Design and Production Feasibility of Plastic Powder Surfer Snowboards

A study of small-scale realization of novel production methods for powder surfer snowboards

Bachelor's Thesis within the program Product Design Engineering, in collaboration with Moonchild Snowboards and snowboarding legend Johan Olofsson

Samuel Svahn
Axel Ro

DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE

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SAMUEL SVAHN

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SAMUEL. SVAHN, AXEL. RO

Department of Industrial and Materials Science

Division for Design & Human Factors

Chalmers University of Technology

SE-412 96 Gothenburg

Sweden

Telephone + 46 (0)31-772 1000

Cover: Authors' illustration of a user standing on a powder surfing snowboard.

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Samuel Svahn

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Abstract

This project was conducted to explore the feasibility of producing plastic powder surfer snowboards for small scale production. It was initialized due to the product development of a cost-effective powder surfing board by Moonchild Snowboards, in order to lower the entry barrier into the sport.

Analyses were conducted regarding user experience, available production processes, sustainability of plastic products and available materials, as well as analyses synthesizing information from the different areas. Throughout the project, concepts were generated for the different possible constructions of the powder surfing board, which were reduced by selection methods based on sustainability, production implications and user implications. Some of the choices of concepts were left to Moonchild Snowboards.

The final concept was based on the production process of Twin-Sheet Thermoforming of two HDPE sheets to create a thermoplastic shell, which would then be filled by PU foam by the Foaming in Place process. The seam between the upper and lower sheet was placed along the side of the board, without significant implications to user experience. The fastening point for the leash was integrated by creating a hole in the board in post processing and using resin to secure a leash plug commonly used in surfing. CAD-files for production were created using surface modeling in Rhino 8 of the final concept. The structural stability of the final concept could not be verified.

Keywords: snowboarding, powder surfing, production, plastic, small-scale

Contents

1. Introduction

This report describes an academic study conducted at Chalmers University of Technology in connection with a real-world product development project. The project was carried out in collaboration with the company Moonchild Snowboards, which hereafter will be referred to as MCS. The project was based on a predefined shape for a so-called powder surfer snowboard created by Johan Olofsson, living snowboard legend (Methodmag, 2011).
The goal of the project was to realize the product by identifying a suitable production process, construction and material, as well as creating CAD-models for the production. The work was structured such that the academic study examined relevant areas for the project and thereby produced results which the company could use as a basis for decision-making. All major decisions regarding the product were then made by the company.

1.1 License Use and Ownership

In this academic study, several CAD and analysis softwares were used for purposes of gathering information, in which case available programs from Chalmers were used via a student license. However, the production files intended for commercial use were created from scratch in software with a commercial license. None of the files, nor any part of the files, originating from softwares using Chalmers' student licenses have been used for commercial purposes, but have instead only been used to provide insights for the academic study.

All academic research and accompanying results are owned by the authors of the report, while the rights to the product in development are owned by MCS. Furthermore, the rights to use the CAD-files for production are granted to MCS.

1.2 Background

Since snowboarding began to take shape in the late 1960s, the design of the sport's equipment has undergone significant changes. Many different models have been tested in the course of time, leading to the current established standard for what a snowboard should look like, complete with bindings that mechanically connect the rider to the board (Vermont Ski and Snowboard Museum, n.d.). In relatively recent years however, a new trend has slowly begun to emerge called "Powder Surfing," which draws inspiration from the earliest form of snowboarding, the "Snurfer," in that the board does not include bindings. Instead, the rider is connected to the board solely through the friction from two traction pads. As the name suggests, the product is only intended for use in the off-piste (Moonchild Skunkworx, n.d.). In order to prevent a runaway board in the case of a fall, a leash is usually fastened between the user and the board (Burton, n.d.). Today, there are only a few brands that produce Powder Surfer boards, which hereafter will be referred to as PS-boards, either as highly exclusive and expensive products or as simple plywood boards without significant product development. Thus, there might be a potential gap in the market for PS-boards that have an attractive design and good riding characteristics, yet are not priced or marketed as exclusive products.

Image 1. Mellow off-piste in Chamonix, suitable Powder Surfing terrain

With this opportunity, MCS has launched a product development project partially based on a previous product, which was produced in collaboration with Johan Olofsson. To create a new less exclusive product with a similar shape to the previous model, the vision for the new product was defined as a PS-board produced in a small batch size of approximately 100 units per year, made entirely or mostly out of polymers. The general choice of material contrasts existing products on the market, which primarily consist of sandwich composite constructions containing mostly wood, fiberglass and plastics.

1.3 Purpose

The purpose of this report is to explore how a plastic PS-board can be designed and produced in small batches, as well as which specific polymers it can be made from. This will be done by analyzing a pre-designed shape from MCS and by developing a simple production solution based on constraints both directly given by MCS and as identified throughout the project. The shape of the board is intended to be adapted for production through the creation of CAD-models tailored to MCS's decisions of material and process. Overall, the work aims both to academically investigate how a PS-board made of polymers could be created and to provide MCS with the basis for conducting small-scale production of the final concept.

The project aims to analyze the mechanical properties, available materials, possible constructions and user implications stemming from certain production processes, as well as conducting a sustainability study to examine the environmental impacts of the choices regarding production and materials.

1.4 Research Questions

Below are the research questions which the report aims to answer in order to pursue its purpose:

- How does the properties of a PS-board's shape affect the user experience?
- What approaches can be taken in order to combine production processes, constructions and material groups of a PS-board to optimize for environmental sustainability?
- Which production processes may be suitable for small-scale production in terms of the produced shape, material groups and cost?
- What types of constructions can be created using the suitable production processes and material groups to meet requirements for form and strength?
- Which specific materials within each material group can offer the desired properties and are compatible with suitable production processes and constructions?
- What shape modifications may be required to adapt the established design to suitable production process and how can these be optimized for positive impact on the user experience?
- What are the requirements for CAD-files using in production? How can a CAD-file be modeled for these requirements?

1.5 Limitations

The following limitations were set to restrict the scope of the project in order to adhere to available time and resources:

- Since the academic study was based on a product development project with a predetermined shape, no alternative designs which might satisfy user requirements in a different way could be explored.
- No prototypes were built during the process due to time constraints and lack of access to both production processes and snow.
- The effects of production choices on aesthetics and their subsequent impact on user experience were not investigated due to time constraints.
- No leash system was investigated beyond the integration of the attachment point for the leash, due to time constraints.
- No fiber reinforcements consisting of experimental natural fibers were considered due to time constraints.
- Specific additives for plastics such as UV-stabilizers have not been considered, due to the amount of polymer-additive combinations necessary to research exceeding the time frame of the project.

2. Methods and Execution

A number of methods were used to develop the decision-making bases for the project. These have been divided into three phases which reflect the project's iterations and the company's decision-making process. The information gathered in each phase was compiled and presented to MCS in order for the company to make decisions required for the subsequent phase. The purpose of this structure was to allow the project to be continually redefined and narrowed as more detailed analyses were conducted, both to limit the scope and to increase applicability of the project to companies with small-scale production.

2.1 Phase 1

The purpose of the initial phase was to explore potential strategies for how production and sustainability could be applied in the development of the product. The goal of the phase was to provide MCS with a basis for decision-making containing several different Sustainability Strategies, with sufficient detail for MCS to choose between. To achieve this, studies of the shape and requirements for a plastic PS-board were conducted. In addition to this, analyses were conducted regarding a plastic PS-board's potential mechanical properties, production, and sustainability. Concepts were also generated for how a construction of the board could be achieved, the most promising of which were sorted to the Sustainability Strategies they were compatible with.

2.1.1 Shape and Design Interpretation

A drawing was received from MCS and Olofsson regarding the products' design which was used as a basis for exploratory surface models of the board created in CATIA V5. The board's design was then refined and adjusted iteratively based on feedback from MCS and Olofsson, including clarifying images of sketches, self-made boards, and previously manufactured products (see Appendix A). The main purpose of the CAD-model was to ensure that there were no misunderstandings regarding the details of the shape. During modeling, the terminology used for referencing different parts of the board was also defined.

In order to gather information regarding how the established design affected user experience, an introductory interview was conducted with Olofsson (see Appendix B1), based on his experience working on a previous model with MCS. Olofsson had also been involved in the design of PS-boards independently for several years, granting him extended knowledge on the subject. The information in the interview was compiled into a list of insights.

2.1.2 User Study

In order to develop a product that will meet the needs of its users, knowledge of their experience is required from real users (Bligård, 2015). To acquire this knowledge, a second interview was arranged with Olofsson. The interview was prepared using a set of qualitative questions (see Appendix B2) regarding the user experience and the characteristics that distinguish powder surfing from conventional snowboarding.

Information regarding user experience was also sought from other users, preferably without a background in professional snowboarding, in order to include a broader range of perspectives. A survey was created with the same interview questions used in the interview with Olofsson (see Appendix B2), and sent out on social media platforms, including the snowsports forum hosted on the website Freeride.se (Svahn, 2026). The users participating in the surveys were also given the option to further elaborate on the answers. All gathered information from the interview with Olofsson and the online survey was then compiled into a text describing the user experience of powder surfing.

The interview with Olofsson was conducted as a structured interview, therefore only involving pre-determined questions, which made it more similar to the surveys, since surveys are considered a version of structured interviews (Bligård, 2015). The reason for this was to avoid discrepancies between the data from Olofsson and the other participants.

2.1.3 Analysis of Structural Requirements

In order to identify measurable structural requirements of a PS-board, MCS and Olofsson were asked to describe the highest load cases which a board should withstand, as detailed as possible. An early CAD-model roughly interpreted from the Shape and Design Interpretation was then used to simulate the described sequence of events. Simulations were performed using the Finite Element Analysis (FEA) which is a type of computer simulation that analyses how stresses arise in a component, given a certain load (Ansys, n.d.).

2.1.4 Sustainability Investigation

To establish a sufficient foundation for developing a sustainable product, expertise was sought from various recycling companies and research institutes regarding the circular use and recycling of plastics. Once contact was established with some experts, interviews were conducted based on prepared open-ended questions (see Appendix B3), but were also expanded with follow-up questions as needed. Thus, the interviews were semi-structured, which is preferable when qualitative data is sought (Bligård, 2015). The questions focused on the opportunities and limitations in plastic recycling, as well as how designers can use plastics in products as circularly as possible. All interview responses were compiled into lists of insights, which was reviewed by the experts and adjusted in order to make sure that no information was misinterpreted. The insights were then developed into Sustainability Strategies which could be applied in the design process of the product.

2.1.5 Requirements Analysis

In order to screen construction and material options in later stages, as well as evaluating some user implications of production choices, a List of Requirements was created, which is a type of documentation of the requirements of a product, structured to allow for verification at a later stage (Bligård, 2015). To produce the list, information was compiled from correspondence with both MCS and Olofsson, as well previous methods.

2.1.6 Initial Production Analysis

In order to find suitable production processes, a screening was conducted with the program Granta EduPack (see Appendix C1), which is a program and database used to choose production processes, among other things (Ansys, n.d.). The screening focused on finding processes satisfying the identified requirements for batch size and production cost. One screening was done for each of the two main plastic groups; thermoplastics and thermosets.

For supplementary information on the suitable processes found in the screening, expertise in plastic production and construction was sought. Among others, expertise was sought from potential factories for production, as well as lecturers and researchers at Chalmers. Interviews were conducted with the available experts, based on prepared questions (see Appendix B4). Follow-up questions were asked as needed, following the definition of a semi-structured interview, which is preferable when seeking qualitative data (Bligård, 2015). Insights from the interviews were reviewed by the experts for adjustment and were compiled in a list of insights.

2.1.7 Concept Generation

To create Concepts for how constructions produced by the suitable production processes could satisfy the Sustainability Strategies, the PS-board's shape was divided into subfunctions which were achieved by different solutions. These were then organized in a Morphological Matrix, which is a method used for combining such subfunctions and solutions into Concepts (Bligård, 2015). The solutions were based on information from the Initial Production Analysis and were combined methodically to create a list containing every Concept which was deemed feasible by the information from the Initial Production Analysis. The list of Concepts was also made to include the number of process steps required for each Concept, in order to get a rough estimate of the production complexity. It also included the required material groups for each Concept, for later analysis of sustainability.

