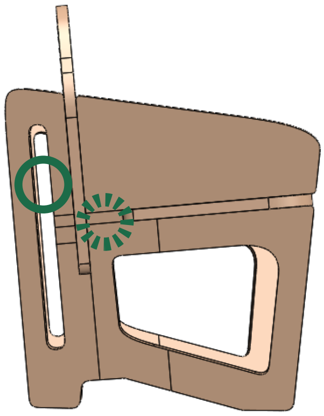
After the last phase, and through a dialogue between the team, some changes should be made. These were associated with functionality and construction. The first change was the need for interaction areas for the user to assemble and disassemble the chair. Therefore the team placed a slit on the backrest, seat, and sides, seen with the A points, in illustration 272, 273, and 274. The other issue was that the outer taps from the backrest and seating plate followed alongside the side panels. These had previously followed along the entire length of the board, however, the team saw these as possible areas that could break if people would apply too much force on them by accident. Seen with point B in illustration 271, and 273. The team shortened the outer taps, to reduce the risk for such occurrence. From here the team did some slight adjustment to the different fillets one each of the corners, to reach an overall better design.



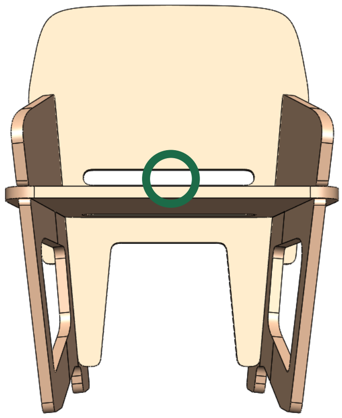
Ill 271 3D Detailing round 2 final isometric view



Ill 272 3D Detailing round 2 final top view



Ill 273 3D Detailing round 2 final side view



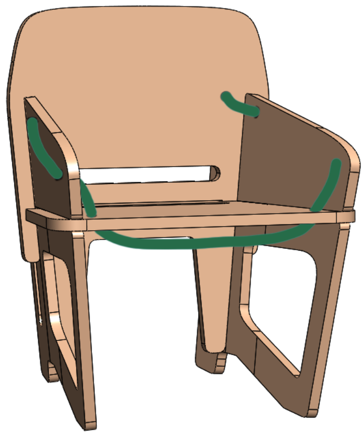
Ill 274 3D Detailing round 2 final front view

A=

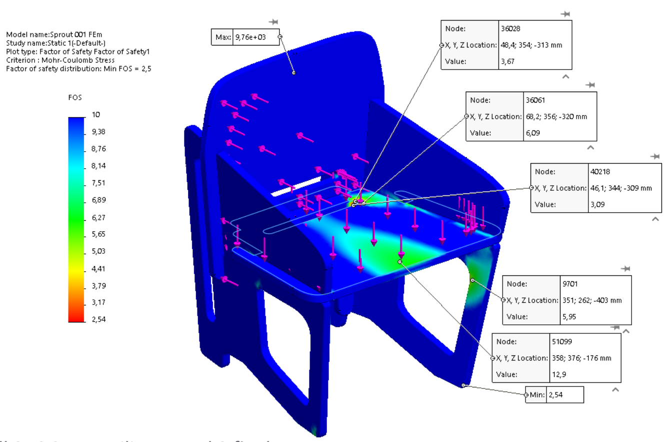
B=

As the team discussed the inclusion of the rope handles, the idea was to utilize the rope further. Here the idea was for the rope to be used as a locking mechanism. Meaning that when the chair is assembled, the rope would insure that the plates could not be moved. Also by doing this, the team talked about the fact that the rope could be used for packaging and transportation. In illustration 275 the green line represents the rope going the boards and locking them.

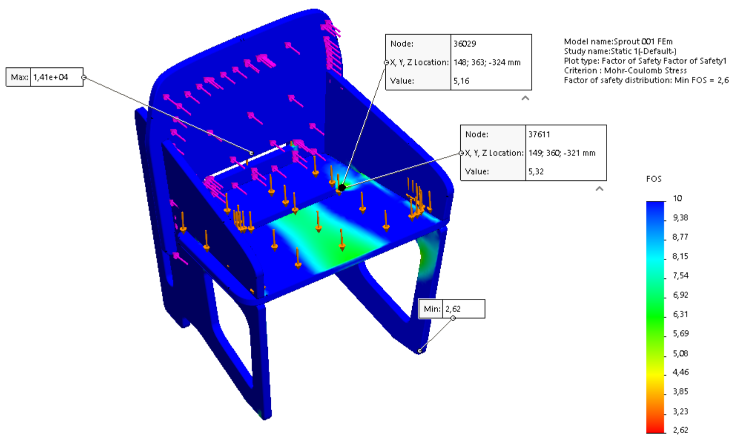
Via the concept made, the team did an FEA to ensure that the chair is capable of withstanding the weight of an 85 kg person. The FOS showed minor issues with the slit cut in the seat, with a FOS around 3. From this the team identified that the slit was where the side panels did not support the seat, therefore moving the slit cut further to the middle of the seat, where it then got support from the sides. This improved the FOS to around 5. Again the lowest FOS seen in these are due to the simplicity of the FEA model, as these are placed at the bottom of each foot, in a singular point.



Ill 275 Initial idea for rope locking mechanism



Ill 276 3D Detailing round 2 final FEA A



Ill 277 3D Detailing round 2 final FEA B

It was from here the team saw a need to create a prototype of the model. This was to test the ideas of the rope, and how it should be transported by the rope. The creation of the prototype, would also help the team get a better understanding of the overall concept, and see which improvement there could be.

Locking mechanism of plates via ropes !

Main form language defined !

3.5 | Sprout Prototype

To get a better understanding of the concept in terms of its construction and design of the chair, both in aesthetics or comfort, a 1:1 model was made. Along with an investigation of how to, transport the chair. This was done in oriented strand board, a material which is also orthotropic as the developed material (WS 3.7).

Backrest angle:
During the initial testing, it became quite clear that the angle on the backrest should be increased. On the prototype, the backrest is angled 90 degrees from the seat, which was deemed to narrow.

Board:
During the assembly of the prototype, it was discovered that the tolerance on +-0,2 mm needed to be increased to +-0,5 mm. This is due to the angle between the parts. Also, the prototype used a plate thickness of 18 mm, which was seen as an adequate thickness for the concept, which had previously been set to 20mm.

Ill 278 1:1 Prototype outdoor

Fillet curvature:
On the assembled prototype many of the fillets have the same curvatures, this created a dysfunctional dynamic that may be able to get fixed by changing some of the fillets. One of the noticeable fillets that were those on the top of the backrest. An idea might be to increase the curvature.

Seating area:
It was a concern that the ropes on the inside might be an obstacle for the user of the chair while sitting. However, it was quite unnoticeable, due to the divergence of the seating plate.

Ill 279 1:1 Prototype seating

Package and transportation:

1.

Ill 280 1:1 Prototype Transportation investigation step 1

The four parts of the chair were laid out on the floor, and the team considered several ideas to do the packaging.

2.

Ill 281 1:1 Prototype Transportation investigation step 2

First the rope was attached to the four parts so that it could be carried like a backpack.

3.

Ill 282 1:1 Prototype Transportation investigation step 3

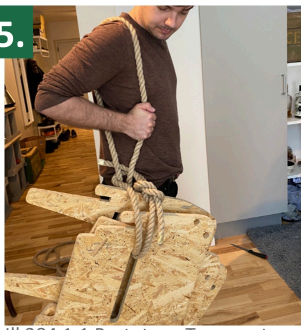
The same type of package could also be used on only one shoulder. This was actually more comfortable.

4.

Ill 283 1:1 Prototype Transportation investigation step 4

Now that the team had a packaging that was satisfying, the rope was to be attached to the assembled chair. An issue here was that too much rope was stuck up at the end.

5.



Ill 284 1:1 Prototype Transportation investigation step 5

The amount of rope was cut in half, from 6 meters to 3 meters. This meant that the bag pack opportunity was devoted, seen in the illustration 281.

6.

Ill 285 1:1 Prototype Transportation investigation step 6

The amount of rope was now suitable after a knot was made.

0.5 mm tolerance. 18 mm board thickness.
Transport mode of the chair is identified

Backrest angle needs to be increased,

!

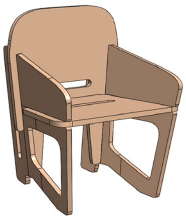
3.6 | 3D Detailing: Round 3

With the knowledge gained from the prototype, the following activities present what changes were conducted. The following also included investigation based on advice from the supervisors on what to look at. The following work was conducted with the team creating the concept together over skype, via screen share, to ensure that the changes were in both team member's vision, and following a systematic approach (WS 3.9).

Backrest top fillet

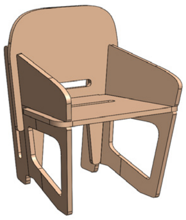
The fillets seen with the prototype were too "squared" as it did not achieve what the team was seeking. The team noticed that the curvature needed to be rounded out but still was in synergy with the geometrical form language as a base. Below are different variations of the fillet where the radius is increased from A to E. A and B were felt by the team that even though it was better it had an essence of the same issue as the prototype version had. F was seen where the curvature went too far. It was a choice between C and D where the team chose D, as the team felt the curvature was just right.

A



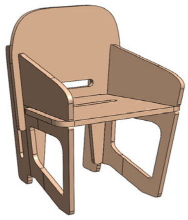
Ill 286 Backrest top fillet A

B



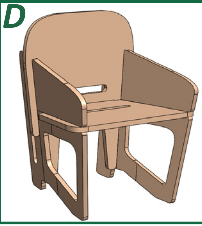
Ill 287 Backrest top fillet B

C



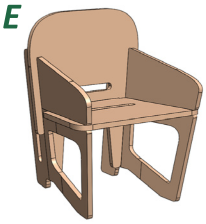
Ill 288 Backrest top fillet C

D



Ill 289 Backrest top fillet D

E

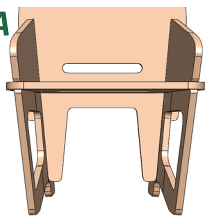


Ill 290 Backrest top fillet E

Backrest bottom fillet

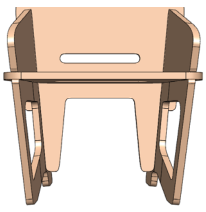
The next fillet the team saw clashing was the bottom part of the backrest. Here "A" presents how the fillet of the backrest was on the prototype. The first change the team did was B to flatten the curvature more, this however was seen as a worse alteration. Therefore the team made the endpoints circular. This variation the team saw as fitting, was to create contrast but did not clash with the more geometrical design of the chair. This curvature was then also applied to the taps on the side, with both the backrest and seat as to create symmetry.

A



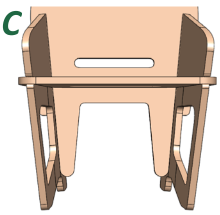
Ill 291 Backrest bottom fillet A

B



Ill 292 Backrest bottom fillet B

C

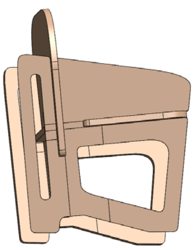


Ill 293 Backrest bottom fillet C

Sides bottom fillet

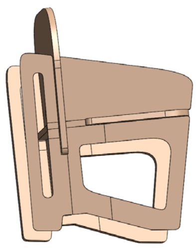
The next area was the bottom of the sides. It was clear that utilizing the same radius in the fillets, it was quite visible, and resulted in repetition, and a bit plain. The list is from A to E, where A shows the version that was used with the prototype. The following shows a progression, where E was the final version. The first was to make a more drastic radius at the back leg seen with B. This was to make more drastic transitions between the back leg to the cut in the bottom. Hereafter C, D, and E are working with the fillet at the front leg, making the transition more seamless. This was to have a more dynamic contrast between the transition to the cut, between the front leg and back legs. The final was E.