2.1.8 Sustainability Based Concept Screening

In order to evaluate how the different Sustainability Strategies would affect the construction of a PS-board, information from the previous methods was synthesized to analyze which Concepts would be suitable for the different strategies. To initiate the screening process, every Concept with 5 or more process steps was considered unsuitable, due to high production complexity likely leading to increased cost. The most suitable Concepts for each Sustainability Strategy were then chosen for further consideration in the project. To assess the Concepts, they were compared within groups which shared the same solution to the *Create Shell* subfunction, and assessed by their level of compliance with the relevant Sustainability Strategy. They were also assessed by how well they were expected to fulfill the List of Requirements as well as their production feasibility, according to the list of insights for production.

The Sustainability Strategies along with their suitable Concepts then formed the basis for decision-making regarding the selection of a strategy, and were presented to MCS before the next phase was initiated.

2.2 Phase 2

The second phase was carried out with the goal of producing a decision-making basis for MCS to choose between production processes, in accordance with the selected Sustainability Strategies. In order to achieve this, pros and cons of each production process were identified. Some previously generated Concepts were also selected and refined to represent their respective production process and analyzed based on processing properties. In order to further understand the potential outcome from the different production processes, an analysis of user implications was also conducted.

2.2.1 Material Screening

The first method used for identifying pros and cons of the suitable production processes was a screening for suitable materials for each process, based on the List of Requirements. The screening process was conducted in the software Granta EduPack (see Appendix C2), which includes data and tools for material selection (Ansys, n.d.).

2.2.2 Literature Review

In order to gather more information regarding the production processes, a Literature Review was conducted, which is a method commonly used for gathering data on the available knowledge in a given field (Bligård 2015). The review was conducted by searching for available information regarding the various production processes, and then searching for information on the suitable materials for each process. In the case that any new suitable methods or materials were identified, they were researched further in turn. For the information search, both easily accessible search engines such as Google Search and more specialized search tools such as Google Scholar were used. The search primarily focused on finding studies or review articles, but in areas where these could not be found, industry sources from relevant fields were used.

2.2.3 Concept Selection and Assessment

In order to further analyze the implications of each production process, one Concept was selected to represent each process based on findings from the Literature Review. Only Concepts relevant to the chosen Sustainability Strategies were considered for this selection.

The Selected Concepts represented the final iteration of construction for each production process and included a prescribed set of material types. Still, specific materials were not chosen for the concepts, only material groups. After the selection, a study was conducted in Granta EduPack using the EcoAudit tool (see Appendix C3), which is a Life Cycle Inventory tool for quickly assessing the environmental impact of materials, production, transportation, use and End of Life (EOL) of a product (Ansys, n.d.). The tool was used in order to produce an estimate of the environmental impact in carbon dioxide equivalents (CO_2e) of the materials and production processes in the Selected Concepts.

2.2.4 Analysis of User Implications

An Analysis of User Implications was conducted to determine exactly how the Selected Concepts, and in turn production processes, would impact the desirable properties of a PS-board, which were established in the User Study and the Shape and Design Interpretation. The assessment of the implications was based on information from the Material Screening, Literature Review, and correspondence with MCS.

The findings from the analysis and the Selected Concepts formed the basis for decision-making regarding the selection of a final production process, final material and thus a Final Concept. It was presented to MCS before the initiation of the next phase.

2.3 Phase 3

The final phase was carried out with the main goal of providing a basis for decision-making regarding the remaining adjustments in production of the Final Concept. Due to this being the final phase MCS was more heavily involved and made decisions, regarding the aforementioned decision-making basis, continuously. The chosen production process was also further investigated in order to identify any remaining potential risks and ensure producability of the Final Concept. During this phase, the CAD-model for production was also created and measured to determine the weight of the Final Concept.

2.3.1 Final Concept Refinement

The goal of the refinement was to ensure that the chosen materials and construction would align with the requirements of the chosen production process. The refinement was conducted by reviewing literature regarding how the necessary steps within the chosen production process could be optimized in order to best satisfy the List of Requirements and positively impact user experience. In addition to the necessary production steps, compatible solutions for attaching the leash to the PS-board for the Final Concept were created to be assessed by MCS.

2.3.2 Surface Modeling for Production

The final stage of the project was to create files for production in the chosen CAD-software. Correspondence was once more sought with potential factories in order to ensure the tolerances within the production file met the requirements for production. The goal for the final model was to adhere to the Shape and Design Interpretation and be suitable for the production process. The model also needed sufficient surface quality without significant bumps or sharp edges, as well as to not include any internal gaps. The quality and continuity of surfaces was controlled with tools within the program. Thereafter, volumes and weights could be calculated along with final renderings of the model granted to MCS.

3. Results

The results obtained through the execution of the project have been divided into three phases to match the structure of the Methods and Execution chapter. Most methods provided useful results, culminating in a refined Final Concept.

3.1 Phase 1

Four Sustainability Strategies were developed; the Public Recycling Strategy, Internal Collection Strategy, Recycled Input strategy and Longevity Strategy. The most promising Concepts regarding the construction of the PS-board were chosen for each of the strategies, highlighting the possible options from production within each strategy. The PS-board's shape was also analyzed and interpreted in the form of an initial CAD-model, and the user experience of powder surfing was described. A List of Requirements was created based on the findings in this phase. After the phase, the Sustainability Strategies and production implications were presented to MCS as a basis for decision making.

3.1.1 Shape and Design Interpretation

Sketch and image material received from MCS and Olofsson was gathered and used to interpret the design with an early CAD-model. While receiving iterative feedback with Olofsson and MCS, terminology for the different parts of the PS-board was also established.

The first model created was a very rough solid form of the design, creating a bounding geometry of the board (see Image 2). The model was based on a dimensioned drawing (see Appendix A) and was intended to be used as a size guide for more detailed surfaces. The side view profile in the drawing depicted the board bending upwards in the front and the back, which constitutes a, so called, *Rocker.* The thickness of the model was chosen arbitrarily and varied between different iterations of board design, as the total thickness was yet not defined.

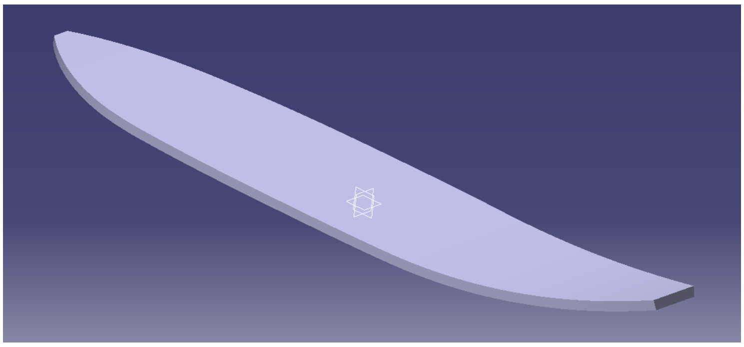


Image 2. Early CAD-model of the PS-board, with the front of the board to the right

The first detailed surface to be created was the *Spoon Nose*, defined as a convex shape on the underside of the front of the board. This shape was created by modeling the bottom surface of the PS-board, with a higher upward bend in the curves at the edges than in the center of the board (see Image 3).

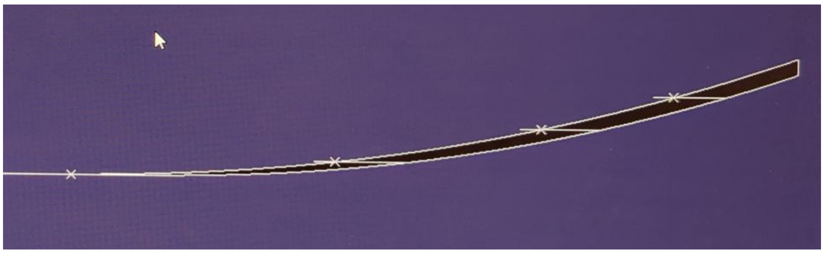


Image 3. Bottom surface of the model, showing a height difference between curves in the Nose

The next detailed surface to be created was the back end of the board, which was designed to have a, so called, *Pin Tail*. Which meant that the right and left sides of the board narrowed towards a single point at the furthest backmost position of the board. (see Image 4). The Tail and Spoon Nose were created based on sketch material as well as images of a self-made physical board from Olofsson (see Appendix A). The Tail also included a custom *Reverse Spoon*, which was defined as two wide smoothened grooves through the underside of the board at the rear. The Reverse Spoon needed to smoothly transition from the flat bottom surface in the middle of the board, into concave surfaces towards the Tail. (see Image 5). The concave surfaces also needed to cut through the sides and the Pin Tail shape at the back (see Image 4).

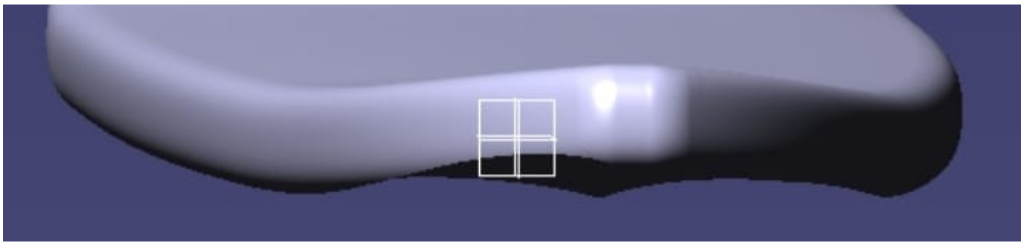


Image 4. The back end of the board, showing the Pin Tail and Reverse Spoon

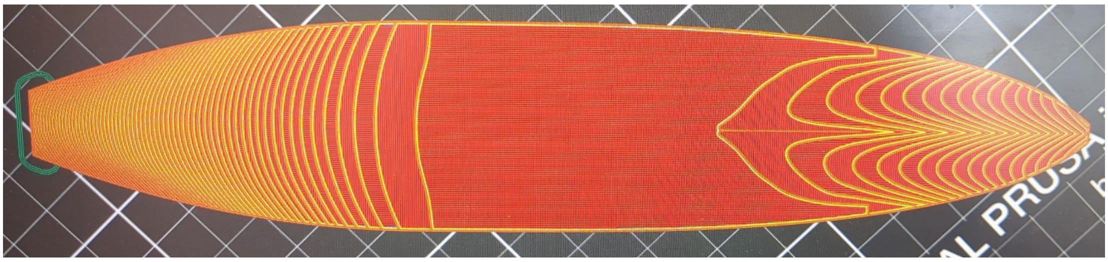


Image 5. CATIA model visualized in PrusaSlicer, showing the entire bottom surface of the board, including the Spoon Nose and Reverse Spoon

The top surface also had a contour, which was specified in sketches (see Appendix A). To achieve the correct geometry, the top surface needed to be drawn upward into a convex arch (see Image 6).

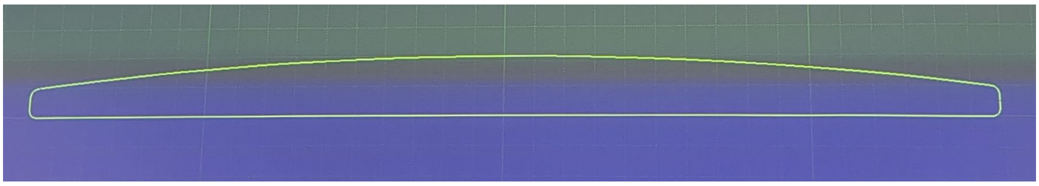


Image 6. Profile section view of the boards top, bottom and side surfaces in the center of the board

The designated area for the user to stand on, the so-called *Traction Pads*, took the form of truncated pyramids placed along the top surface in a certain pattern (see Appendix A). Some pyramids along the edge were meant to be connected in rows. The frontmost rows at the middle of the board angled slightly toward the rear, whereas the rows toward the rear changed their angle progressively (see Image 7).

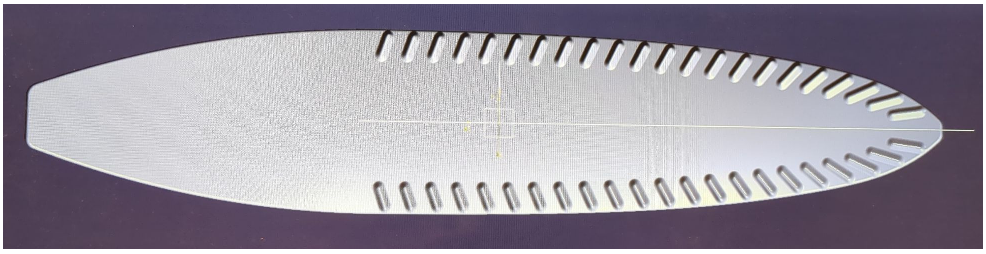


Image 7. Top view of the board, showing the placement for outer rows of pyramids

Thereafter, the internal pyramids required an organic arrangement between the outer rows. The tops of all pyramids were aligned to the same horizontal plane, which carried the implication that the height of the pyramids over the top surface would change due to the curve of the top surface (see Image 8).

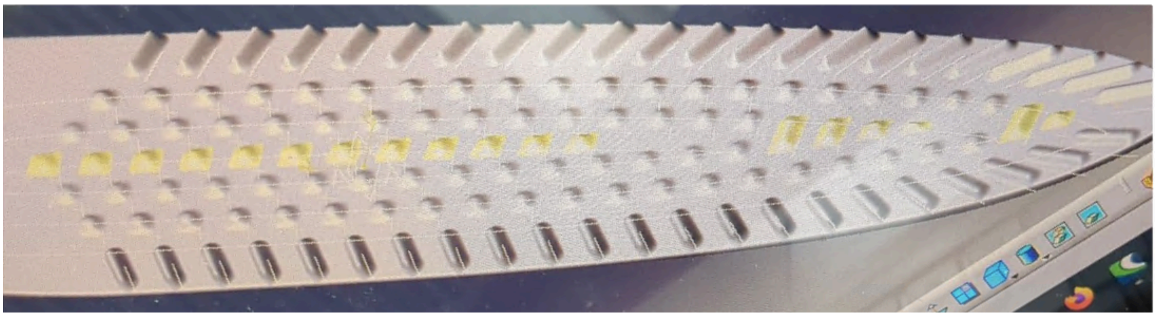


Image 8. Top view of the board, showing the full set of pyramids

The surfaces connecting the top and bottom surface along the right and left side of the board were called *Rails*. Their intended design allowed for a compromise between cutting through the snow and surfing on top of it, requiring a complex interaction between the top and bottom surface. Through correspondence with MCS and Olofsson the profile was defined (see Image 9), however it proved challenging to replicate in CATIA and were left to be further implemented at a later stage of the project. Except for the profile of the Rails, MCS and Olofsson agreed that the final CATIA model described the intended shape in a sufficient and satisfactory way (see Image 10-12).

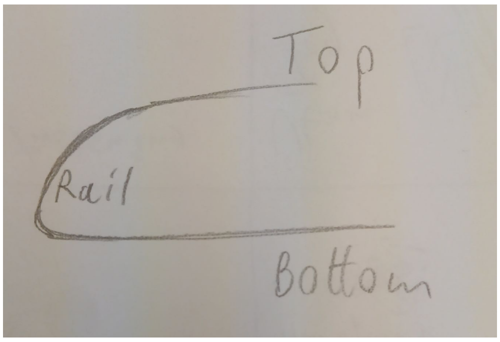


Image 9. Sketch of rail profile

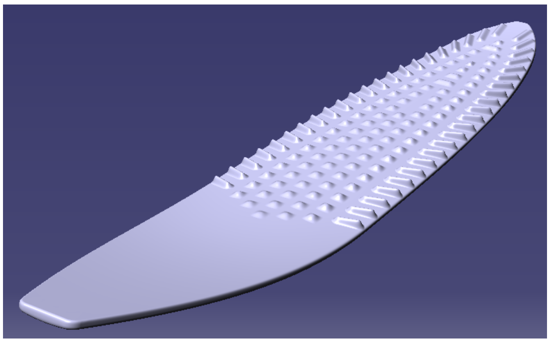


Image 10. Perspective view of the final model

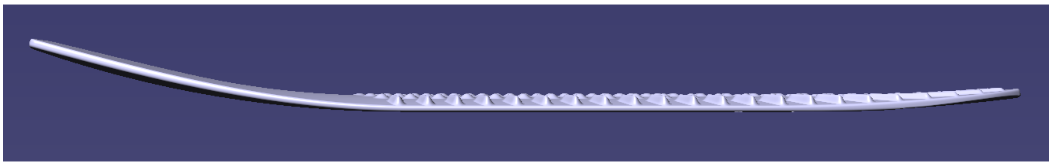


Image 11. Side view of the final model

Image 12. Lower perspective view of the final model

The information gathered in the interview with Olofsson resulted in a list of insights, regarding how the design of different parts of the PS-board affected the user experience (see Appendix D1).

3.1.2 User Study

The information collected in the second interview with Johan Olofsson was combined with the answers provided from five survey participants and subsequently summarized in the following descriptions of user experience.

The experience of riding a PS-board was described as a looser form of snowboarding with a greater focus on balance, gliding and continuous movement between turns. The focus of the discipline was described as lying in the interaction between the rider, the board and the snow; "you have to ride the board more according to how it wants to be ridden," (our translation)

Olofsson explains. Using Traction Pads instead of bindings was described as requiring a more balance-based riding style, similar to surfing on water. With regular snowboarding, on the other hand, the bindings allow the board to be forced into different positions, enabling more extreme turns and maneuvers. The feet not being locked in whilst powder surfing was described as allowing for greater variation in foot positioning, enabling the rider to adjust their stance for different maneuvers, situations, and styles.

Another difference between powder surfing and regular snowboarding was the places where it is practiced. In contrast to snowboarding practiced at ski resorts or other places with large mountains, powder surfing was described as being more forgiving with location and even comparatively engaging in smaller hills, "...you can easily take it to the hill behind your house or any other place without needing to travel to a resort" (our translation) one survey participant claimed.

Olofsson and the survey participants expressed preferences to certain board attributes. One user expressed a dislike for thinner, narrower boards due to an experienced increase in difficulty of riding. Olofsson and several survey participants deemphasized the role of flexure in riding, saying they preferred a stiffer board. Another aspect users had preferences for were the Traction Pads. One expressed a dislike for concave pads whilst preferring strictly flat ones instead. Olofsson and two other survey participants emphasized the importance of sufficient coverage and grip of the Traction Pads, allowing for large enough adjustments in foot placement to achieve different stances. Several users described a better leash system as an area of improvement. An aspect users had differing opinions of was placing pressure along the rail of the board during turning. Most users wrote that placing pressure along the rail was important, while Olofsson advocated for a style of riding that deemphasized placing pressure on the rails when not needed. He described preferring to skim on top of and surf across the snow rather than cut into it.

Several users had described uncomfortable experiences when falling off the board, either through simply landing on the snow in a rough manner, or through impacts with the board during the fall. A scenario which was described as a dangerous possibility was that a user could fall and land downhill of the board, subsequently risking getting hit by it.

3.2.3 Analysis of Structural Requirements

Two load cases were identified from MCS and Olofsson. The first one would occur if a user fell off the PS-board in such a situation where the board would keep traveling at high speed, hitting a solid object in a frontal collision such as a tree or a rock at 30 km/h. This scenario would require the board to strike the solid object before it could be slowed down by the leash. The second load case would occur in the case where a user of 100 kg would travel down a slope which would sharply transition from a steep incline of 35 degrees, to a horizontal plane.

The value of stresses in all simulations were deemed to be inconclusive as a result of problems with meshing, or other errors in the simulation setup. This was due to the high numerical values and extremely localized stresses, which is a common problem when creating improper meshes in the setup (Shumak, 2025). Therefore, no numerical results from the simulations were used further in the project.

3.1.4 Sustainability Investigation

Contact was successfully established with some of the sought-after expertise, which resulted in three interviews. The first interview was conducted with Linnea Granström, who is a Climate and Environmental Strategist at Svensk Plaståtervinning. The second interview was conducted with Magdalena Juntikka, who is a senior researcher at RISE in the field of polymer composites, with particular expertise in areas such as sustainability and the circular economy. The third interview was conducted with Rickard Jansson, a Development Engineer at Svensk Plaståtervinning. All information gathered in the interviews was compiled into respective lists of insights (see Appendix D2-D4).

From apparent themes in the list of insights, four Sustainability Strategies were identified with the purpose of guiding the design process to ensure some level of sustainability of the finished product. In some cases, these strategies could also be combined or pursued simultaneously in the design process.

3.1.4.1 Public Recycling Strategy

The aim of this strategy was to produce a product which could be handed to public recycling centers by the user and processed in the correct ways to be part of new plastic feedstock. This would create the possibility for the plastic in the product to avoid incineration or landfill at

EOL and be put into new products by MCS or other companies. However, letting the plastic in the product be combined with all other disposed plastics during public recycling would reduce the quality of the produced feedstock, most likely causing it to be downcycled into a lower value product in its next lifecycle. There is also the substantial risk that the customer would not hand the product to a public recycling center, or that the center would send it to incineration regardless. This strategy would entail that the PS-board would only be constructed with a single type of polymer, or that it could be manually disassembled by the user into single-polymer components before being handed to the recycling center. The use of foams in the product would oppose this strategy due to problems with density identification methods. The strategy would imply a low amount of responsibility and investment from MCS as the responsibility of recycling could be outsourced indirectly through public means.

3.1.4.2 Internal Collection Strategy

This strategy aimed to produce a product which could be recollected from users by MCS or a third-party company, disassembled if necessary, and then recycled by a third-party recycling company. This would provide MCS with recycled materials for new products which contain very little contamination, since the polymers and additives put into recycling would be homogenous and would ideally be able to reach a very similar level of performance to the virgin materials for several cycles. There would be a risk that the user would not choose to return the product, but this could possibly be mitigated by incentives such as discounts or deposit systems. This strategy would allow the PS-board to be constructed out of different polymers and materials, so long as they could be mechanically separated and then identified by a third-party recycling company, through common methods such as infrared scanning and/or density based separation.

3.1.4.3 Recycled Input Strategy

The purpose of this strategy was to construct the product out of recycled materials from other sources of recycled polymer, without the requirement of being recycled again. This would mean that the PS-boards EOL would most likely result in incineration or landfill, but the sourcing of materials would have a lower impact than virgin plastic. This is assuming that the sourcing would not be chosen from a closed loop flow of recycled plastic, such as PET in deposit systems. For the design of the PS-board, this strategy would pose few restrictions on construction and would mostly entail that some dimensions of the boards construction might change due to a possible lower quality of recycled material compared to virgin.

3.1.4.4 Longevity Strategy

This strategy deprioritized the aspects which are affected by recycling and instead aimed to design the board to be durable and last for a long time. This would allow it to distribute its environmental burden over a longer lifetime. The strategy would allow a greater freedom for design and construction, as constraints like single polymer components and recycled materials could be ignored. For example, this strategy would allow for a wide range of composite and thermoset plastic use, which could be an efficient solution for making a low-cost and durable board. On the other hand, this would result in less sustainable material sourcing and EOL. Another benefit would be a lowered bar of entry and capital investment as material sourcing, manufacturing and infrastructure would be simplified. This would also open up a range of options more in line with a small company with lower capital and resources for development.

3.1.5 Requirements Analysis

Below is the compiled List of Requirements which the finished product was required to achieve (see table 1).

Table 1: List of Requirements

Requirement	**Limit**	**Priority**	**Requirement setter**
Be economically suitable for small scale production	Be economically suitable for a batch size of 100 units / year	High	MCS
Withstand cold temperatures	Maintain mechanical properties in use down to -20 Degrees Celsius	High	MCS
Glide well on snow	Sufficiently low friction on snow. Does not need to reach racing standards	High	MCS
Low weight	Maximum 3kg of total weight	Medium	MCS
Withstand compression	Withstand twice a user's body weight	Medium	Authors

Low production cost	Approx. 30 Euro or less	High	MCS
Low material cost	Avoid excessive cost	High	MCS
Withstand abrasion from rocks in the snow	Avoid critical damage and minimize wear	Low	MCS
Resistance to UV degradation	Approx. 1 year's total usage without effects on mechanical performance	Medium	Authors
Resist water degradation	Maintain mechanical properties during normal use	Medium	Authors
Low water absorption	Allow no cavities or other potential accumulation points for water	Medium	Authors
Traction Pads with low snow collection	Avoid accumulation and increase easy of removal	High	MCS
Low toxicity for humans and the environment	N/A	Medium	Authors
Embody the interpreted design	Avoid deviation which negatively affects user experience	High	Authors
Offer a connection point for a leash	Offer a hole for a loop to be threaded through	High	MCS
Be Sustainable	Satisfy the chosen Sustainability Strategy	Medium	Chalmers
High yield strength	Non-conclusive	High	Authors
High stiffness	Non-conclusive	High	Authors
High flexural strength	Non-conclusive	High	Authors
Impact resistance	Non-conclusive	Medium	Authors

3.1.6 Initial Production Analysis

The first Granta EduPack study was conducted for suitable production processes for thermoplastics and resulted in a graph detailing the Capital cost and Relative cost index (per unit) of all applicable production processes (see Appendix E1). After removing the unsuitable process Electrospinning due to inability to produce the required shape, the three processes with the lowest cost according to the graph were chosen; Polymer Casting, Rotational molding (Rotomolding) and Thermoforming.