A



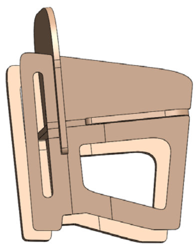
Ill 294 Side bottom fillet A

B



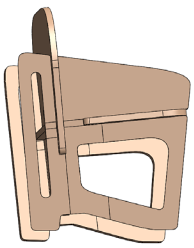
Ill 295 Side bottom fillet B

C



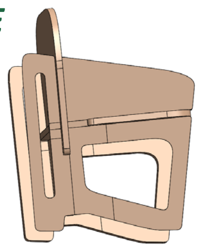
Ill 296 Side bottom fillet C

D



Ill 297 Side bottom fillet D

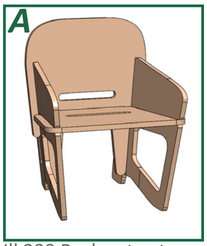
E



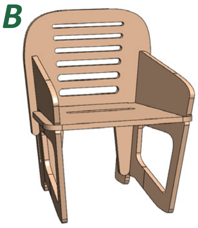
Ill 298 Side bottom fillet E

Backrest Cut out

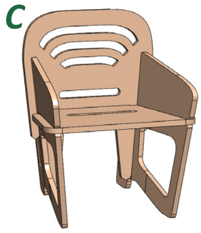
With talks with the project supervisor, he advises the team to investigate making the concept more structural, giving the Nanna Ditzel Trinidad chair as an example. This resulted in an investigation where different cuts were done. Version A shows the original design. B cut out was to follow the same shape as the cut out already there, where the only difference with them being slimmer. C was to follow the curve of the top of the seat. D is inspired by the Nanna Ditzel chair with vertical lines. E is a combination of A and D.
Overall the team disliked the different cutouts in the seat, with B, C, and D being the ones the team had the worse. E was the only one the team saw had some potential, but overall the cut out of the backrest was seen by the team, as removing the aspect of simplicity from the design. Even though this did not achieve any changes, the team investigated it, and now know that this is not the direction for the chair.



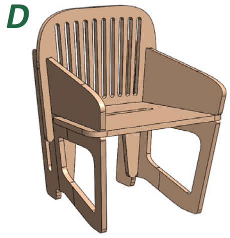
Ill 299 Backrest cut out A



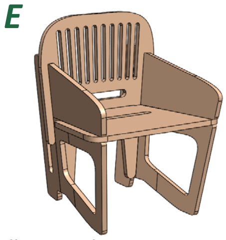
Ill 300 Backrest cut out B



Ill 301 Backrest cut out C



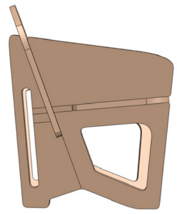
Ill 302 Backrest cut out D

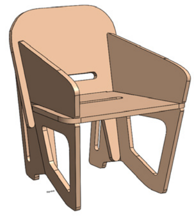


Ill 303 Backrest cut out E

Backrest angle

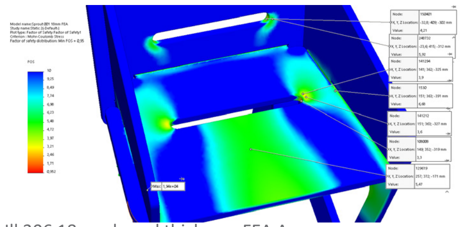
The next change was the backrest of the chair. The prototype had an angle between seat and backrest of 90 degrees. This was seen as a too narrow a degree for the chair, as it affected the comfort of the chair. Here the team decided that an angle of 105 degrees was the best angle, after looking at different angles, and with the knowledge gained from the prototype, as it was noticed from it the angle needed quite more opening up.

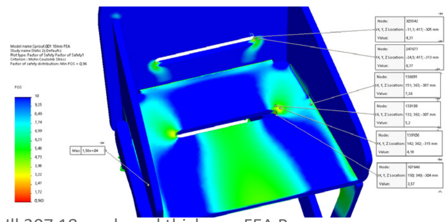

Ill 304 Backrest angle side view


Ill 305 Backrest angle isometric view

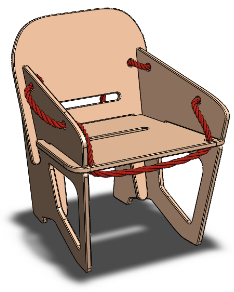
18 mm thickness

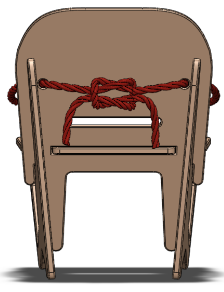
The next change was changing the board's thickness from 20 mm to 18 mm. This change also helped the weight of the concept as at 20 mm it weighted approximated 7150 grams, where changing the thickness reduced this to approximately 6500 grams, which is aligned with the design criteria for the concept. However, with such a change to the board, it was necessary to do an FEA of the current model. From the FEA the place that presented issues was at the slit cut in the seat, seen in the illustration 306. This is due to the change in board thickness. From here the team changed some different aspects, but the one that was chosen was to decrease its width of the slit from 30 mm to 20 mm. This improved the FOS, but not over 4. This however is something the team did not see as such danger, as the developed material is still an indication, and not a fully mature material, where the strength would improve.

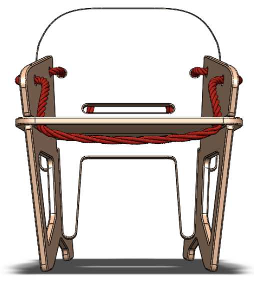

Ill 306 18mm board thickness FEA A

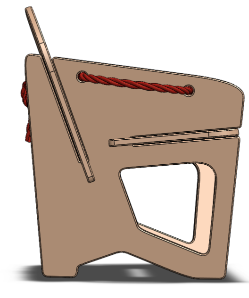

Ill 307 18mm board thickness FEA B

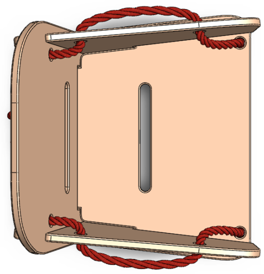
After alternation with the thickness of the material, the last change was including the rope to the cad model, as the prototype.


Ill 308 3D Detailing round 3 final isometric view


Ill 309 3D Detailing round 3 final back view


Ill 310 3D Detailing round 3 final front view


Ill 311 3D Detailing round 3 final side view


Ill 312 3D Detailing round 3 final top view

Sum up

With the current design, the team viewed the concept to be satisfying and compelling overall. The only segment the team needs to finalize is the cupholder. As the rope now has multiple functions, the way of where the beer holder and the rope was one part was not viewed possible, as the rope needs to move through the holes in the plates. Therefore a new version of the cup holder needs to be implemented.


Ill 313 3D Detailing round 3 final transport mode A


Ill 314 3D Detailing round 3 final transport mode B

3.7 | Festival distance mapping

It became relevant for the team to investigate how far it would be required to transport the chair when assembled and unassembled. To investigate this, a map over Roskilde Festival was analyzed in regard to distance. Roskilde Festival was chosen due to it being the largest festival in Denmark. Since neither of the team members had been to Roskilde Festival an acquaintance was asked to help investigate this matter (WS 3.8).

Ill 315 Festival map, shows division of camp sites and their diagonally distance

The acquaintance is Thorvald, who has been at Roskilde Festival five times. With aid from him, the camp areas were separated into six different areas. According to Thorvald the camp you stay at is the primarily used zone for whatever activity you are doing, except for the staging area.
Thorvald further told that with the current camping chairs, you almost never take them away from your own tent site. If you are to leave your own tent site, you will just borrow someone else's chair at whatever site you are visiting. If you are going to move your chair, this will only be approximate 5-10 meters to a nearby tent site.
During this investigation, it was discussed that with the market strategy where you will buy the chair at the festival, there is no need for the same mobility as there are with the current camping chairs.
It can be concluded that while the chair is assembled, it should be able to be moved 10-15 meters. To get a feel regarding the movement distance while unassembled, it would have been optimally to have Thorvald test the prototype. However, it was chosen to use the diagonal distance of the festival, which is 2 km.
The location of the selling booth should be located in collaboration with the festival, however, according to Thorvald the area marked with the red arrow, could be a fine location.

3.8 | Design criteria revisited

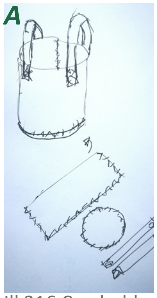
With new insights and gained through developing the product prototype, the team saw that updating the design criteria was necessary. This is to add new criteria, define older criterias, and remove criteria that have not been driven criteria. In the new criteria a color coding system was used where, green is a new criterion, yellow is an edited criterion, and red is a removed criterion (WS 3.11).

Nr	Criteria	Unit	Marginal value	Ideal value	Reference
1	The chair should withstand the weight of 85 kg person sitting on the chair.	FOS	4	5	WS 2.34
2	While unassembled the chair must be able to be moved X m	m	2000	2500	WS 3.8
3	While assembled the chair must be able to be moved X m	m	10	15	WS 3.8
4	Chairs should not exceed a certain weight.	Kg	<7kg	<5kg	WS 1.15
6	The chair should utilize rope as interaction areas for carrying.	Binary	Pass	Pass	WS 2.32 WS 2.34 WS 3.7
7	The chair should include cup holder, that can have 330ml beverage can.	Binary	Pass	Pass	WS 2.32 WS 2.34
8	The chair should highest consist of x different materials.	Binary	>5	>3	WS 2.32 Ws 2.34
9	The chair shall include a backrest with a height of x	Binary	Pass	Pass	WS 2.32 WS 2.34 WS 3.7
10	The chair shall include a armrest with a height of x	Binary	Non	Pass	WS 2.32 WS 2.34 WS 3.7
11	The chair shall have a wide seat	mm	420 mm	560 mm	WS 2.32 WS 2.34
xx	The chair should have easy to clean in corners or notches.	Binary	Difficult	Pass	WS 2.32 Ws 2.34
12	The chair should be steady	XYZ coordinates Center of gravity	< Half of total height < 30% from XY center	< 40% of height < 20% from XY center	WS 2.32 Ws 2.34
13	The chairs thickness of parts should not exceed X.	mm	20 mm	15 mm	WS 2.30 Ws 2.34 WS 3.7
14	The chairs feet surface area should not be focused on small areas	Binary	Pass	Pass	WS 2.30 Ws 2.34
15	The chair shall be made via a sheet manufacturing process	Binary	Pass	Pass	WS 2.33
16	The tolerance between the parts should be +- 0,5 mm		0.5 mm	0.2 Angle cutting manufacturing	WS 3.7
17	Include rope used as locking mechanism, and for transportation.	Binary	Pass	Pass	WS 3.7
18	The ropes for the chairs shall be available in x colors	Binary	8	4	WS 3.1

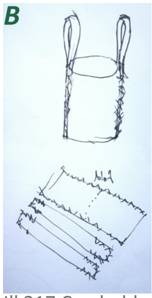
3.9 | 3D Detailing: Finalization

With the design criteria defined, the team was to finalize the chair. Here the final details of the cup holder was to be finished. These were done through dialogue and investigation, via model and 3D drawing. These changes heighten the concept and were aligned with the updated design criteria (WS 3.10, 3.12)

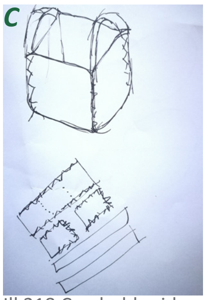
First, the team had a dialogue about how the cup holder should be made. The dialogue went that a fabric-based cub holder made from the same material as the rope, as this would result in the rope and fabric could come from the same manufacturer. With this, there were some simplistic ideas of how the cub holder should look like. From these simplistic ideas, the team saw B as the best solution, as it was the most simple, and would be the least expensive to produce.



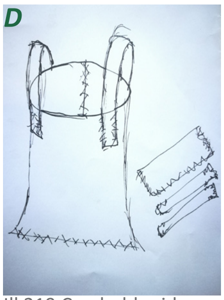
Ill 316 Cup holder idea drawing A



Ill 317 Cup holder idea drawing B

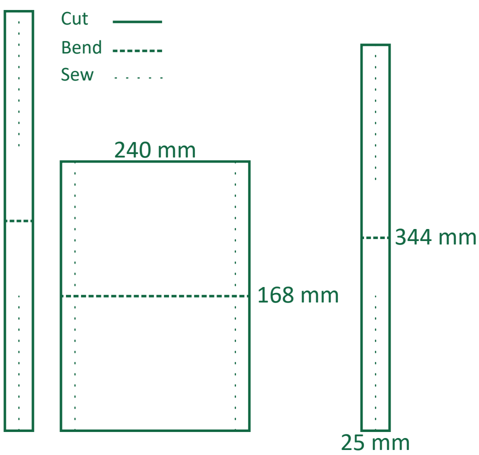


Ill 318 Cup holder idea drawing C



Ill 319 Cup holder idea drawing D

From here a mock-up was made. This mockup was made based on the dimensions of a normal 330 ml aluminium can. The dimension of a 330 ml aluminium can is 115 mm in height, a body diameter of 66 mm, with circumference 416 mm (Ball, 2020). With these dimensions, the mock-up model was made.