The second study was conducted for thermosets and composites and resulted in a graph over suitable processes (see Appendix E1). Then, processes like Electrospinning and the additive manufacturing processes; Material Jetting, Stereolithography and Mask Projection Stereolithography, were removed because they were deemed incompatible with the size requirements for the PS-board, by comparison to information found in Granta EduPack. Subsequently three processes were selected for further consideration based on factors of cost; both capital investment costs and production cost per unit. The three processes selected were Thermoforming, Polymer Casting and Vacuum Assisted Resin Transfer Molding (VARTM).

The search for contact with production expertise resulted in two interviews. The first one was conducted with Lars Almefelt, Vice Prefect at the Mechanical Engineering institute at Chalmers, who has a background in construction. The information gathered during the interview was then compiled into a list of insights (see Appendix D5).

The second interview was held with Johanna Xu, Assistant Professor at the Department of Mechanical Engineering, Division of Computational mechanics and Materials Engineering at Chalmers. The information from the interview was compiled in a list (see Appendix D6).

3.1.7 Concept Generation

Four main subfunctions were identified and included in the Morphological Matrix; *Create Shell, Create stabilizing interior, Outer reinforcement* and *Joining method* (see Image 13). Two secondary subfunctions were also identified; *Material type* and *Sustainability Strategy*, which relied on the solutions to the main subfunctions. The solutions to the subfunctions were combined in every way deemed feasible, which produced a list of all feasible Concepts (see Appendix F1).

Subfunction	Solution					
Create Shell	Rotomolding	Thermoforming in two halves	Thermoforming solid	Polymer Casting solid	Vaccuum RTM	
Create stabilizing interior	Foaming in place	Pre-shaped Foam	Solid Thermoforming / Polymer Casting	Well-Structure through Thermoforming	Two halves with internal structure	Layers of fibreglass
Outer Reinforcement	Outer Fiber Reinforcement	Outer Ribs	Extra Thickness	Silicone Bumpers	Without Reinforcement	
Joining Method	Glue	Plastic Welding	Without Joining Method	Resin	Friction	
Included Material Types	Thermoplastics	Foams	Fiberglass	Thermosets	Resin	

Image 13. Morphological Matrix. Subfunctions are listed in the leftmost column, with the solutions to each subfunction listed in the rows on the right

3.1.8 Sustainability Based Concept Screening

The Concepts were screened and compiled into the Sustainability Strategies they supported, with some Concepts included in several strategies. The Concepts for the Public Recycling Strategy only stemmed from the production processes Thermoforming and Polymer Casting, which would then have been used to create constructions consisting of only a single polymer, due to the use of public recycling (see Image 14).

Create Shell	Create stabilizing interior	Outer reinforcement	Joining method	#Process Steps	Included Materials
Thermoforming in two halves	Well-Structure through Thermoforming	Without Reinforcement	Plastic Welding	4	Thermoplastics
Thermoforming in two halves	Two halves with internal structure	Outer Ribs	Plastic Welding	3	Thermoplastics
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Outer Ribs	Without Joining Method	1	Thermoplastics
Thermoforming solid	Solid Thermoforming / Polymer Casting	Outer Ribs	Without Joining Method	1	Thermoplastics

Image 14. The suitable Concepts for the Public Recycling Strategy

The Concepts for the Internal Collection Strategy were quite similar to the previous strategy, due to the ease of recycling if a single polymer were to be used for the entire product (see Image 15). However, since the Internal Collection Strategy allowed for multiple materials in the product, so long as they were easily separable with common methods, the Concepts below would have had the ability to combine different polymers within the *Included Materials*. Two potential examples were the Concepts relying on *Thermoforming in two halves*, which could have been constructed with different thermoplastic polymers in the top and bottom half. The only Concept which was not included to some extent in the previous strategy was the Concept based on Rotomolding, since it relied on *Foaming in Place* for the subfunction *Create*

Stabilizing Interior, thus including foam as a necessary second material group. In the Internal Collection Strategy, however, the foam and shell could possibly be recycled through mechanical and density based separation, rendering the concept suitable.

Create Shell	Create stabilizing interior	Outer reinforcement	Joining method	#Process Steps	Included Materials
Rotomolding	Foaming in place	Extra Thickness	Without joining method	2	Thermoplastics, Foams
Thermoforming in two halves	Two halves with internal structure	Without Reinforceme	Plastic Welding	3	Thermoplastics
Thermoforming in two halves	Well-Structure through Thermoforming	Without Reinforceme	Plastic Welding	4	Thermoplastics
Thermoforming solid	Solid Thermoforming / Polymer Casting	Outer Ribs	Without Joining Method	1	Thermoplastics
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Outer Ribs	Without Joining Method	1	Thermoplastics/Thermosets

Image 15. The suitable Concepts for the Internal Collection Strategy

The Recycled Input Strategy involved similar Concepts to the Internal Collection Strategy, since easily recycled thermoplastics likely could be sourced as recycled material as well (see Image 16). However, there were also several more Concepts added due to the absence of a requirement for recycling. These included Concepts with the solution *Outer Fiber Reinforcement* to the subfunction *Outer reinforcement*, as well as one Concept based on the process Vacuum RTM, since both relied on glass fibers, which could possibly be sourced as recycled materials.

Create Shell	Create stabilizing interior	Outer reinforcement	Joining method	#Process Steps	Included Materials
Rotomolding	Foaming in place	Extra Thickness	Without joining method	2	Thermoplastics, Foams
Thermoforming in two halves	Two halves with internal structure	Without Reinforcement	Plastic Welding	3	Thermoplastics
Thermoforming in two halves	Foaming in place	Extra Thickness	Plastic Welding	4	Thermoplastics, Foams
Thermoforming in two halves	Well-Structure through Thermoforming	Extra Thickness	Plastic Welding	4	Thermoplastics
Thermoforming solid	Solid Thermoforming / Polymer Casting	Outer Fiber Reinforcement	Resin	2	Thermoplastics, Fiber glass, Resin
Thermoforming in two halves	Two halves with internal structure	Outer Fiber Reinforcement	Plastic Welding, Resin	4	Thermoplastics, Fiber glass, Resin
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Outer Fiber Reinforcement	Resin	2	Thermoplastics/Thermosets, Fiber glass, Resin
Vaccuum RTM	Layers of fibreglass	Without Reinforcement	Resin	1	Thermosets, Fiber glass, Resin

Image 16. The suitable Concepts for the Recycled Input Strategy

For the Longevity Strategy, Concepts were selected solely based on the estimated durability, which favored Concepts including fiber glass and resin for the subfunction *Outer Reinforcement*, or *Create Shell* (see Image 17). A multitude of these Concepts also included *Resin* as a material group, which would have complicated any Sustainability Strategy focused on recycling. Two Concepts were also included with *Silicone Bumpers* as solutions to the subfunction *Outer Reinforcement*, which had previously been excluded.

Create Shell	Create stabilizing interior	Outer reinforcement	Joining method	#Process Steps	Included Materials
Rotomolding	Foaming in place	Outer Fiber Reinforcement	Resin	3	Thermoplastics, Foams, Fiber glass, Resin
Thermoforming solid	Solid Thermoforming / Polymer Casting	Outer Fiber Reinforcement	Resin	2	Thermoplastics, Fiber glass, Resin
Thermoforming solid	Solid Thermoforming / Polymer Casting	Silicone Bumpers	Glue	3	Thermoplastics, Silicone, Glue
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Outer Fiber Reinforcement	Resin	2	Thermoplastics/Thermosets, Fiber glass, Resin
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Silicone Bumpers	Glue	3	Thermoplastics/Thermosets, Silicone, Glue
Vaccuum RTM	Layers of fibreglass	Outer Ribs	Resin	1	Thermoset, Fiber glass, Resin

Image 17. The suitable Concepts for the Longevity Strategy

3.2 Phase 2

Out of the Sustainability Strategies presented in Phase one, MCS decided to mainly adapt the Longevity Strategy, and where possible also use the Recycled Input Strategy. During some early contacts with manufacturers, MCS also received some early quotes regarding Rotomolding which proved it would be too expensive to implement. Any Concepts relying on Rotomolding were therefore removed from their Sustainability Strategy or, where possible, reworked between phases. MCS were also made aware of restrictions on thickness for Thermoforming which would render all concepts with the solution *Thermoforming Solid* obsolete. During this Phase, the most suitable Concepts were selected and analyzed on the bases of their production, such as potential emissions, and implications on usage, compared against our User Study. The Selected Concepts were presented to MCS along with the results of the analyses.

3.2.1 Material Screening

Firstly, unfilled thermoplastics were analyzed using Granta EduPack, screening all available materials on the basis of Yield strength, Young's modulus, density and price (see Appendix E2). The materials with the most optimal observed properties were PVC, PET, PLA, PC, SMMA, ASA, AES and PE-HD (HDPE). However, PVC showed to be too toxic to be further considered. A published review of the ecological impacts of PVC found the polymer type to be responsible for threatening a multitude of ecosystems through the release of toxins when degrading in the environment (Kudzin, et al., 2023). Thus, the only suitable materials found by the analysis were PET, PLA, PC, SMMA, ASA, AES, HDPE.

For the analysis of fiber-reinforced thermoplastics for Thermoforming, similar metrics as the previous analysis was used (see Appendix E2). The three most suitable materials were PET 45% glass fiber with recycled content, PC 20-30% long glass fiber and SMA 42% long glass fiber.

Then Polymer Casting was also analyzed by the same metrics (see Appendix E3). The materials with the most promising properties were PF, PA12, Novolac with glass and mineral filler, polyester SMC, Epoxy with glass fiber and Polyester SMC 50% glass fiber. However, some materials were excluded from further consideration due to toxicity. DAP was identified in Granta EduPack as a phthalate, which is a group of chemicals which are toxic to humans through different pathways of exposure, unless treated through processes described as high-level water operations for water treatment by one study (Tran et al., 2023). Novolac and PF were both identified in Granta EduPack to be formaldehydes, which pose health risks such as, but not limited to, carcinogenic, neurotoxic and respiratory risks (Sun et al., 2025). Polyester SMC 50% glass fiber was also excluded from the suitable materials since it is a sheet molding compound (UTI, 2026), which is a large sheet made to be molded into different shapes (Nicolais et al., 2012). Since Polymer Casting is not a molding process, the only suitable materials found in the analysis was Epoxy with glass fiber and PA12.

The analysis of VARTM was performed with the same methodology (see Appendix E4), however the only suitable material identified was Polyester with 65% woven glass fiber.

3.2.2 Literature Review

The Literature Review produced detailed information on the three previously considered production processes and their respective relevant materials (see Appendix G). Additionally, a process variant of Thermoforming called Twin-Sheet Thermoforming was identified, which had the ability to create hollow components with a lowered production complexity and cost. It combined shaping both top and bottom surfaces with welding, into a continuous process, enabling the creation of hollow shells to be filled with foam, whilst using half the number of molds needed in usual Thermoforming, as found in the Literature Review. Twin-Sheet Thermoforming was hence reworked into new Concepts which were in turn appended to the Recycled Input and Longevity Strategies. The strategies were also appended with the material groups of fiber-filled thermoplastics and thermosets, which were identified as containing suitable materials in the Material Screening. This inclusion also removed the necessity for outer fiber reinforcement for some Concepts (see Image 18-19). Since the Twin-Sheet process is a variant of Thermoforming, similar possible materials which were identified for regular Thermoforming were also deemed suitable for Twin-Sheet.

Create Shell	Create stabilizing interior	Outer reinforcement	Joining method	#Process Steps	Included Materials
Twin-sheet Thermoforming	Foaming in place	Extra Thickness	Without joining method	2	Thermoplastics (filled/unfilled), Foam
Twin-sheet Thermoforming	Foaming in place	Without Reinforcement	Without joining method	3	Thermoplastics (filled/unfilled), Foam
Thermoforming in two halves	Two halves with internal structure	Without Reinforcement	Plastic Welding, Resin	4	Thermoplastics (filled/unfilled)
Thermoforming in two halves	Foaming in place	Extra Thickness	Plastic Welding	4	Thermoplastics (filled/unfilled), Foam
Thermoforming in two halves	Well-Structure through Thermoforming	Extra Thickness	Plastic Welding	4	Thermoplastics (filled/unfilled)
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Without Reinforcement	Without joining method	2	Fiber filled Thermosets
Vaccuum RTM	Layers of fibreglass	Without Reinforcement	Resin	1	Thermosets, Fiber glass, Resin

Image 18. The updated suitable Concepts for the Recycled Input Strategy

Create Shell	Create stabilizing interior	Outer reinforcement	Joining method	#Process Steps	Included Materials
Twin-sheet Thermoforming	Foaming in place	Outer Ribs	Without joining method	2	Thermoplastics (filled/unfilled), Foam
Twin-sheet Thermoforming	Foaming in place	Extra Thickness	Without joining method	2	Thermoplastics (filled/unfilled), Foam
Thermoforming in two halves	Two halves with internal structure	Extra Thickness	Plastic Welding	3	Thermoplastics (filled/unfilled)
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Without Reinforcement	Without joining method	2	Fiber filled Thermosets
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Silicone Bumpers	Glue	3	Fiber filled Thermosets, Silicone, Glue
Vaccuum RTM	Layers of fibreglass	Outer Ribs	Resin	1	Thermosets, Fiber glass, Resin

Image 19: The updated suitable Concepts for the Longevity Strategy

3.2.3 Concept Selection and Assessment

For each of the production processes, one Concept was selected from the Recycled Input and Longevity Strategies, following the update from the Literature Review (see Image 20).

Create Shell	Create stabilizing interior	Outer reinforcement	Joining method	#Process Steps	Included Materials
Thermoforming in two halves	Two halves with internal structure	Extra Thickness	Plastic Welding	3	Thermoplastics (filled/unfilled)
Twin-sheet Thermoforming	Foaming in place	Extra Thickness	Without joining method	2	Thermoplastics (filled/unfilled), Foam
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Without Reinforcement	Without joining method	2	Fiber filled Thermosets
Vaccuum RTM	Layers of fibreglass	Without Reinforcement	Resin	1	Thermosets, Fiber glass, Resin

Image 20. The chosen Concepts for each production process

The Thermoforming Concept used the attributes of Thermoforming two halves, with Internal Structures as support, Extra Thickness as reinforcement and the two halves needed to be combined with Plastic Welding. The chosen material types were thermoplastics, with unfilled thermoplastics on the bottom half and fiber reinforced thermoplastics on the top half, in order to increase the strength of the construction as much as possible, without reducing gliding properties of the bottom. This would have required 2 pairs of matched molds, which entailed that 4 tools needed to be produced and paid for in order to produce the Thermoformed components. Additionally, plastic welding would have likely added an extra cost. The EcoAudit for the Thermoforming Concept resulted in a chart over CO_2e for a few material variations of the Concept (see image 21).

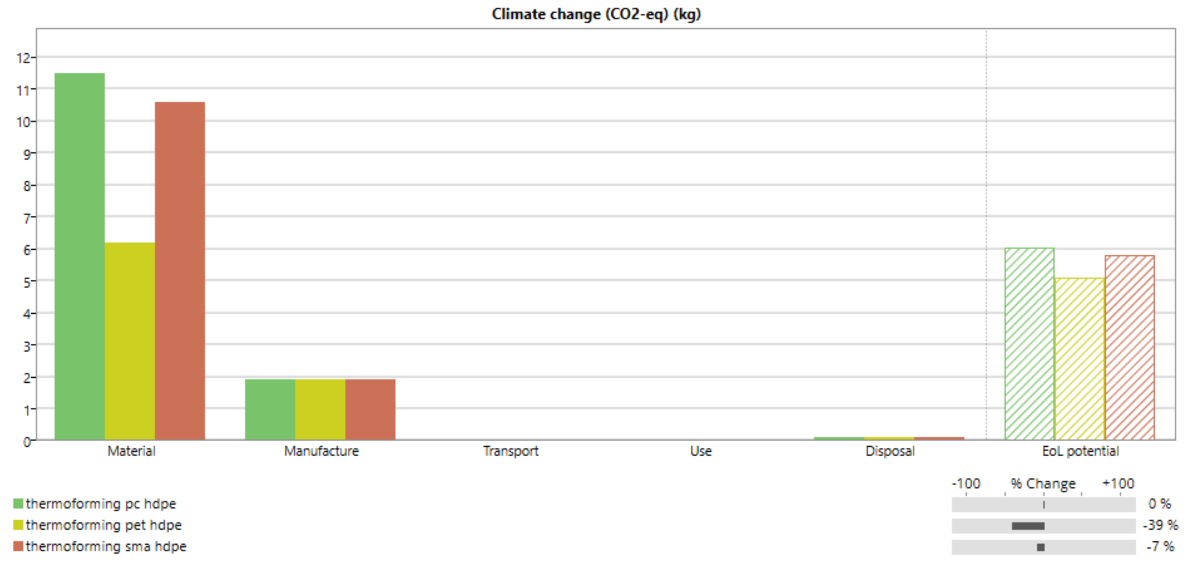


Image 21. EcoAudit Chart over thermoforming processes. Images used courtesy of ANSYS, Inc.

The second Selected Concept was based on Twin-Sheet Thermoforming, with Foaming in Place to stabilize the interior and was further reinforced by adding extra thickness to the foam. The concept required no joining method. The material types were both unfilled and fiber-reinforced thermoplastics for the same reasons as in the Thermoforming Concept, as well foams. The process would require 1 pair of matched molds, entailing that 2 tools needed to be produced and paid for. In addition, the foaming process would likely have added an extra cost, both in material and use of machinery. The EcoAudit for Twin-Sheet resulted in a chart over CO_2e for a few material variations of the Concept (see image 22).

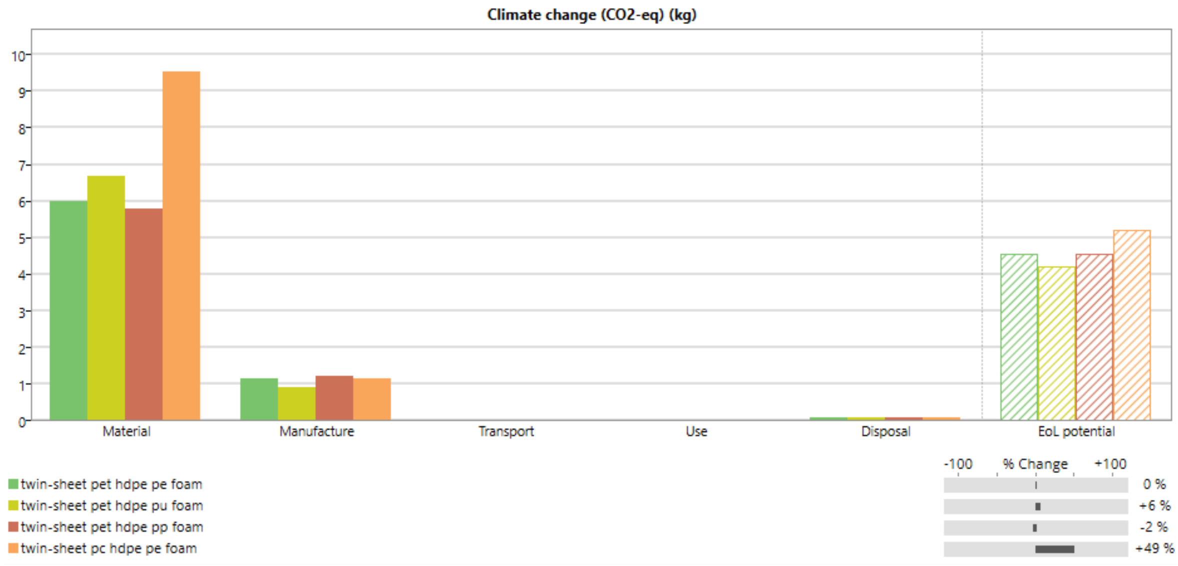


Image 22. EcoAudit chart over Twin-Sheet processes. Images used courtesy of ANSYS, Inc.

The primary process in the third Selected Concept was Polymer Casting solid, without any reinforcement. Since Polymer Casting would have produced the finished component immediately, no joining method was needed. The included material types were fiber-reinforced thermosets. This Concept would have required a parent mold to be created in order to then manufacture the single-used molds, which would be needed for every unit produced, likely entailing an initial cost for the parent mold, and an extra cost for each single-use mold. The EcoAudit for Polymer Casting resulted in a chart over CO_2e (see image 23).

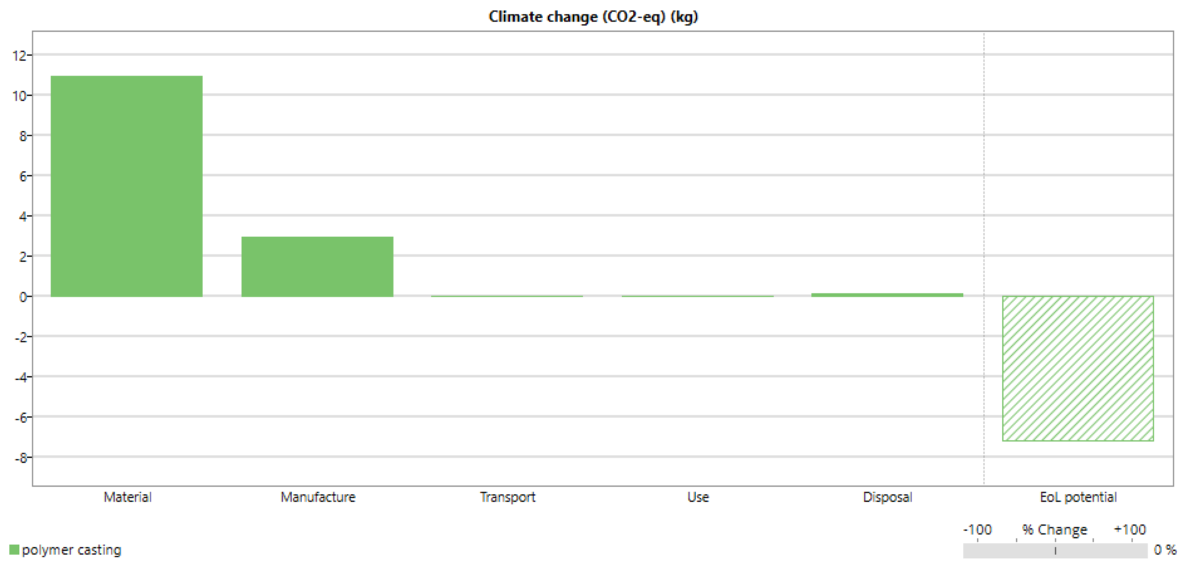


Image 23. EcoAudit chart of a Polymer Casting process. Images used courtesy of ANSYS, Inc.

The VARTM Concept was based on solid Vacuum RTM, with layers of fiberglass as the stabilizing interior. No reinforcement was included and the component was joined with resin in the VARTM process. The included material types were thermosets, fiber glass and resin. This would have required one pair of matched molds, entailing that 2 tools would need to be produced and paid for. The EcoAudit for Thermoforming resulted in a chart over CO_2e for a couple material variations of the Concept (see image 24).

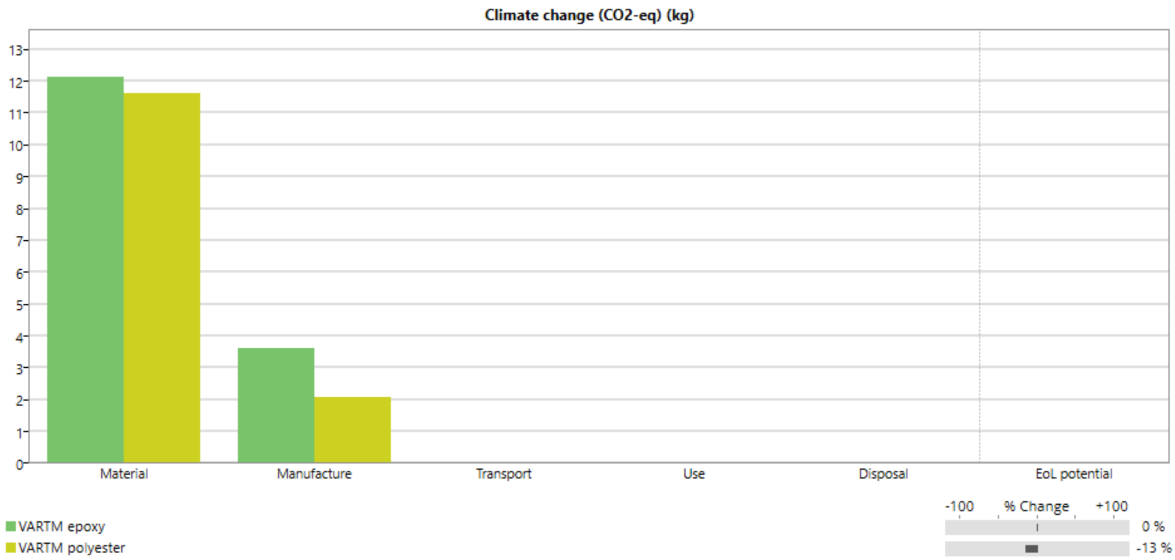


Image 24. EcoAudit chart over VARTM processes. Images used courtesy of ANSYS, Inc.