Ill 320 Cupholder sew and cut pattern


Ill 321 Cup holder mock-up step 1


Ill 322 Cup holder mock-up step 2

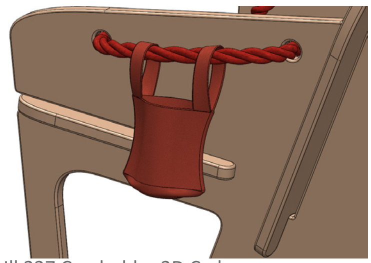

Ill 323 Cup holder mock-up step 3

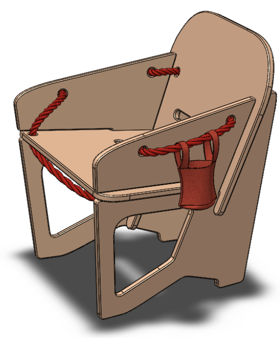

Ill 324 Cup holder mock-up step 4


Ill 325 Cup holder mock-up step 5


Ill 326 Cup holder mock-up step 6

The model proved that a pattern as such could be utilized as a simple cup holder. With the model showing proof of concept, the team made a variation of it in Solidwork, to finalize the last part of the concept in cad.

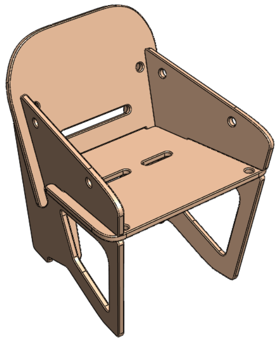

Ill 327 Cup holder 3D Cad model A


Ill 328 Cup holder 3D Cad model B

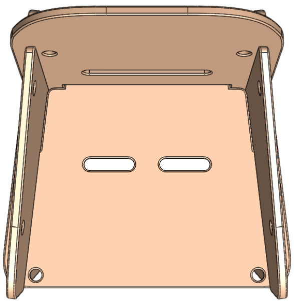
After the cup holder was finished the concept was presented to the supervisors. Through this a dialogue with the team and supervisors, the talk was directed toward: The rope, beer holder, and middle slit. The dialogue resulted in new ideas and tests that would improve the concept. These were then investigated, to see if they could improve the concept.

Seat slit

The dialogue went first toward the slit in the middle seat. Here it was discussed that splitting the slit in the middle would help the seat to handle loads. This change was conducted on the model, to both see the change clashed with the aesthetics and thereafter do an FEA.



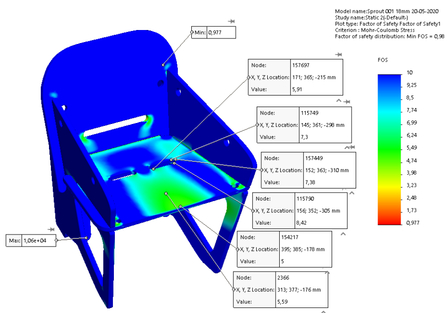
Ill 329 Seat split isometric view



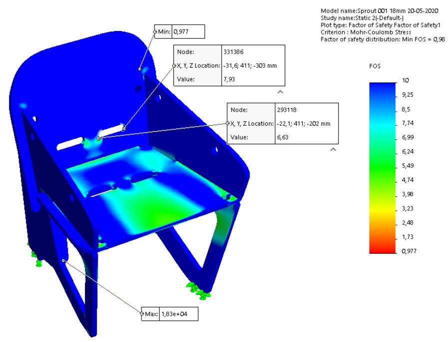
Ill 330 Seat split top view

The team viewed the change still had the same essence of the form language, as previously. However, it was deemed by the team that to have consistency the backrest should include the same slit.

From here the team did an FEA, with a person of 85 kg. The result of the FEA showed a positive result. The issues that previous was with the slit with a FOS of around 3.5, is now raised to around 5.9 to 7.3. With the great improvement to the overall seat of the chair, the team chose to use this variance of the slit. This was also tested with the backrest and showed the same promising results.



Ill 331 Seat split FEA A



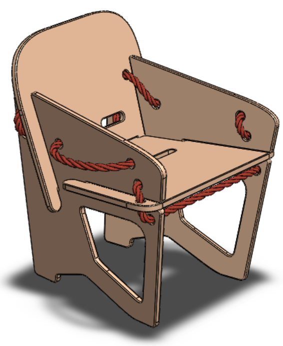
Ill 332 Seat split FEA B

Rope locking mechanism.

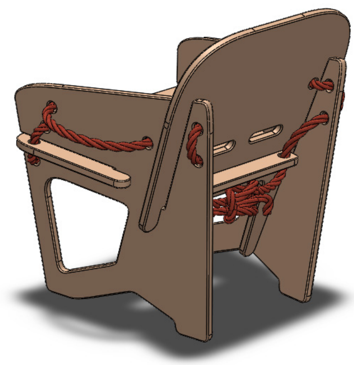
Through the dialogue, the idea of using the rope as a locking mechanism was seen as an ideal function toward the concept, but it could be taken even further. Here it was seen that following the rope though more segments of the plates, that a higher degree of securing could be reached. This was then tested on the previous prototype to see if this solution was possible. What the investigation resulted was that it indeed worked, in locking the plates more together. This however did increase the complexity to assemble the chair, but only by an incremental. The aesthetics of the change was also viewed quite positively as it resulted in being more dynamic and intriguing than before. Therefore the team decided to incorporate the following change. In the illustration below, the changes are visualized

Ill 333 Rope locking mechanism revision prototype A

Ill 334 Rope locking mechanism revision prototype A



Ill 335 Rope locking mechanism revision cad model A

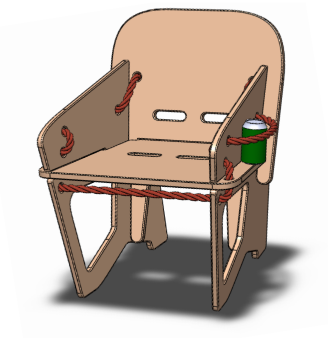


Ill 336 Rope locking mechanism revision cad model B

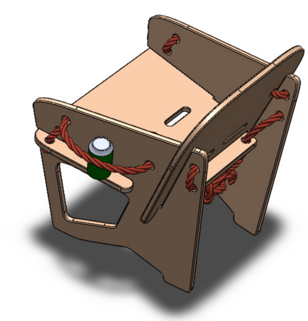
Cupholder.

The last final change was the cupholder. Through dialogue, it was discussed if a better stitching pattern could be done with the cup holder. Here the dialogue went to how the team viewed the simplicity of it, was importance for a cup holder. It was here that an idea came to be. Here a team member tested the idea to use the rope already as the cup holder, by placing a 330 ml can between the rope and the side plate, where the sides of the seat were used as the bottom. This was seen by the team as an epiphany, as it was a more simplistic solution, and created more balance to the overall concept, as the previous cup holder, did clash a bit with the design. A change that had to be made for this to function, was extending the sides of the seat with 10 mm, for the can to have more resting areas. This was also done to the backrest, for consistency.

Ill 337 Cup holder revision prototype



Ill 338 Cup holder revision cad model A

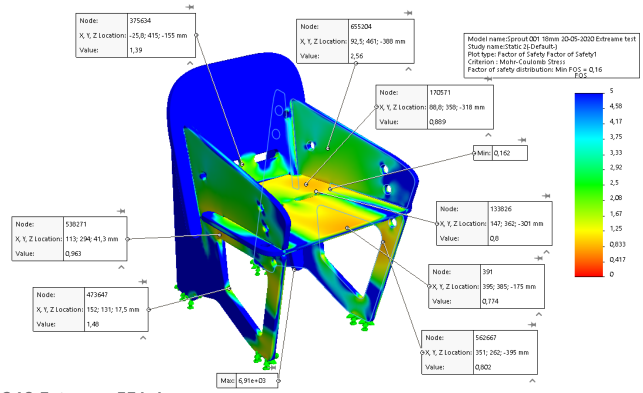


Ill 339 Cup holder revision cad model B

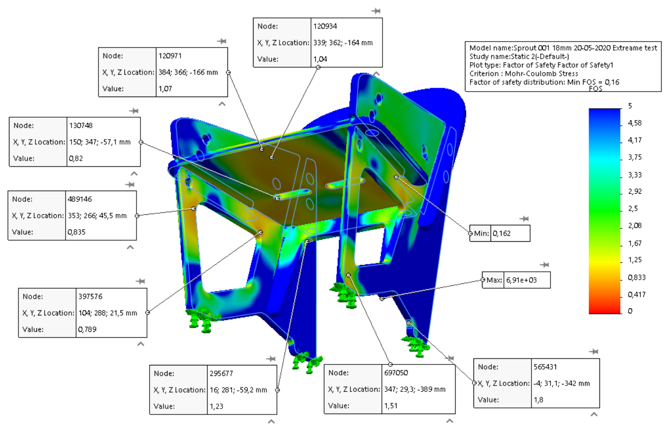
Extreme test.

Through dialogue, it was discussed what the load capacity of the chair was. As it was proven that the chair can handle a load of a person of 85 kg, with a FOS of 4, more extreme occasions were considered. This pointed to the direction of conducting an extreme FEA test, to simulate a person of 85 kg jumping 200 mm up in the air, and landing again. Here the team utilized the calculation of impact force of a falling object (HyperPhysics, 2020). The input is a person of 85 kg lands from jumping 200 mm on the chair, where he then bends his legs 100 mm down, to simulate the distance traveled after impact. This resulted in a force of 1666 newton. With this, a small area based on the size of one of the team member feet size on the seat was exposed to these forces.

From the FEA test, it was visible that the chair would fail under such a condition. Here the chair failed in the following areas: middle of the seat; each top corner of cut out of the sides; the back corners of the seat. Here the FOS ranges from 0.7 to 1 of the failing areas. This however was not surprising for the team. That the FOS of these areas were close to a FOS of 1, proves that if maturing the material, there is a possibility that the concept could handle such a scenario.



Ill 340 Extreme FEA A



Ill 341 Extreme FEA B

Sum up.

The team was delighted with the new changes, and improvements to the concept overall, both aesthetically and its construction. Here the team is satisfied with the current design of the festival chair but also learned that in the design with a chair that it never ends. Still, the team viewed that the concept was finished, both in terms of satisfaction, and remaining time with the project.

CLØVER™

The outcome of the detailing process is the sustainable and transportable festival chair, Cløver by Spriva. Cløver is made of the grass composite material, under the name GROWTH™, which has been developed by Spriva. The chair itself consists of four parts that are to be assembled when the customer buys it on the festival site. The rope comes in a total of four colors and has the function of keeping the parts together so that they will not slide out of each other when assembled. The rope also has the function as a can holder, as it will keep the can in a fixed position when inserted.

When the chair is bought at the festival, all the parts are packed as a flat package with the rope surrounding for transportation.

Ill 342 Cløver presentation

4 | Implementation

This chapter researches manufacturing, economics, and the approach of market strategy. This was conducted by analysis, and interviews with experts. This culminated with an insight into how the manufacturing, and how the chair, Cløver, and material, GrowthTM should be marketed.

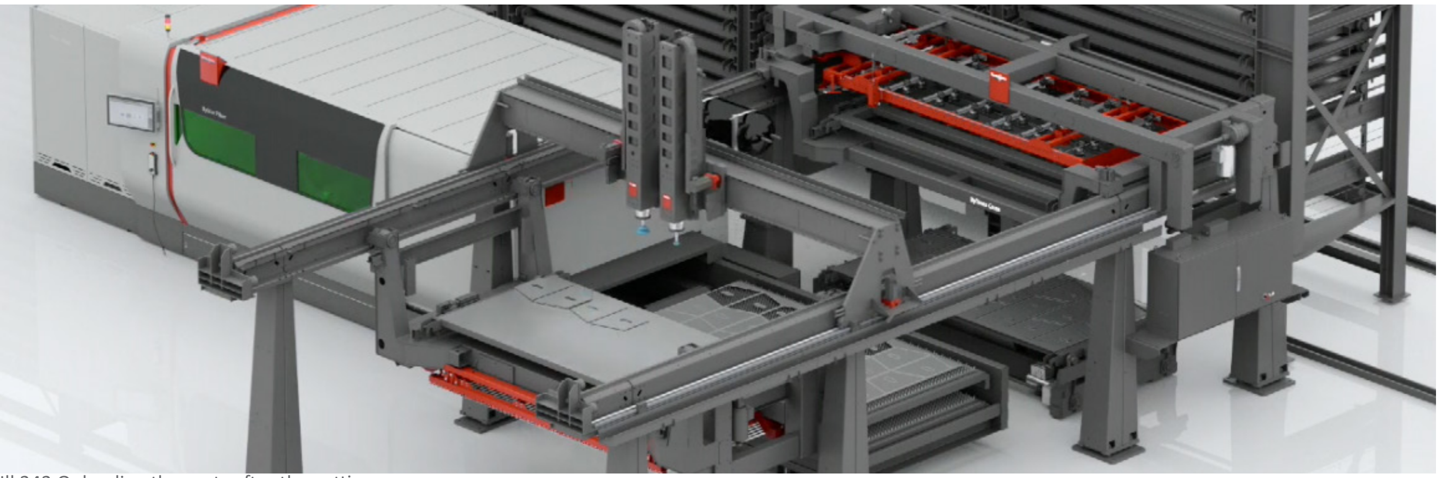
4.1 | Production and manufacturing

To define the production and manufacturing of the Growth™ and Cløver. This is to get an understanding of the process required to realize the product, and how the manufacturing would occur (WS 4.1).

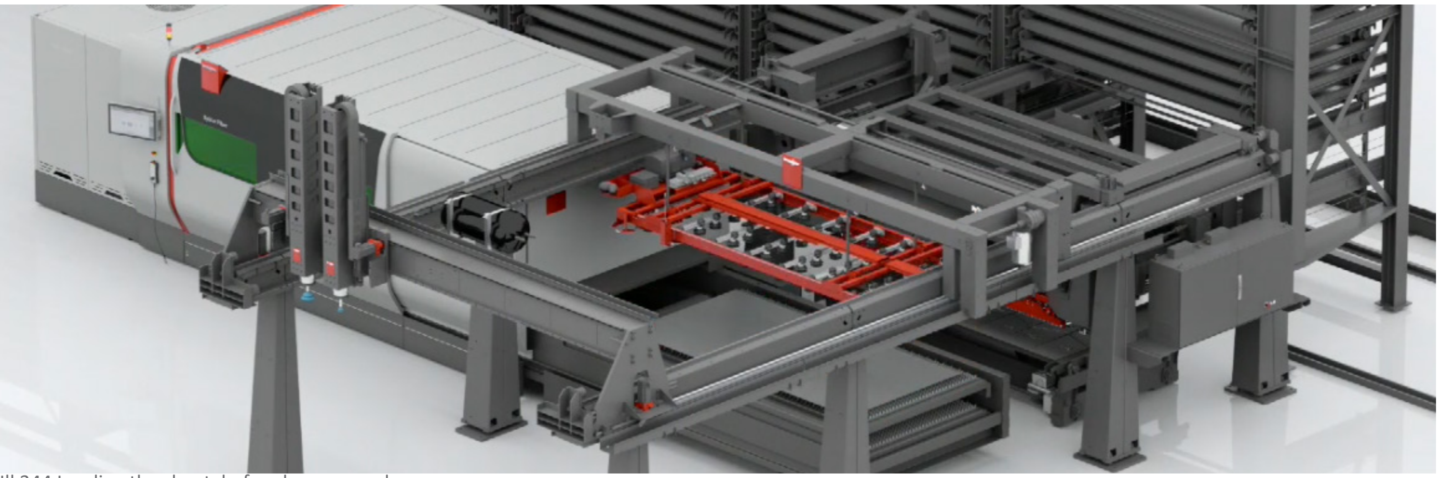
The production process can be derived into two processes. First the production of the material, under the name Growth. Next the production of the chair, Cløver.

The grass mycelium composite is developed by utilizing the known technologies by Ecovative Design. As previously mentioned they have developed mycelium composite from corn as material.

It has since the conceptualization phase been discussed to use the laser cut processing, however, the team also investigated the use of water-jet cut.
To get a more in-depth understanding the team contacted Kasper Sørensen, who is the service manager at ByStronic, one of the world's leading suppliers of sheet processing solutions. Kasper received a picture of the final concept and an explanation of the market strategy. Although water cut has some advantages with precision and cut edge quality it was quickly eliminated due to the high running cost, as water jet is five times the cost as laser cut. On top of this, the production rate is 2-3 times as slow, depending on the thickness and material.
As for laser cut, there are primarily two types; CO2 laser and fiber laser. CO2 lasers can maximum cut through 8-10 mm, regardless of the material. Fiber lasers can cleanly cut through 20 mm wood. The cutting precision of a fiber laser is +- 0,05 mm and with a medium cut edge quality, depending on the material. It has a general production rate of 50-170 meters pr. minut. Compared to water jet cut there will be a heat affection. However this is very low when cutting in wood compared to metal. When cutting the mycelium composite, there is most likely a possibility that the heat will produce a burned edge on the parts. Just after the cutting, this edge will be able to stain on objects that come in contact with the cut, however this will not be permanent.
For a full automatic system that would only require man operation two times pr. 24h, Kasper Sørensen, suggested the BySprint Fiber 3015 fiber cutter, along with a full setup of automatic refilling and unloading systems. This type of machine itself has a cost of 3 million DKK and the automation tower has a cost of around 5 million DKK.
This is a setup that requires a high investment, however, it can be calculated whether or not the full automation is cost-beneficial in this case.



Ill 343 Onloading the parts after the cutting process.



Ill 344 Loading the sheet, before laser procedure.

GROWTH manufacturing

Preparation: Grass pulp will be transported from the biorefinery. From here the grass is steamed to eliminate any other Microbial organism (Frazier I, 2013)

Mycelium mix: The grass pulp and mycelium tissue are mixed together (Frazier I, 2013), and next put in a thermoformed container. Here the material consumes the grass pulp, resulting in an initial percentile of mycelium of 1% upward to 16-20%, over the course of 4 days (S. W. Angus, 2016)..

Heat pressing: When the growth period has finished, the material is placed within a continuous hydraulic heat-press, for ten minutes (Bloomberg, 2015), with the heat between 137-204 Celsius (S. W. Angus, 2016).

Sizing: The sheets have been manufactured as 19 mm sheets. The sheets will be run through an electrical planner, to achieve a flat surface, with a contentious thickness of 18 mm all over.

Cløver manufacturing

Sheet processing : The manufacturing of the chair will take place on the same site as the manufacturing of the sheets. The sheets are after production placed on a large tower, which is a part of an automated fiber laser. The fiber laser is then fed with sheets to be laser cut. The ratio to cut the material is unknown, however, it is estimated to take 40-45 seconds per. chair. From here, the main parts of the chair have been produced.

Rope : The rope will be made by the jute plant at an extern factory, such as Shandong mayi industrial trade (Mayi, 2020). From here the 20mm jute rope will be delivered in 3-meter pieces. Jute was chosen as it is one of the cheapest and most abundant natural fibers in the world. (Shodhganga, 2020).

Cløver assembly : A worker will assemble the chair to its transportable mode. This would help transport from Cløver to the festivals.

4.2 | Economy

This section sums up the basics of the business case (Skov Laursen, 2018) for production and manufacturing of the material and the chair. Including is the project investment, product cost, sales price, budget and break even analysis. The prices are gathering by research and talking to manufactures within the field. The objective for this section is to give an idea of how much will have to be invested and how large the profit will be within the first three years (WS 4.2).

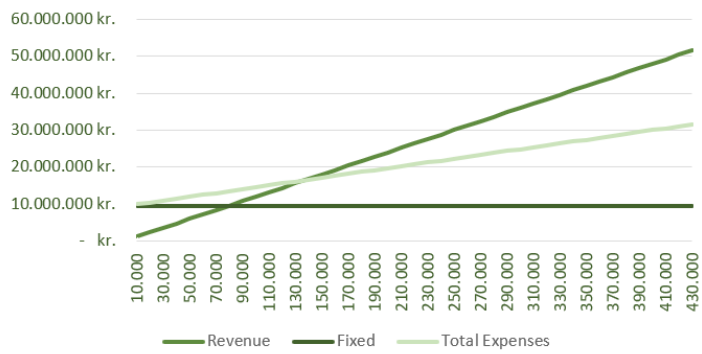
Project investment			
Mixing machine	1	7.935	DKK
Steamer	2	20.998	DKK
Thermoformed container	1000	100.000	DKK
Hydraulic heat press	2	136.826	DKK
Electric planner	1	66.500	DKK
Laser cutter	1	5.000.000	DKK
Laser cutter automation tower	1	3.000.000	DKK
Salary	2	832.000	DKK
Prototypes		50.000	DKK
Travelling		100.000	DKK
Material development		100.000	DKK
Storage	2484 m^2	500.000	DKK
Total		9.406.324	DKK

Ill 345 Project investment table

Denmark is the frontrunner in implementing biorefineries technology. Due to this, it is chosen that the production is to be facilitated in Denmark – close to Ausumsgaard. Ausumsgaard has the capacity to produce close to 4.000.000 kg of grass pulp within a season. And thereby enough to get the production started. By facilitating the production close to Ausumsgaard the transportation cost of these many tons can be cut down to a minimum.
Within the product cost the transportation of the grass is missing, this is very hard to estimate, however as mentioned, the price will be lowered considering the short distance between manufacturing facility and biorefinery. The operational salary is for three people working 8 hours a day, for a wage of 200 DKK/h. They are to produce 400 hairs a day.
The chairs are to be sold by the festival. The festivals will earn a contribution of 20%, which in return would provide a location for a booth, volunteer to work in the booths, and promotion of Kløver. The products are to be sold for 120 DKK. This price is set based on proping from users.

Project cost		
Grass pulp	3,5	DKK
Mycelium	3,0	DKK
Jute rope	3,0	DKK
Operational salary	12,0	DKK
Finalize package	6,0	DKK
Product cost	27,5	DKK
Sales price (incl. VAT)	120,0	DKK
Festival contribution (20%)	24,0	DKK
Product cost incl. cont.	51,5	DKK

Ill 346 Project cost table



Ill 349 Break even graph

Budget	Year 1	Year 2	Year 3
Chairs sold	98.600	147.900	197.200
Chairs sale price	120	120	120
Product cost (DKK)	51,5	51,5	51,5
Turnover (DKK)	11.832.000	17.748.000	23.664.000
Variable cost (DKK)	5.077.900	7.616.850	10.155.800
Contribution margin (DKK)	1470000	6247500	9371250

Ill 347 Budget table

Break even analysis	Year 1	Year 2	Year 3
Investment (DKK)	9.406.324	3.984.224	7.478.926
Contribution (DKK)	6.754.100	10.131.150	13.508.200
Remaining (DKK)	2.652.224	6.146.926	20.987.126

Ill 348 Break even analysis table

Since one-sixth of every Dane goes to festivals, the first-year sales number is estimated to be 10% of these. Next year the sales number is to increase with close to 50.000 and the same with the third year.
A break-even analysis has been made to see when the investments have been recouped , seen in illustration 348 and 349. It is shown that in mid-year 2, with a final profit of 6.146.926 DKK the investment has been recouped.
Converted to a number of chairs, the break-even point will be after the sale of 137.319 chairs.

Circular Economy

The market strategy is based on circular economy. At first, we have the biorefineries at Ausmsgaard, from here the grass pulp will be applied in sheets and chair production, at a total cost of 27,5 DKK Pr. Chair. The chairs are to be transported to the festivals, where the festivals will sell them for 120 DKK, with a contribution of 20%.
If a chair is brought back to the selling booth, the guest will have a deposit back of 40 DKK, both in the case if it is fine or broken.

Hypothetically, if 75 % of the chairs are to be returned during a year of festivals, a total of 2.958.000 DKK is paid back as a deposit. If 50 % of the chairs returned are in perfect shape, these can be sold at another festival for a total of 4.437.000 DKK each. This will make a revenue of almost 1,5 million DKK through this strategy, based on the first years of sales. This is an estimate and can not be calculated into the budget

Market strategy estimate		
75% of 98.600	73.950	Units
73.950*40DKK	2.958.000	DKK
50% good shape	36.975	Units
36975*120DKK	4.437.000	DKK
Revenue	1.479.000	DKK

Ill 350 Market strategy estimate table

Ill 351 Redefined market strategy illustration

4.3 | Business Model

The business model canvas is a tool for describing and analyzing business models. The proper way to make a business canvas could be to have a board where the team collaboratively fill out the nine segments with sticky notes and have a proper discussion regarding the business. The key benefit of the model is to create a clarity of the company's core aims. While doing so, potential weaknesses and strengths might occur. For a start-up company as ourselves, it could be a good idea to look at this model weekly, to keep your business DNA up to date. Underneath an initial model has been made, however at the start of the business start-up, it might look totally different, due to the many aspects that have an influence. Furthermore potential leveraging has been investigated, with product architecture potential to make the business more horizontal (WS 4.2, WS 4.3).