3.2.4 Analysis of User Implications

The most relevant identified requirements to the user experience were regarding the Weight, Friction, and the Shape itself, consisting of the different parts defined in the Shape and Design Interpretation. These findings were also supported by the findings in the User Study. The requirements regarding structural stability would also have an effect on user experience, but were not analyzed due to their inability to be verified.

The height of the board could affect the user experience due to a shift in the pivot point when the rider is switching from riding on one edge or the other, as discovered in the Shape and Design Interpretation. No conclusions have been made regarding which height is the most preferable, but it does affect the user nonetheless. Since the Twin-Sheet Concept is filled with foam and has “extra thickness” as its reinforcement method, using this Concept would certainly raise the height of the board and also the user's pivot point. No approximations of thicknesses were done for the Thermoforming, Polymer Casting or VARTM Concepts, but since they rely on other methods for reinforcement they would likely not require a significant raise in the PS-boards height. Material data from GRANTA showed that the materials suitable for VARTM had higher strength and density than the materials for Thermoforming, it is likely that a PS-board made from the VARTM Concept would have the lower relative height.

The weight was another crucial aspect for the user, not as much in terms of riding experience, but rather in handling the board in between descents. A heavy board would have made it uncomfortable to carry and in turn make the product directly unattractive to users. However, the weight of a Concept could not be calculated until a final CAD-model had been created, which would only be done for the Final Concept. Therefore, only approximations of weights were assessed (see Appendix C3). According to the approximations, the Polymer Casting and VARTM Concepts were expected to achieve the lowest weights due to their use of thermoset epoxies and glass fibers, which were expected to increase strength and in turn lower the needed amount of material in the product. The Thermoforming Concept was expected to be heaviest due to its use of thermoplastics, which could provide less structural stability, requiring more material to be used. The Twin-Sheet Concept was assessed to be between the other Concepts in eight, due to its use of thermoplastics with lowered density, extra stability and leverage stemming from the use of foam.

The friction of the product on snow could have a substantial impact on the user experience as it affects the speed of the PS-board. As discovered in the Shape and Design Interpretation and User Study, the PS-board would need to be able to slide down a mellow slope of snow, even if it is not necessary for the friction to be as low as a racing snowboard. As mentioned in the Literature Review, a research gap of specific studies regarding the tribological properties of different polymer types on snow has severely limited the ability to assess which materials would have satisfactory sliding properties, apart from versions of HDPE which have documented satisfactory friction properties. However, it was concluded in the Literature Review that materials with fiber reinforcement present at the surface of a component would have a significant increase in friction. This implies that the Polymer Casting Concept might have had an undesirable effect on friction, given that all the suitable materials found for the process in the Material Screening contained short fibers in random placement and orientation, which was also supported by the Literature Review. The found literature on VARTM did not specify whether or not it is possible to easily control the position of the fiber reinforcement mats inside the component, from which it follows that the VARTM Concept poses a potential risk of affecting friction, if mats are not able to be kept separate from the bottom surface. The Thermoforming and Twin-Sheet Concepts could both have fiber-reinforced thermoplastics only on their top half, with unfilled thermoplastics on the bottom, which eliminates the risk of fibers coming into contact with the snow and affecting friction.

A production factor which unavoidably would have had to be accounted for in the design of the PS-board was whether it needed to be produced with multiple matched molds, which all the Concept apart from Polymer Casting did. One design implication the matched mold would cause was the need to place a seamline all around the PS-board where the molds meet. This line could be placed in different places but would most suitably have been placed along the *Rails* of the board to reduce mold depth, since greater mold depth requires more complex machinery (BMG, 2024). This could have had an impact on the overall shape of the *Rail* as required adjustments to the geometry or even escaped material left protruding from the seam, so called flashing, would likely had effects on the riding performance. Flashing would have especially affected the user as it would have likely caused drag if it came into contact with snow during use. This could possibly have been mitigated through post processing steps such as CNC routing. Similarly, the release of the matched molds would also require minimum draft angles throughout the model. This could impose restrictions on the geometry which areas such as the Rails, Traction Pads and Tail would have had to account for. The added angles would have removed the possibility of creating any completely vertical geometry, which would for example necessitate an edge along the Rail where one draft angle from the lower tool needed to transition into another draft angle from the upper tool. Changes to geometry at critical areas like the rails and tail are in turn likely to change the riding performance and user experience.

One possible user implication which had not been considered in the Shape and Design Interpretation and therefore did not appear in the List of Requirements, was the implications of potential damage caused to the bottom of the PS-board, for Concepts where a shell is formed. This could have serve as an entry for snow, water and other contamination into the product. Even though this in and of itself was not listed as a requirement, adding more mass in hollow spaces in the PS-board would definitely have increased the weight, which would have a documented effect on the user's experience. Therefore, the Thermoforming Concept posed a risk of increasing weight of the product significantly if external damage opened an entrance to the internal cavities. The Twin-Sheet Concept could potentially have posed a similar risk, if an entry was created in combination with a foam which absorbed water or snow. As found in the Literature Review, this risk could have been mitigated by choosing a closed-cell foam.

3.3 Phase 3

Based on the information from the previous phase, MCS chose the Twin-Sheet Concept to be the Final Concept for the project. They also chose the final materials to be HDPE for the entire outer shell and PU-foam or the inner core. The production of the Final Concept was then analyzed thoroughly. Concepts were generated for how the seamline could have been optimized for user experience, yet information from potential factories concluded that an “invisible” seamline was possible to achieve. Concepts were also generated for how the leash fastening point could be integrated in production, with MCS choosing to utilize post processing and existing leash plug components for surfboards. A surface model was also created to the few standards which were attained from potential factories.

3.3.1 Final Concept Refinement

The Final Concept included aspects which required verification and exploration. The aspects of the production of the board which were further explored were, among other things; the seamline of the shell, the foaming process and methods of leash attachments.

3.2.1.1 Creation of shell

The chosen Concept was based on utilizing Twin-Sheet Thermoforming, which would create the major outer geometry of the PS-board as a shell. Even though Twin-Sheet was considered significantly cheaper than the previously considered Rotomolding by some sources (Universal Plastics, n.d.), MCS received a quote from one factory which was higher than expected, making the production process slightly less profitable for small scale production.

The Twin-Sheet Thermoforming process is performed by heating and shaping two sheets of thermoplastic and joining them (Engelmen, 2012, chapter 6, p. 43). The two sheets are conventionally held in place against a top and bottom mold half respectively and heated in order to soften (see image 25). Then, a vacuum is drawn and the softened sheets are pulled into their respective molds (see image 26). Then the molds are brought together, pulling the shaped sheets along with them, and applying a force along the seam of the mold halves (see image 27). While they continue to be heated and pressed against each other, a weld between the top and bottom sheet is formed. Once the molds are released, a joined hollow component will have been formed (see image 28). Since the finished component would need to be released from the molds, a draft angle needs to be applied, usually set to around 2 degrees (Klein, 2009).

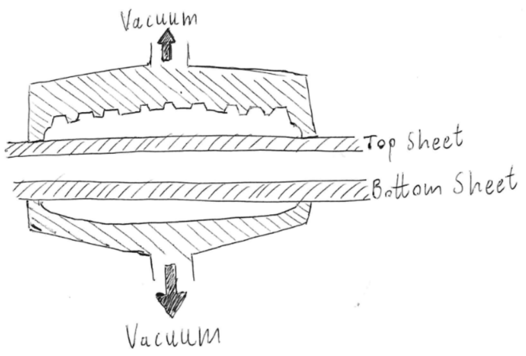


Image 25. Two plastic sheets placed between two mold halves

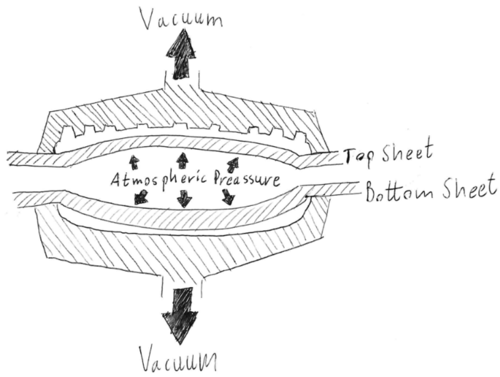


Image 26. Plastic sheets being drawn into mold halves with vacuum

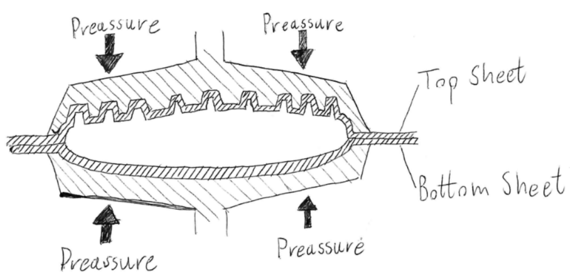


Image 27. Pressure being applied on two formed halves to create a weld

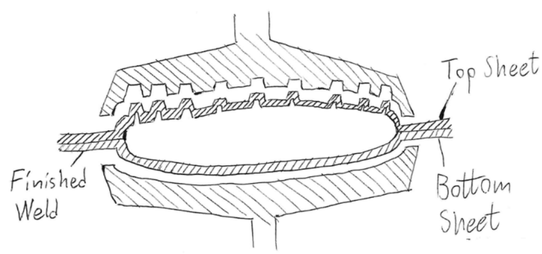


Image 28. Mold halves being removed leaving finished components

As previously mentioned in the Analysis of User Implications and Literature Review, different materials could be used in the top and bottom sheet in order to achieve varying material properties in the finished shell. This would have enabled the combination of fiber-reinforced thermoplastics for increased strength in the top layer, with unfilled thermoplastics for the bottom layer in order to avoid the increase in friction associated with fiber reinforcement. However, the material chosen by MCS was unfilled HDPE for both the top and bottom sheet, which allowed for utilization of well documented and desirable gliding properties on snow. Apart from affecting the speed of the PS-board on snow, these choices also affected the adherence to the chosen Sustainability Strategies. As previously mentioned, the foam-sandwich construction was too complicated to be properly mechanically analyzed, yet the choice of HDPE was possible to source as a recycled material, enabling the choice to adhere to the Recycled Input Strategy. According to Material data from Granta EduPack, HDPE was the cheapest unfilled thermoplastic, thus making the choice of material contribute to the requirement of low production cost.

Following the initial processing step, some further processes would have needed to be performed before the PS-board would be finished, one of which was the trimming of excess material along the seamline, where the top and bottom part of the shell met to be welded together. However, the most optimal manner for which the excess material would be cut depended on the specific placement and execution of the seam. There were different options for the execution of the seam, by letting excess materials protrude from the welded component in either a flat plane, or in an angle upwards or downwards. A possible post-processing step to the seam was a "Conical Trim", which removes all protruding material from the seam (Associated Thermoforming INC., n.d.).

Since it was initially unclear which specific capabilities the potential factories would have regarding the seam, it was deemed necessary to prepare a strategy for creating a seam which would impact the user experience as little as possible. In order to achieve this, the aim of the Concepts was to adhere to the Rails defined in the Shape and Design Interpretation as closely as possible, with a tilted side and a small radius at the bottom. In a generative phase, several solutions were explored for how such a seam could be made in order to best preserve the desirable shape of the rails, depending on the cutting and welding capabilities of the factory. The reason for placing the seam along the rail was, as previously stated, to decrease mold depth. One unknown factor was how deeply the weld would be able to penetrate into the top and bottom sheets, and thus if there was any need for any excess material to be left as a load bearing weld. For the case where the weld penetrated far into the sheets, two solutions were created and described by sketches, with the primary difference being the angle in which the sheets were leaving the mold and therefore the angle of the *Preferred Cut* (see image 29-30).