Key Partners

To start with a partnership with SEGES would be implemented. SEGES can help with the professional guidance in order to raise investment from biorefineries and other possible stakeholders.
Also, a partnership with Ausumsgaard is to be created, to have a supplier of the grass pulp. At a previous conversation with the director of Ausumsgaard, they had a big interest in selling the grass pulp to 0,5 DKK pr. kg.

To keep developing the material a partnership with Ecovative would be ideal.

Dansk live would be ideal, to get a good stand on the danish festival market and get connected to the danish festivals.
If a partnership can not be made with Dansk Live, it is essential that we create contact with festivals ourselves, as they also are a key partner, in order for us to sell the chairs.

Key Activities

The key activities are to grow and manufacture the grass composite and keep developing the material to the highest standards. By doing this a large storage of composite sheets would be built up.

Key Resources

There are Key Resources which the Value Propositions require.
The key resources are:

- Manufacturing labor
- Grass
- Mycelium
- Storage
- Expertise with the aid of SEGES and Ecovative
- Circular economy

Value Propositions

The value proposition is to develop a luxurious on-the-spot green alternative to the camping chair that is currently being used at festival sites.
It is a product for the festival guest, however, it will also help the festival with waste handling and thereby make the festival more sustainable.

Customer Relationships

The chairs are to be sold to consumers, B2C. However, with the festivals as dealers, B2B, sales depend on festivals, therefore an extra contribution can be awarded to festivals if they sell x amount of chairs. This could be an extra contribution per chair.
The cooperation is beneficial for both of us since we can increase their income by very limited resources.

Channels

The channels our Customer Segments are to be reached:

- Instagram
- Facebook
- Google
- Physical appearance on the festival site (mouth to mouth)
- Festival marketing

Customer Segments

Festival guests are our primary customers, however, in order to sell the chairs, our key partner, the festivals, are essential.

Cost Structure

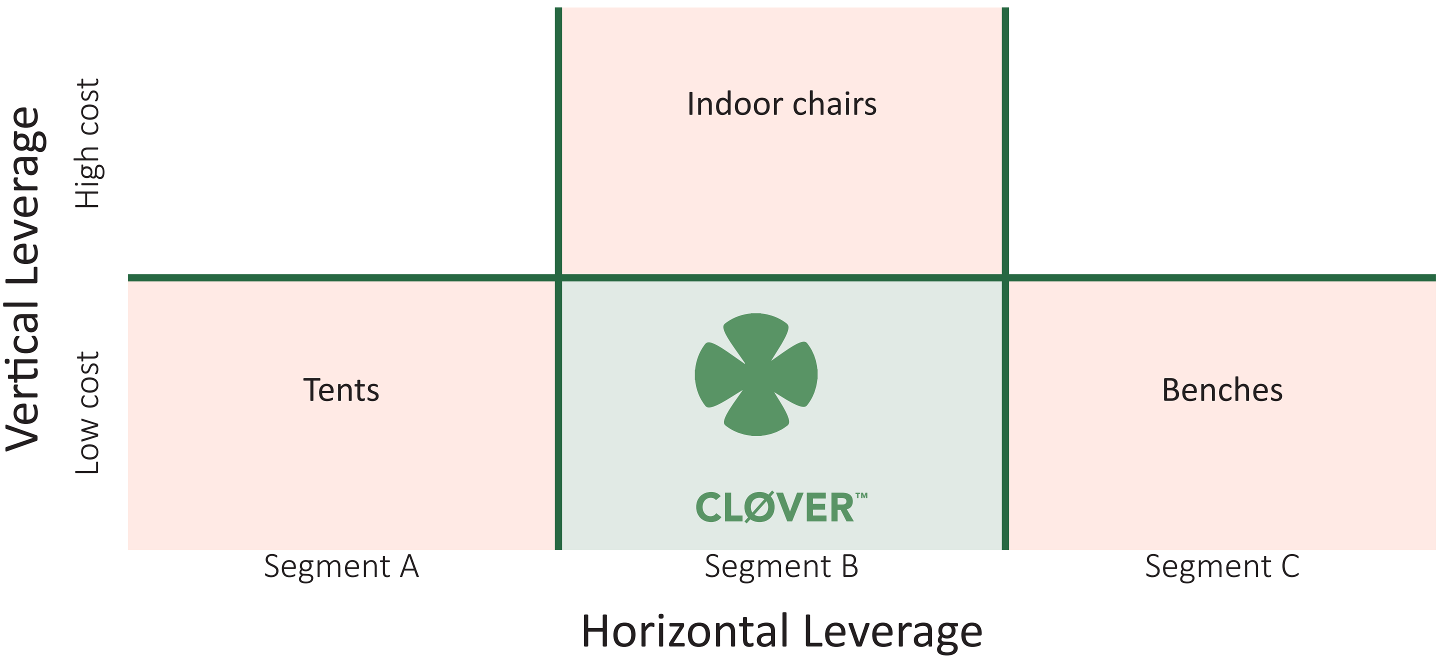
The cost is primarily used in manufacturing, as well as marketing. Initially, some of the costs are used on development, until a satisfying material has been developed.
The cost structure is both value-driven and cost-driven. However, more value-driven due to the value proposition.

Revenue Streams

The customers have a desire for sustainable festivals and are willing to pay for green initiatives.

Product family

Due to the module production method, a production family can be made. If taken a look at the product platform (Meyer, 1996) (Meyer M. H., Zack M. H., 2008) the material can be divided into other niche products at festivals, but at the same low cost. Furthermore, the chair can also be leveraged in the vertical direction, to create more luxurious products, as for example an indoor chair.

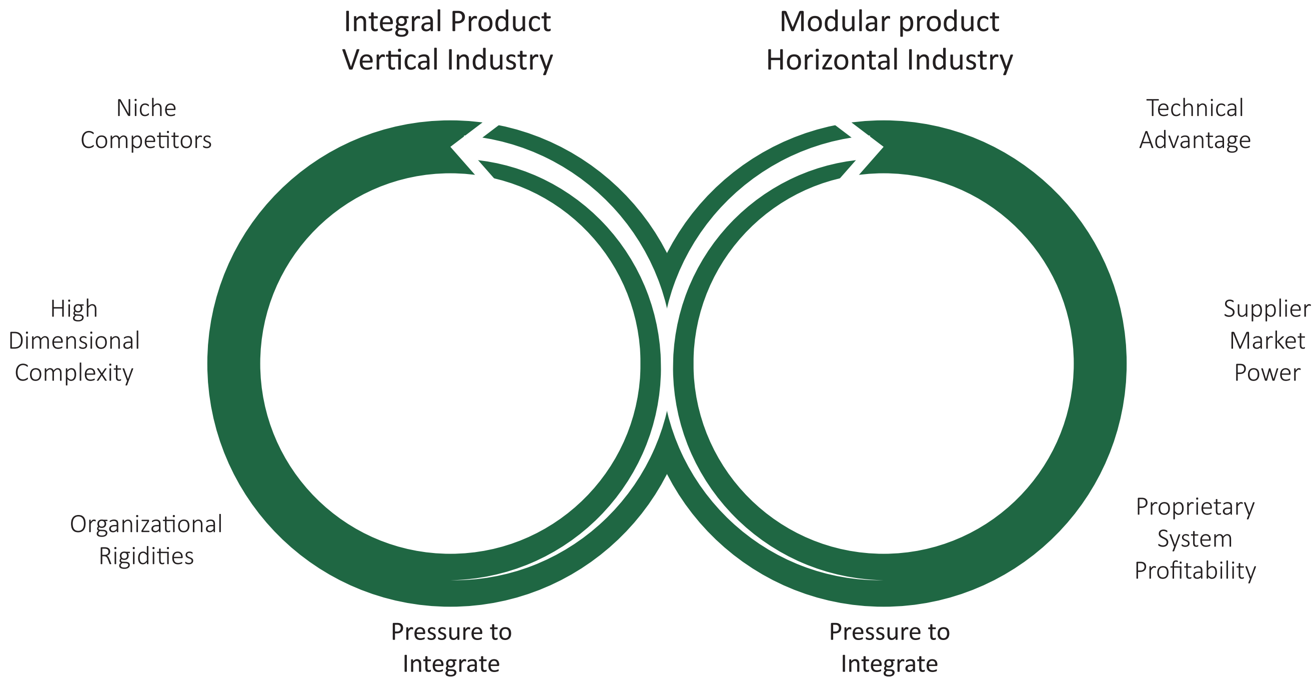


Ill 352 Vertical - Horizontal Leverage

The Double helix model offers a simple way to analyze an industry as well as a product and its product architecture throughout the development of an industry. The aim of the model is to prepare companies for shifts in the industry structure and the losses that might occur from these shifts.
(Malone T. W., 2005)

The left side of the double helix model seen in illustration 353, indicates integrated industries where there is a proprietary complexity within the product. These types of products have a high barrier to enter the market. The focus within these industries is performance and functionality.
The right side indicates the steps during a horizontal industry structure, where modularity is important and there are low barrier barriers to entry to other segments. The focus within these industries is flexibility and customization.

When looking at the Spriva's placement within the double helix model, it is approximated that the company is placed at the Integral Product Vertical Industry. Spriva is looking into niche competitors, both in terms of a grass-based composite and festival chairs. It is a desire from Spriva to move over to a Modular Product Horizontal Industry over time, due to Spriva's plan of a product family in the future, this is, of course, easier when a technical advantage has been established.



Ill 353 Double helix

5 | Epilouge

The last chapter presents the teams closing conclusion about the project and the product solution. Along with reflection of the entirety of the process, and the solutions.

5.1 | Conclusion

The following master thesis project aimed to create a biodegradable composite Growth™, that would create a potential opportunity of a business, that would work in synergy with the growing new industry of biorefineries. Here it was seen that the Danish music festival would be an ideal starting ground for a product made from Growth™, which resulted in the festival chair Cløver.

This was however not seen as the initial direction of leading into the project. In the early stage of the project, the first direction was into the problems with the fermentation of the current process of biorefineries. Research and findings presented a highly technical or chemical problem, which was at that time indicated to be out of the teams professional expertise.

It was however through dialogues and interviews with Mogens Kjeldal and Ausumgaard, that the team found the issues with a large amount of grass pulp produced, and the lack of usage for it. These dialogues and interviews resulted in the direction of the team creating a composite material.
Via further investigation and interview with Rie Berggren from Nibe Festival, the team saw an opportunity to create a synergy between the tailing material and the context and the drive of festivals.

With the framing of the project defined, the work of developing the material was conducted. Via research of multiple biodegradable products, binding agents, and testing of mechanical properties, the team was led to Growth™, a composite material with mycelium as a binder. Due to the process of developing the material, it can be concluded that Growth™ is not fully matured material and that more development is necessary to fully realize it.

With the development of the material, the team was able to find the final solution, that bridged the festivals with the biorefineries, which is the biodegradable festival chair Cløver, though conceptualization, investigation, and analyses. The utilization of FEA in product development was a key point in the verification that GrowthTM, was capable to be used for a festival chair. This allowed the team via modeling, sketching, and investigation to find a solution that could reach the team's vision, to be the first movers of grass pulp-based biocomposite, by designing a competitive and eco-friendly festival chair for Danish festivals, made from the biocomposite.

5.2 | Reflection

Process

Initial

Looking back on the project we initially looked into the direction of creating a solution solemnly toward the fermentation problem of biorefineries. This however was seen as a highly complex mechanical or chemical issue, that had a low user interaction. This was at the time a bit of a roadblock and knocked us a bit from the direction, and began discussing if they needed to change course. However, we felt that engaging with more people of interest might lead to an opening that the team could work with, which it did via the talk with Mogens Kjelddal.
From here framing of the project began. It was noticed with the inclusion of making the bridge between the biorefineries grass pulp, and festival that the designs process would differ compared to what the team normally had done on previous projects. This was viewed as possible and exciting, but also a bit nerve-wracking.
If the process had followed a more traditional approach of looking into the design needs of the festival chair, it could direct the development of the material more directed, but it could also have not been successful as the material would not be able to live up to the task.
A different thought was if the team had chosen to develop the material and when this was finished, a fitting product could be designed. This direction was however not chosen, as the team saw that choosing a certain product, helped frame the testing. Looking back it would have been wise to have chosen some other products of interest as a backup if the material could not live up to be a festival chair.

Covid-19

Like many others no one expected that a worldwide pandemic would happen, locking down businesses and institutes, like the university. This resulted in a large disruption in how we would normally have worked in close proximity to our designated spaces at the university. During the entire process, we have been working a part on a Skype connection. Looking back we could have chosen to work close to each other, to uphold the normality of work instead of doing so digitally. This would have resulted in even better communication between team members, and work would have proceeded faster. However, we chose not to as one of us was within the risk groups associated with Covid-19. Aalborg University also told students not to meet during the project.
Looking back to previous projects and current, it is visible how we had taken the workshops and equipment available at the university for granted. This aspect was one that was viewed as a disruption, as making models and testing was not possible. This basically resulted in the team making the test equipment for the testing. If the team had access to the test equipment for mechanical properties at the university, the process would undoubtedly have gone faster for testing the material. However, through workarounds, the mechanical properties test equipment was created by ourselves, proving that the requirement of such highly advanced testing equipment is not necessary to create an indication. Not only the test equipment but other solutions as well, such as utilizing 3D cad drawing as a tool of communicating ideas, over video chat.
However, the Covid-19 did not only affect the process and group work but also our mental state. An example is a lack and information gained from the university. The information gained that the exam was to be held digital and the cancellation of the graduation, resulting in a fall in morale for us, due to this being our final semester and our thesis. However, the opposite effect of hearing the exams again was physically again, gave a morale boost.
Looking back the Covid-19 situation has resulted in a grand change in how the process would have resulted in, but it has also given the team insight into how to work in difficult situations, and how to adapt one's work accordingly.

Conceptualization

We saw an issue with the selection of the materials, before testing of the mechanical properties. This was associated with the parameter "Simplicity of Production". Even though we state that the analysis was an estimation, yet it can be seen that this parameter should have been more defined and researched. This is due that it would have had a larger impact on the choice of which material would have been chosen, even though we still see that mycelium and starch adhesive would have proceeded further. An earlier understanding of the production would also have clarified directions for the sketching of the product solution, such as earlier identifying laser cutting. We started the ideation of the chair via 2D sketching, this however resulted in issues with clarifying what the concept should strive toward. This was solved by user propping and defining design criteria, where the team started to ideate in 3D. However, if we had started defining the design criteria, conducting user propping, and looked into the aesthetics of the festival, before initiating the conceptualization, this would have changed how the ideation would occur. Looking back it was the lack of direction for the conceptualization that resulted in the teams frustration when sketching in 2D. This would potentially change the final product solution, as would not have strafed the team away from 2D to 3D sketching so early. This can be discussed if it would result in a better solution, however, it can be noted that defining the direction of the concept earlier and more concrete would have resulted in a more time-efficient process.

Teams learning

Working in the direction of the project and the solution that came about was quite different then what the team had anticipated, as both of us did not envision our thesis product solution being a chair if asked for a year ago. However, with the approach of project and framing of it, we had a drive and curiosity to find a solution, as we were working with framing and process that was somewhat unfamiliar and interesting. The project did present its challenges from a different source, however, it did push us to understand better on what defines a process, and how to overcome obstacles presented in front of one.

Product

Growth™

The material developed by the team presented some challenges when looking back. As the material is based on a growing process, and not one you produce, this presented issues when cultivating the mycelium. This looking back is associated with the lack of control when cultivating living organisms, due to the cultivation of batches. This can be for different reasons, such as the disinfection of the grass was not done correctly, or the mycelium that was used as a starter was not as active. This proves that all parameters of the cultivating of the mycelium are not yet defined and is therefore why more development is needed, not only the mechanical properties but the manufacturing as well. This is, however, something we understood from the start of the project, that a fully matured material would be an endeavor that would not be possible within the timeframe of the project. Also, all the sample that was made were quite thin, and creating a sample with substantial more thickness, would have given the team insight into how the cross-section of the material would be.

Cløver

As the material is not fully matured, we can see that changes to the Cløver are highly possible to some degree. This could be in regard to the thickness of the sheets, however, this is something that would need to be prototyped. Another issue is that we were not able to create a prototype from the material itself, as we did not have access to the necessary machines to make it. This would have given insight that would have been of great assistance to us and helped us understand the entirety of the solution. At the end stages of the project we thought about an issue with the rope, that is it could fray after uses. This is something that would need to be looked further into, as conventional methods like burning or rubber taps would not be possible as these solutions are based on plastic, and so defeat the purpose of a biodegradable festival chair. However, with the identification of the jute rope manufacture contacting them on possible solutions would be the way forward. Another factor to look further into with the solution is assembly of the chair, in regards to the rope, if it might present a complexity too inconvenient for the average users, such as the diameters of the holes being too small, or the flexibility of the rope itself.
A desired test for us was to test the heat deflection of the material. This was due to the amount of heat at the festival created by the sun, but also in terms of the generated heat during fiber lasing. If the heat resistance is low, the material might deform during the process, and this could affect tolerance. This test was planned, but with the issues of the cultivation of some batches, the tests were not conducted.

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60 Ill 180 3d Detailing Round 1: 1A

60 Ill 181 3d Detailing Round 1: 1B

60 Ill 182 3d Detailing Round 1: 1 FEA B

60 Ill 183 3d Detailing Round 1: 1 FEA A

60 Ill 184 3d Detailing Round 2: 1A

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61 Ill 193 Sprout 001 A

61 Ill 194 Sprout 001 B

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62 Ill 197 Laser cut mood board 1

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63 Ill 228 Laser cut 3D concept A
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79 Ill 344 Loading the sheet, before laser procedure.

Video photo snip 0:25 - https://www.youtube.com/watch?v=20zoLXfVmyA&list=PLsgQH2M8p258vepNP3Cxo4PvoKS9RPgfR

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AALBORG UNIVERSITY
DENMARK

Technical Drawings

Aalborg University
June 2020
Industrial
MSc04 ID6

Title page

Project title	Cløver
Theme	Biodegradable festival chair
Report Type	Technical drawings- Master Thesis Industrial Design
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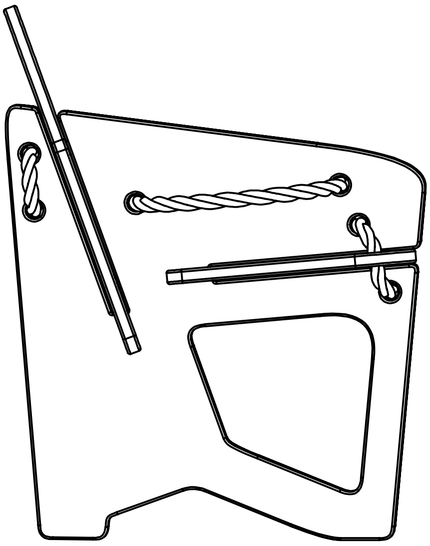
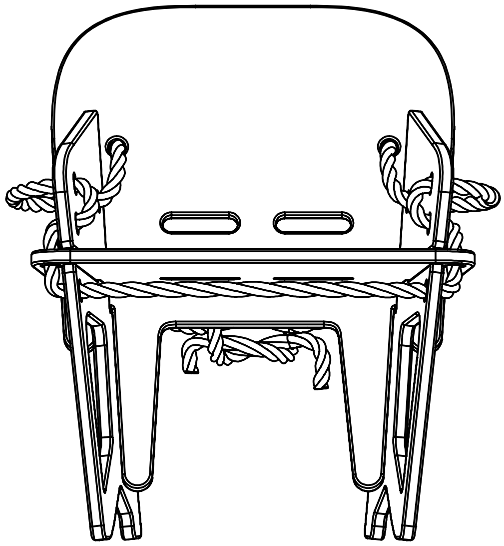
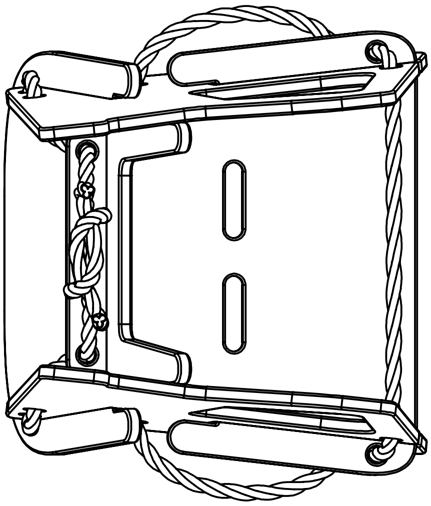
DRAWING LIST

2	*Views*
3	*Perspective*
4	*Side- and front view*
6	*Side*
7	*Backrest*
8	*Seat*
9	*Rope*
10	*Assembly drawing*







CLØVER™

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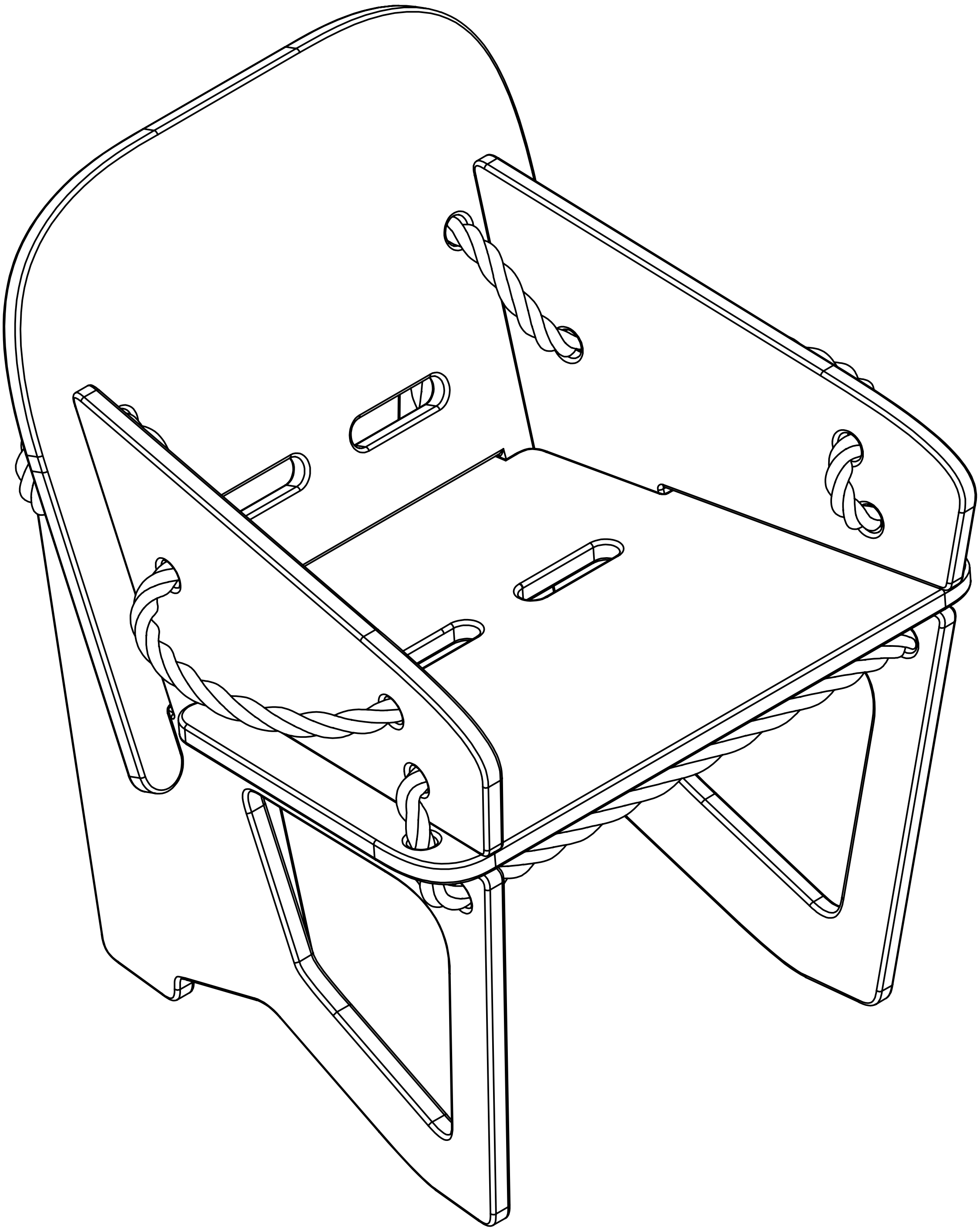
Drawing no.: 01