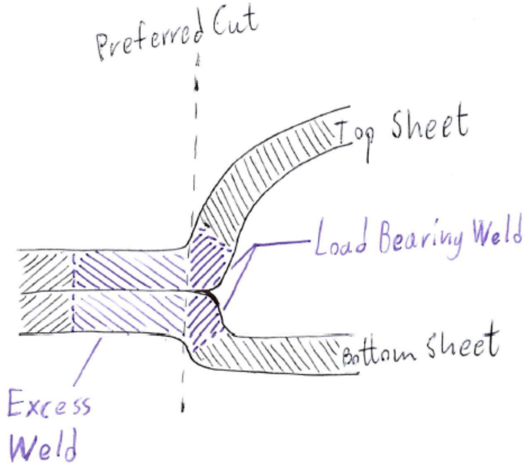


Image 29. Drawing of vertical cut to remove excess material at seam

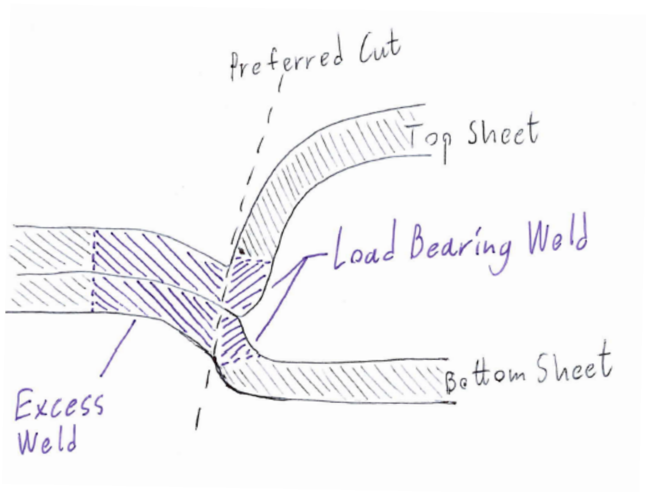


Image 30. Drawing of angled cut to remove excess material at seam

In the case where the weld could not penetrate as far, and excess material was needed in order to act as a protruding loadbearing weld, two other solutions were created and sketched, with the main difference between them being the angle of the *Preferred Cut.* In these two solutions, a bottom fillet was also added in order to recreate the rails bottom edge to some degree (see image 31-32).

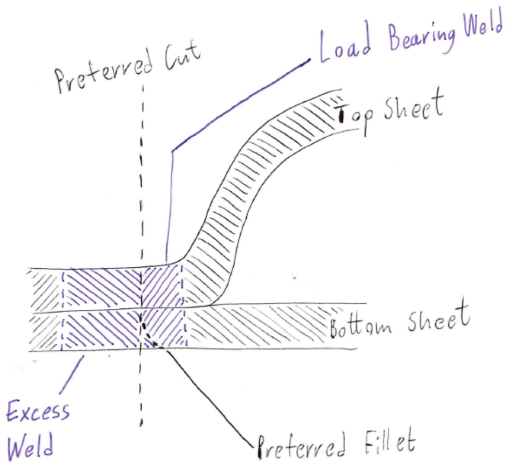


Image 31. Drawing of offset vertical cut to remove excess material at seam

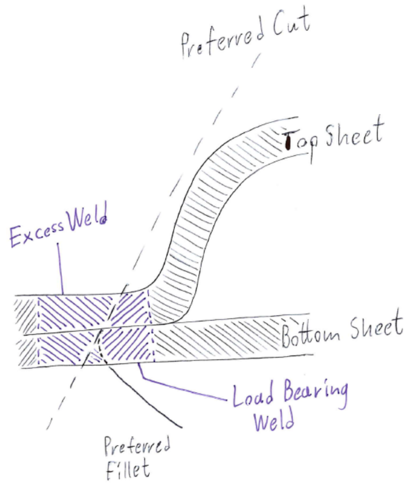


Image 32. Drawing of offset angled cut to remove excess material at seam

However, when contact was established with the final factory for Twin-Sheet, it was concluded that they were able to produce an “invisible” seam by using a Conical Trim, which would not affect the shape, rendering the solutions obsolete for collaboration with that specific factory.

3.3.1.2 Foaming process

After the seamline has been cut it is suitable to fill the still hollow component with foam. In order to accomplish this, access-holes are needed so that foaming agents can be inserted into the cavity. After which they expand to form the foam structure and fill the cavity providing added rigidity and stiffness (Buitenhuis, n.d).

A factor which needed to be considered for a hollow construction was the effect of punctures and leakages. If the board were to be sufficiently damaged on the underside, a hole could allow snow or other outside substances to come into contact with the board's interior. With snow which can melt, this could have become very problematic as an interior that absorbs water would have been weighed down. Therefore, the use of closed-cell foams, which resist water absorption better than their counterpart open-cell foams, would be key to dealing with punctures (see Appendix G).

For the Foaming in Place process, MCS had chosen to use a closed cell Polyurethane foam (PU-foam), because of its precedent as a foam interior used for surfboards (Wyve, 2023). It was expected to provide sufficient structure and impact resistance, while lowering the density.

The Foaming in Place process would be especially suitable for our construction of the Traction Pads since it would likely be forgiving to the complexities of the internal geometry. Since the foam would try to expand to fill every cavity, the pyramid geometries would have become reinforced by foam (see image 33). Manufacturing a similar foam insert as a foam blank with appropriate geometry would have been very technically demanding and required high precision. The complex geometry would also have provided added surface area which would in and of itself increase adhesion between the foam and the outer polymer sheet.

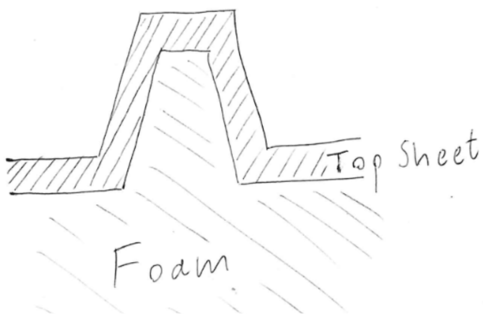


Image 33. Drawing of a pyramid with thermoplastic shell and foam interior

An implication of the foam interior on the overall design of the board was the choice of total thickness. The total thickness also relied on the factors of strength and weight. A key function of the foam was to act as a spacer and allow a greater distance between the topmost and bottom layer of solid thermoplastic, this would increase its strength, while weighing only slightly more than a thin board. By this method, a thicker board was preferable. Although the usage of foams reduced the weight, a larger thickness still meant more used material, which would have impacted the total weight. As per the List of Requirements, the weight was to be minimized, preferably to that of 3 kg or lower, which incentivized minimizing thickness. The precedent of similar construction using PU-foam in surfboards also spoke to the expected strength and durability of their usual thicknesses. An average snowboard could be expected to have a thickness in the range of 5-8 cm (Ruiz, 2015) (Surfing Waves, n.d.). With these aspects in mind along with the information from the Literature Review, MCS decided on a total thickness of 5 cm for the board, in order to provide sufficient strength while maintaining a low weight and slim profile.

3.3.1.3 Leash Attachment

Several solutions regarding how a topological hole could be integrated into the existing components were generated or imported from existing products and sketched. The first solution was to create a depression "*Hole*" in the Twin-Sheet process, which would then be partially covered by a middle beam with two fastening points (see image 34-35). The second solution was similar to the first one, but required no depression due to an arc-shape in the center of the beam (see image 36-37). Since the methods for securing the screws to the PS-Board were not yet decided, they were left as "*Fastening Method*" in the drawings. The third solution was to simply use a single eye-bolt, which is a type of screw or bolt with a closed metal loop attached on top, as both the screw and attachment point.

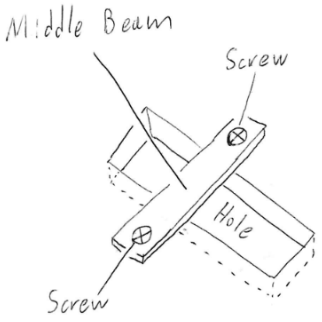


Image 34. Drawing of a beam mounted across a molded channel

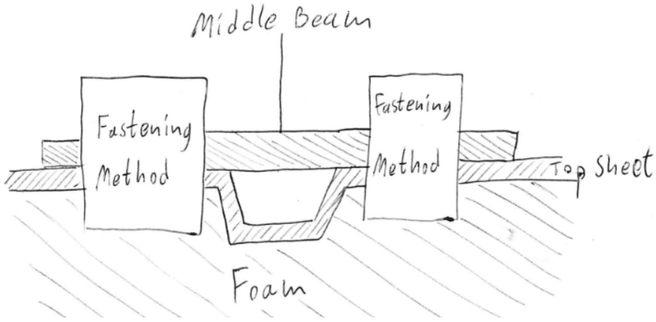


Image 35. Cross section of a beam mounted to the board with a molded channel

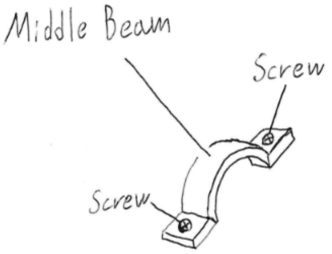


Image 36. Drawing of arced beam

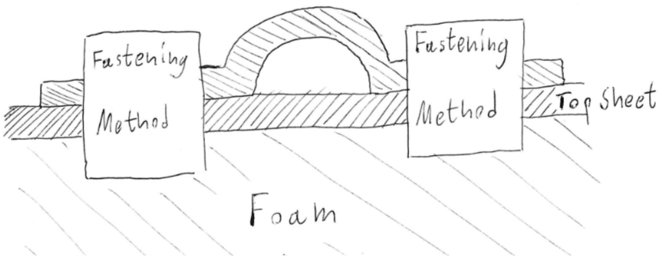


Image 37. Cross section of arced beam mounted to the board

Three fastening methods were explored to connect the screws to the PS-board. The first used the solution of creating depressions in the top sheet in the Twin-Sheet process, so that a screw could thread itself into the top sheet rather than the foam, which could have been desirable if the top sheet offered more mechanical strength than the foam (see image 38). The second solution worked similarly, yet included an insert with internal threads to be heat set into the depression, by heating the insert, lowering it into the depression, melting the surrounding plastic and then letting it cool (see image 39). Both methods would require a draft angle in the top sheet for the sheet to be releasable in the Twin-Sheet process, which might affect the fastening. The third method relied on drilling a hole into the top sheet and underlying foam, which would provide a hole without a draft angle (see image 40). However, it would have required a screw with sufficient fastening to the foam, which in turn might have reduced the alternatives for choice of specific foam. The importance of choosing a closed-cell foam would also increase, due to the hole creating an entry for water into the PS-board, the negative effects of which were disclosed in the Analysis of User Implications.

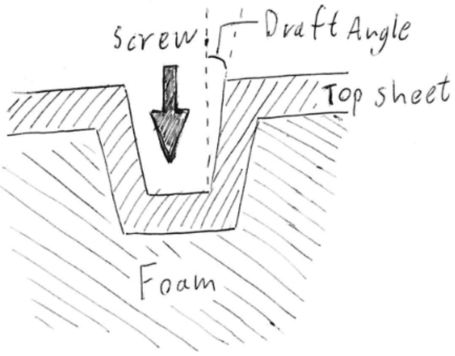


Image 38. Drawing of a molded screw hole

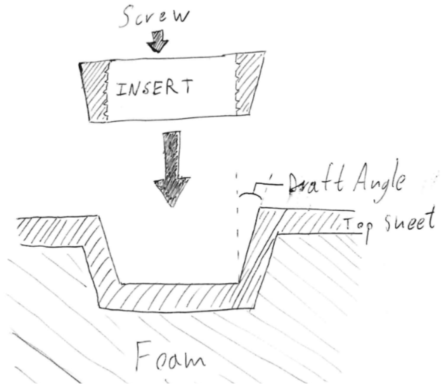


Image 39. Drawing of a screwing insert being mounted into a molded socket

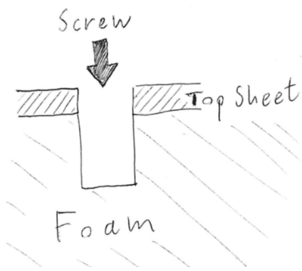


Image 40. Drawing of a predrilled screw hole

Two solutions were also explored which used the backmost ribs in the Traction Pads by drilling holes into them after the Twin-Sheet and Foaming in Place processes. The first was to drill a hole large enough for threading the leash through (see image 41-42). The second solution aimed to distribute the load more evenly and reducing wear by gluing a metal pipe-like insert in place, thus requiring a larger hole to be drilled (see image 43-44). A problem present in both solutions was the height of the ribs, which might have risked limiting the size of the drilled hole to less than necessary for the leash to be threaded through.