Team: MSc04 / ID6

Scale: 1:10



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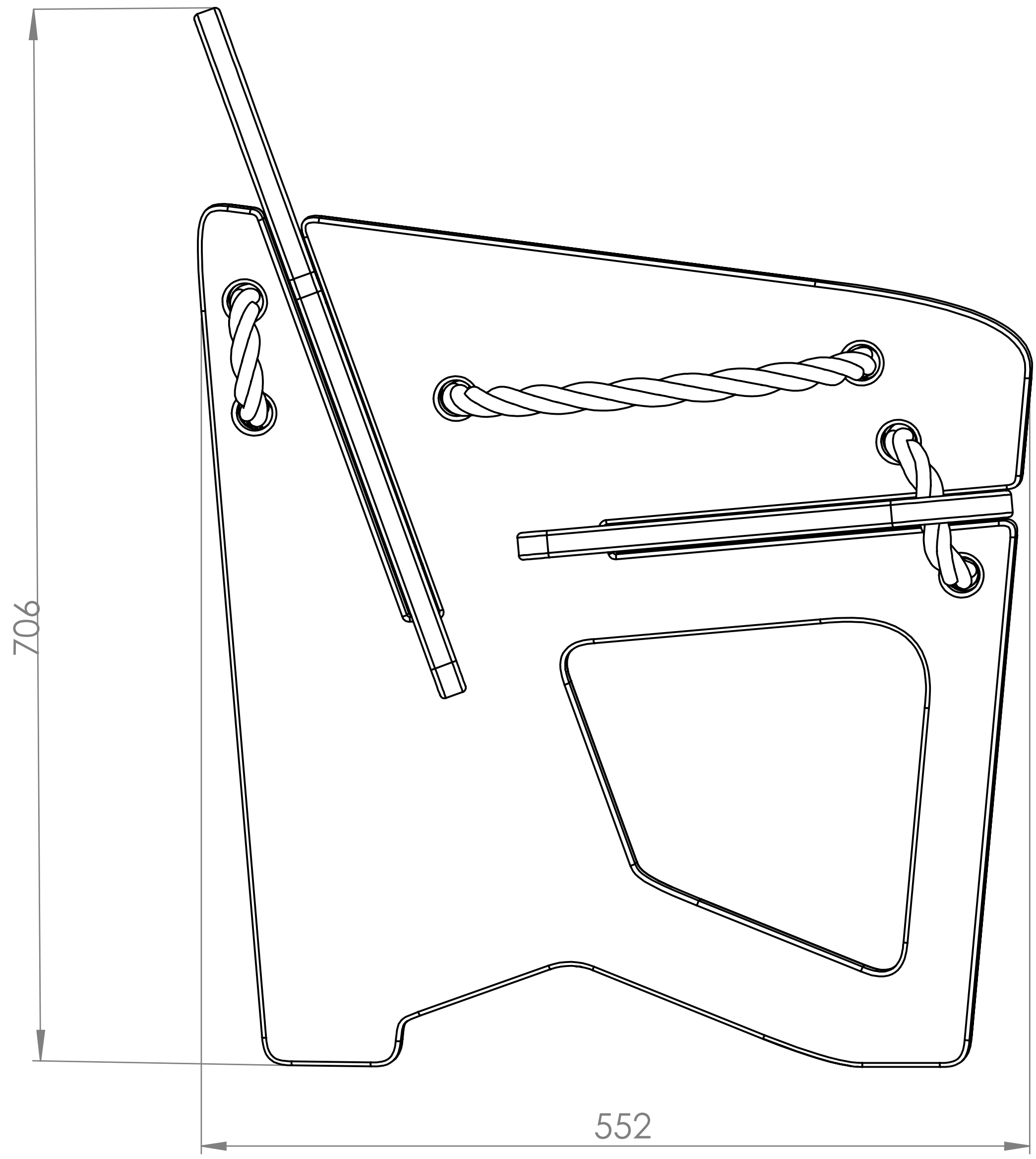
Drawing no.: 02

Team: MSc04 / ID6
Scale: 1:5



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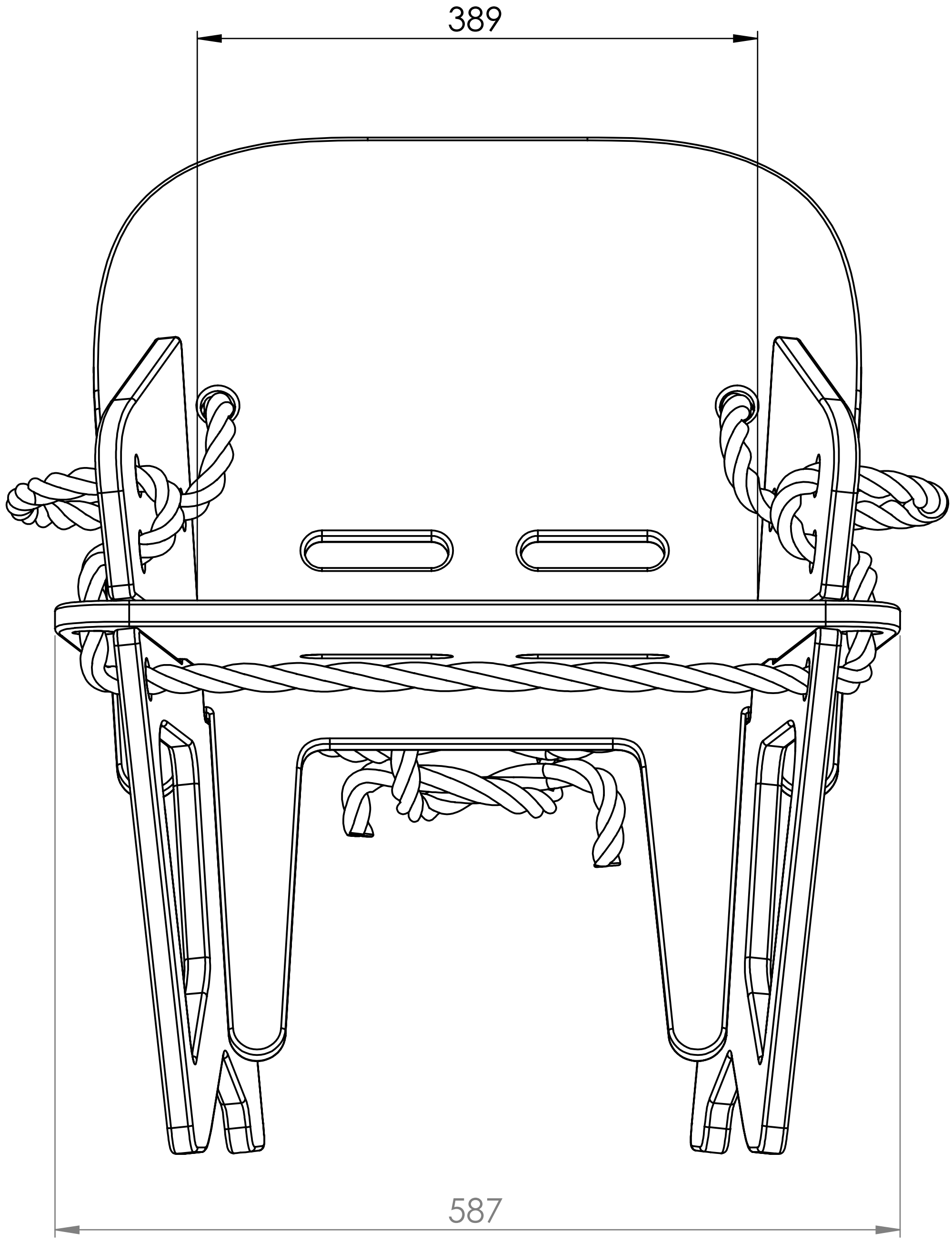
Title: Side view	Drawing no.: 03
Team: MSc04 / ID6	Scale: 1:5



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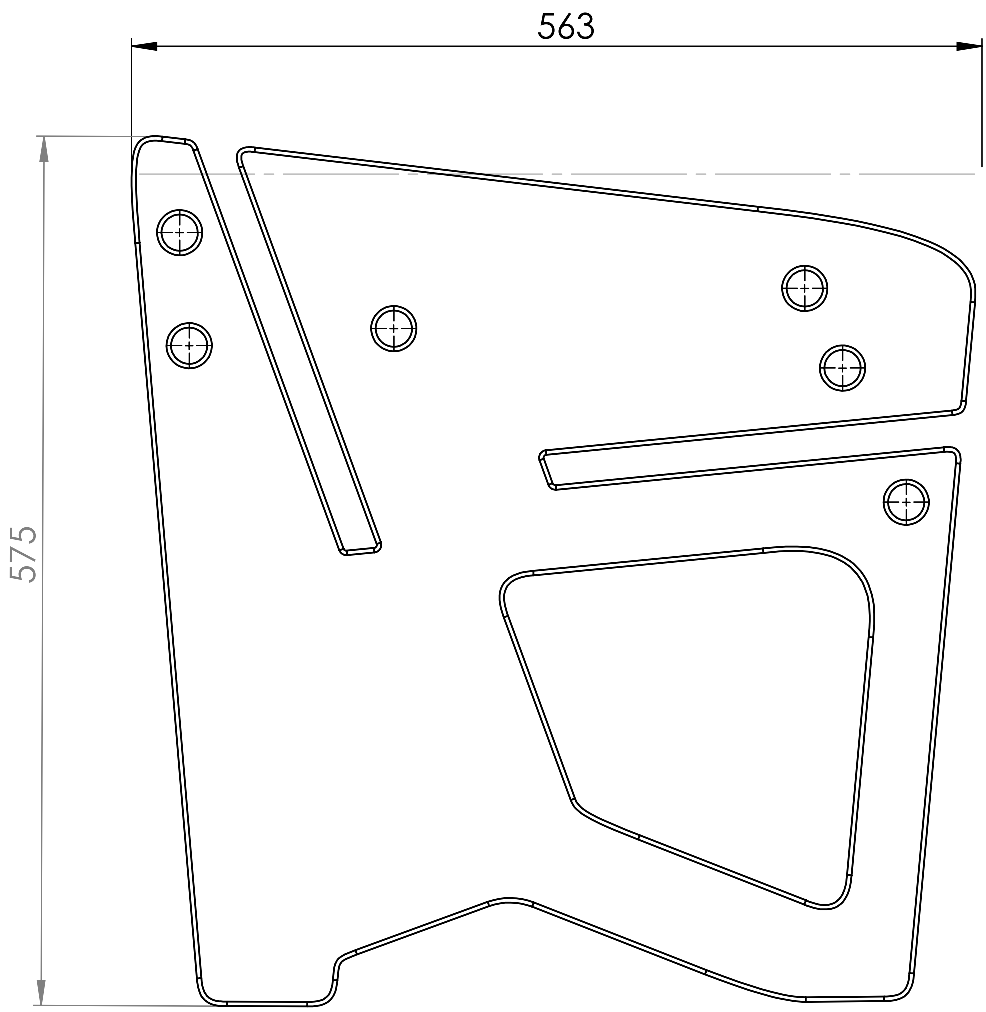
Drawing no.: 04

Team: MSc04 / ID6

Scale: 1:5

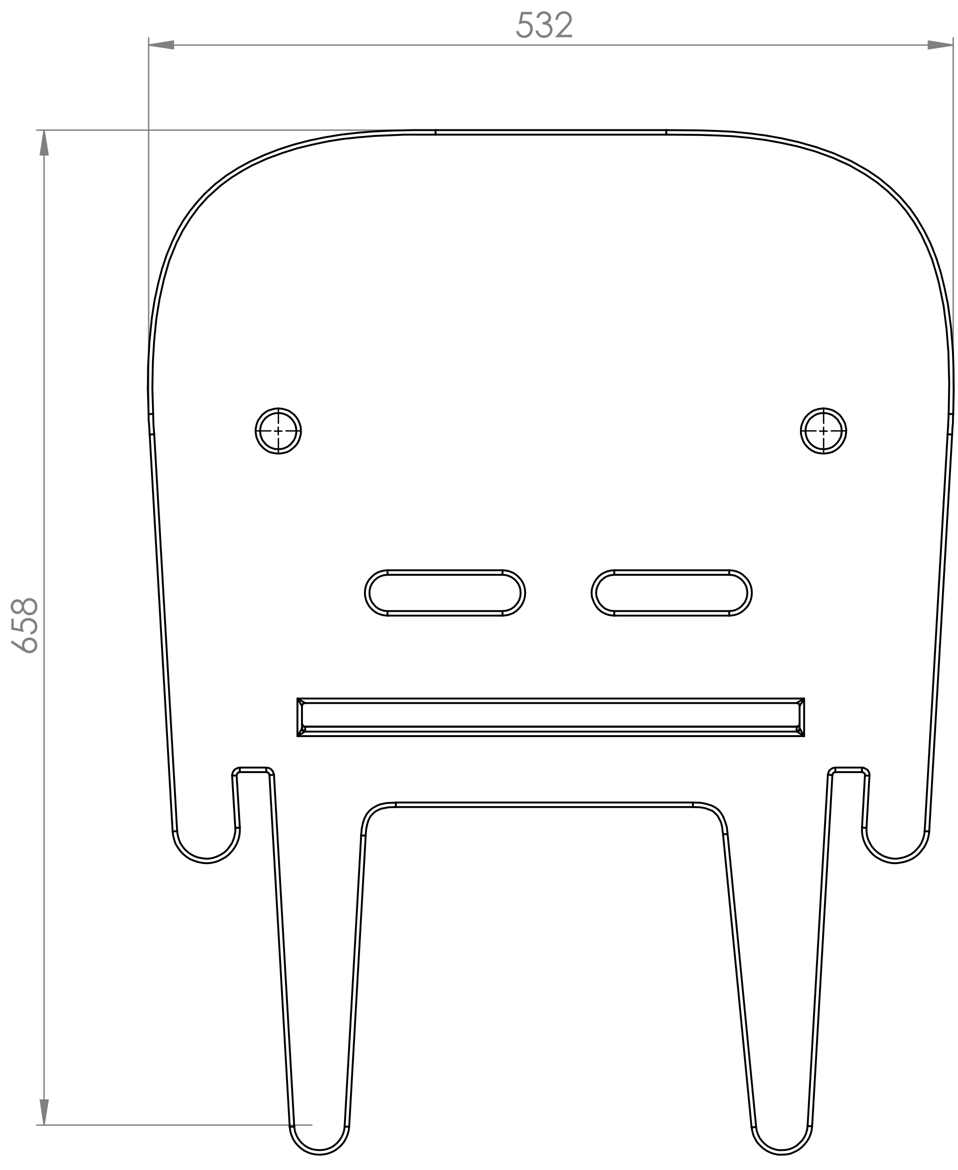


Title: Side

Drawing no.: 05

Team: MSc04 / ID6

Scale: 1:5



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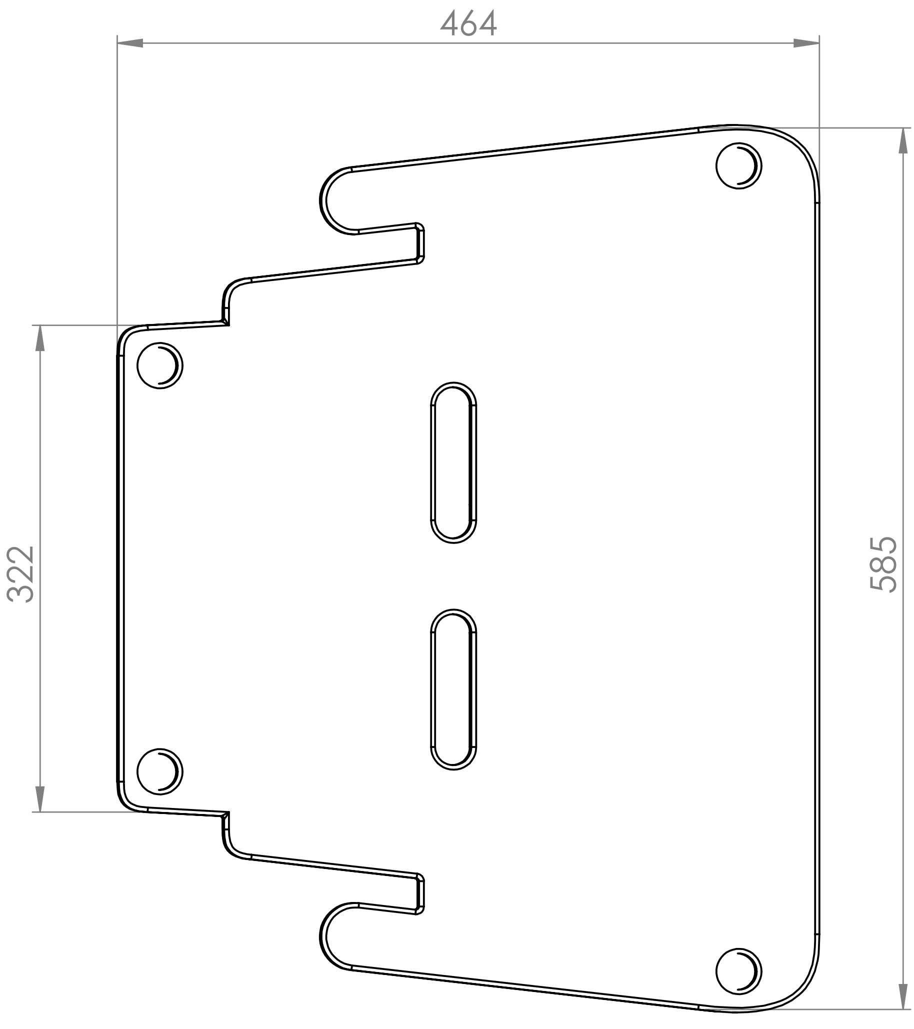
Drawing no.: 06

Team: MSc04 / ID6

Scale: 1:5



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Drawing no.: 07

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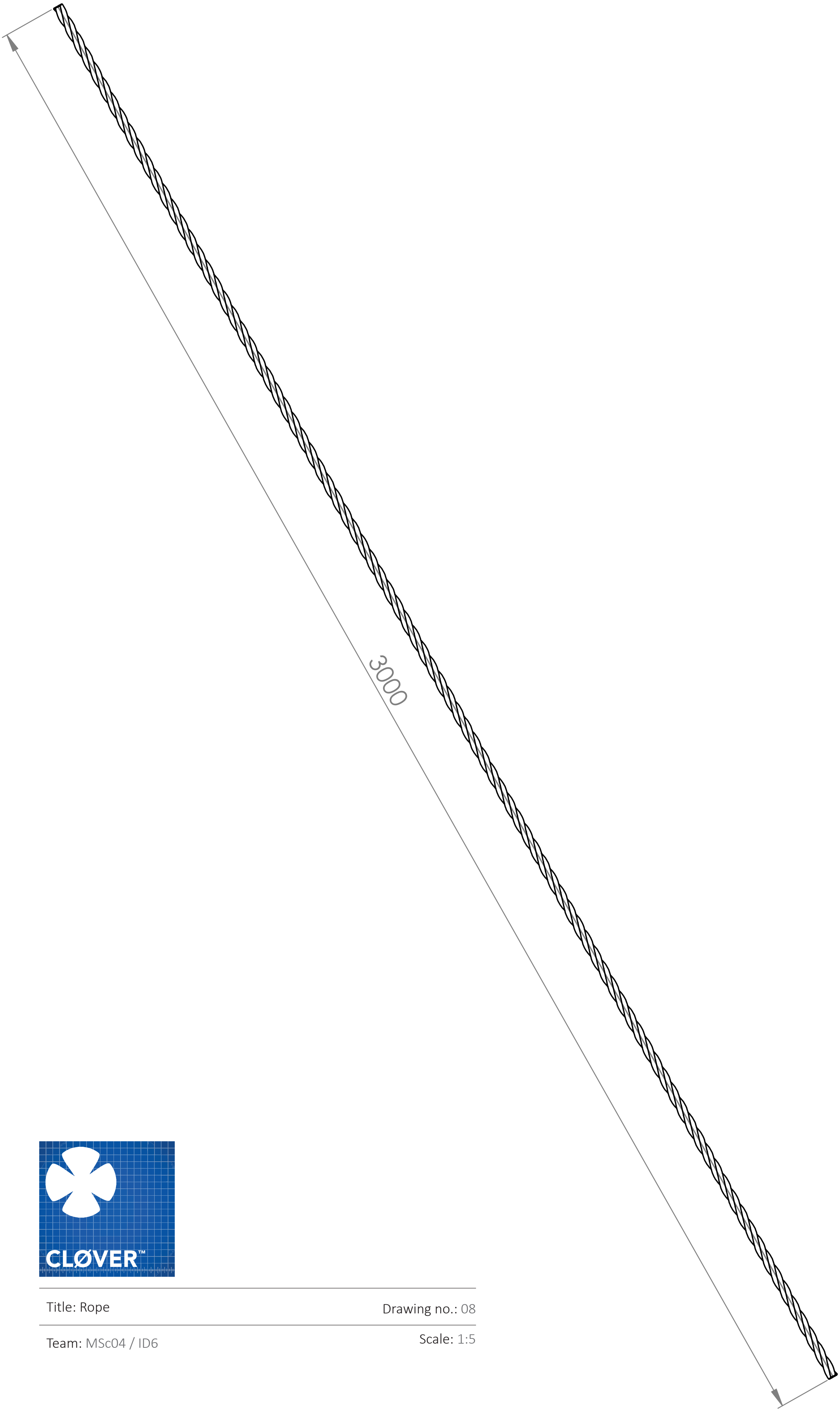
Scale: 1:5



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Drawing no.: 08

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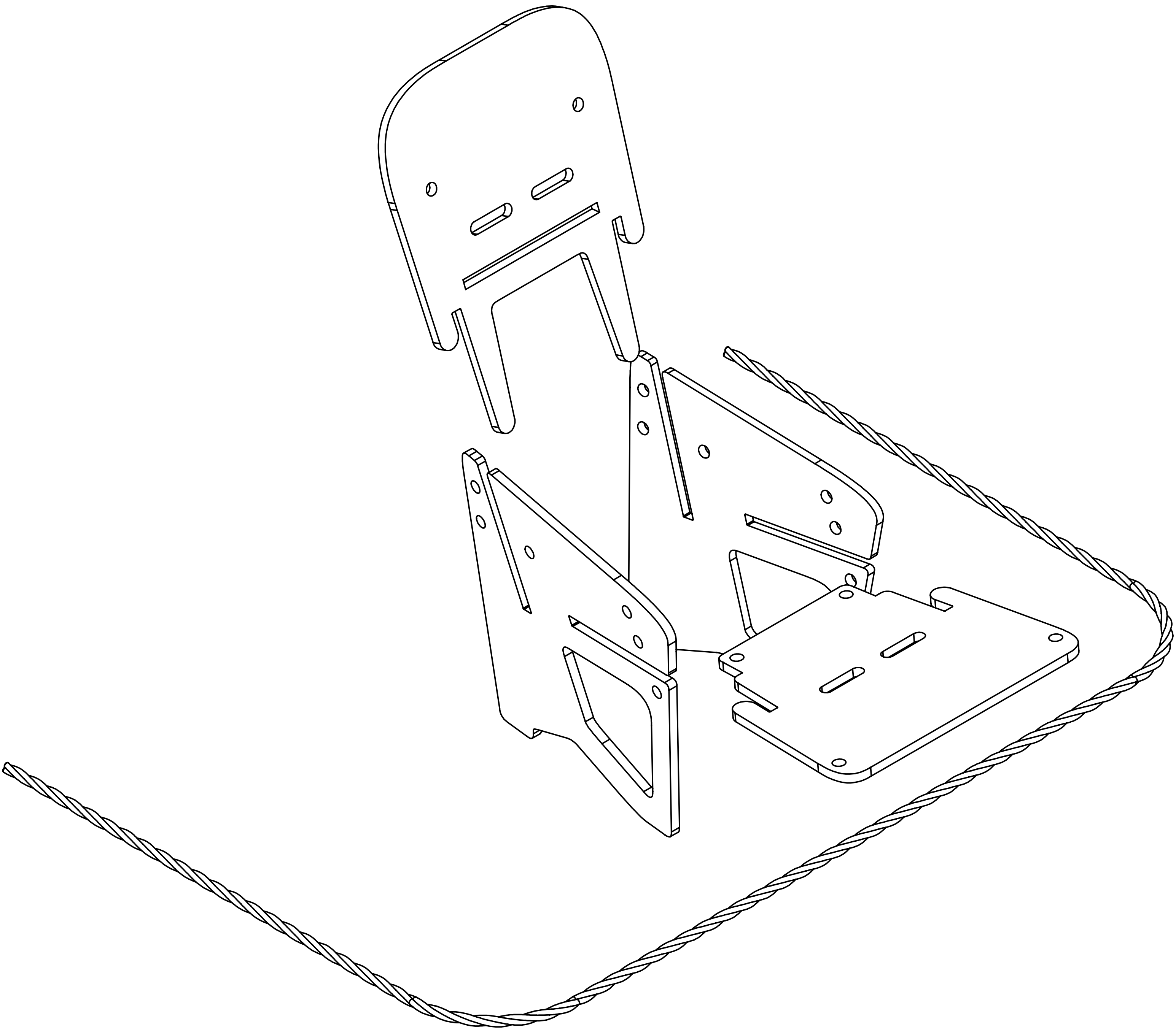
Scale: 1:5



Title: Assembly drawing

Drawing no.: 09

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Scale: 1:5

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