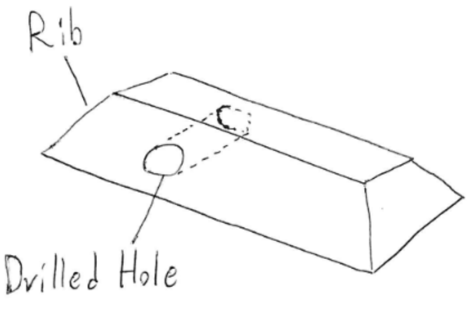


Image 41. Drawing of drilled hole through a rib

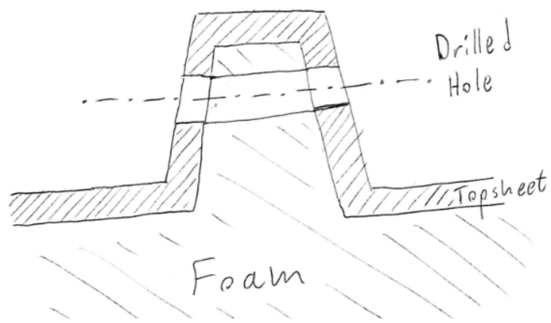


Image 42. Cross section of rib with drilled hole

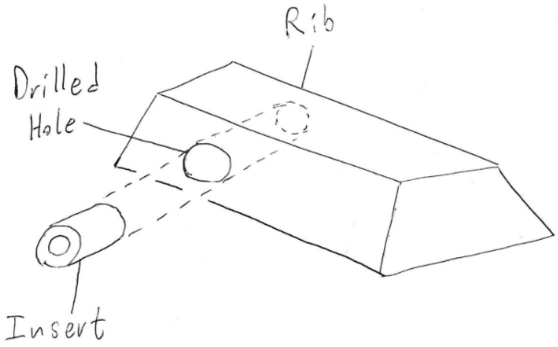


Image 43. Drawing of insert being mounted into a hole in the rib

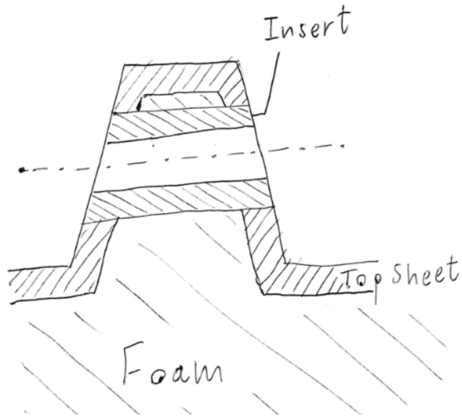


Image 44. Cross section of rib with mounted insert

A more established solution for creating an attachment point for the leash was found to be a *Leash Plug*, which is a common solution for surfboards. These are cylindrical inserts with a metal rod in the middle, which the leash can be wrapped around (Mundo Surf, n.d.). A common method for fastening leash plugs in surfboards is drilling a hole through the shell and foam of a surfboard, to then glue it into place with resin (Mundo Surf, 2014), which could possibly be an alternative for the PS-Board (see image 45). One potential concern was the stability of the fastening between the foam and the *Leash Plug*, if a less stable foam than used in surfboards, such as PE-foam, had been used. Another way to integrate the *Leash Plug* into the PS-board to avoid the aforementioned problem was to glue it into a depression in the top sheet (see image 46). This would, however, introduce the problem of gluing a cylindrical component to a depression containing a draft angle. MCS chose to use the *Leash Plug* with a drilled hole as the leash fastening point for the Final Concept.

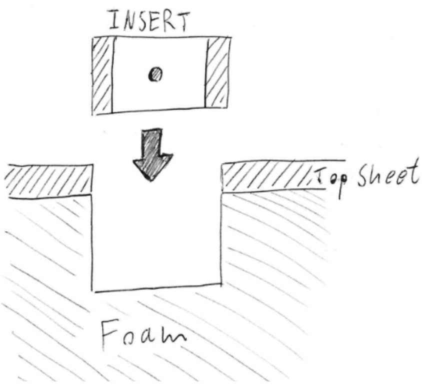


Image 45. Cross section of Leash Plug inserted into drilled hole

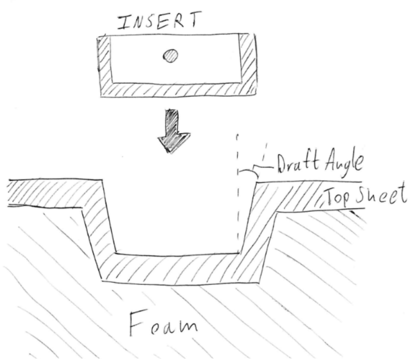


Image 46. Cross section of Leash Plug inserted into molded hole

3.3.2 Surface Modeling for Production

The established correspondence with potential factories provided one source of production tolerances, and the requirement for the file type to be STP, but no satisfactory information regarding the tolerances within the STP files used for production. Thus, the general standard for tolerances was adopted from CATIA V5 with a curve fit distance and max gap distance of 0,001 mm (Autodesk. n.d.). The surface model adhered successfully to the shape identified in the Shape and Design Interpretation, as well as values for thickness for the board of 50mm and a shell thickness of 3.5mm decided by MCS, (see image 47-52).

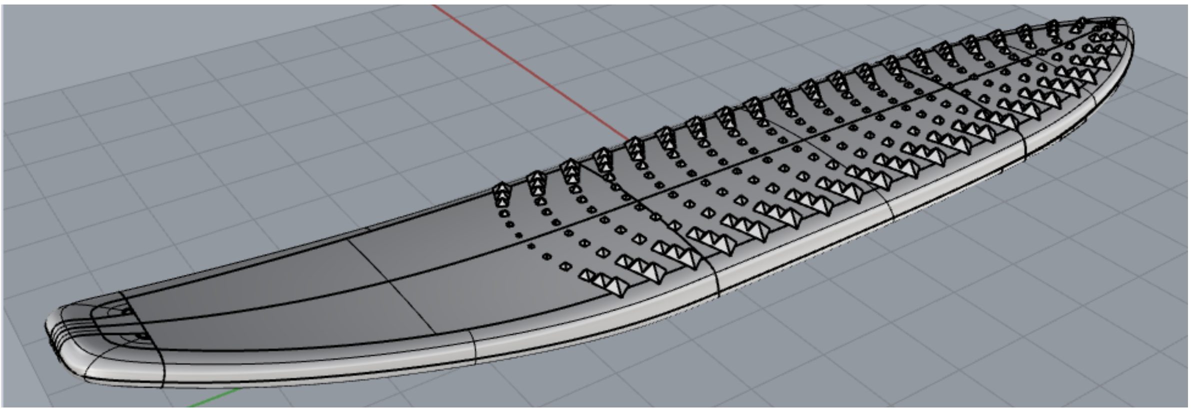


Image 47. Perspective view of completed board

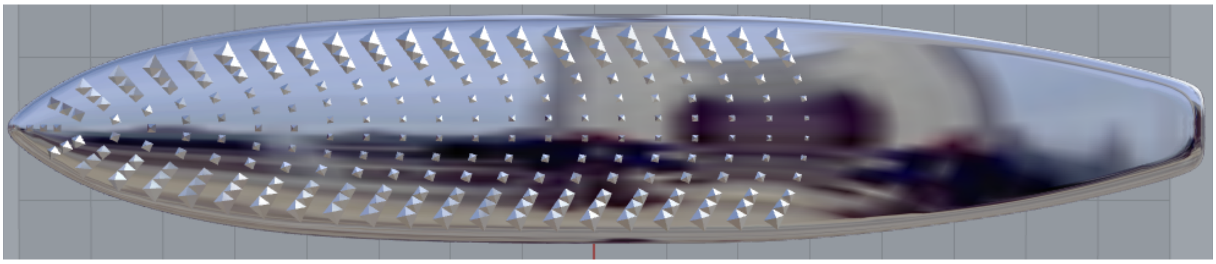


Image 48. Top view of completed board with environment mapping

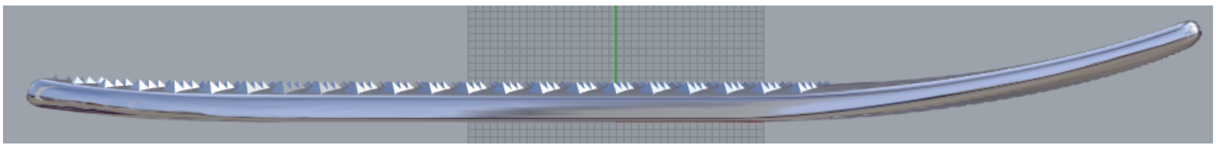
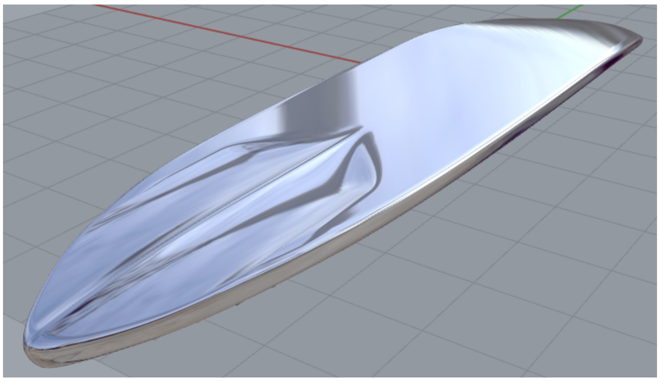


Image 49. Side view of completed board with environment mapping



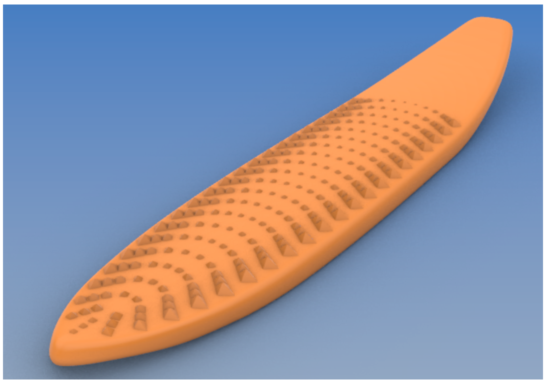


Image 50. Underside and Reverse Spoon Tail of completed board with environment mapping

Image 51. Rendered view of completed board

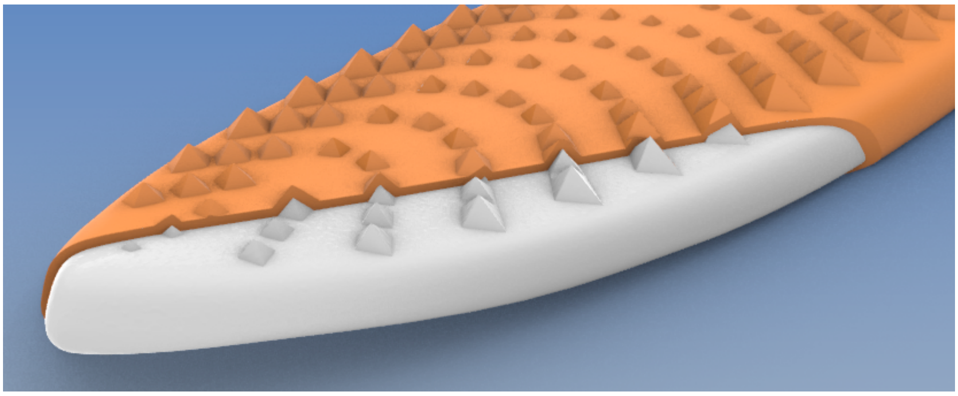


Image 52. Rendered view of sectioned outer shell with exposed foam

The finished production file showed a volume of 0.003 m^3 for the shell and 0.014 m^3 for the foam interior. When multiplied with the respective chosen materials properties, the weight was calculated to approximately 2.8 kg for the shell and 0.7 kg for the foam. When added together, these values amounted to a total weight of 3.5 kg for the PS-board which is slightly higher than the limit of 3kg set in the List of Requirements.

4. Discussion

The project's initial purpose was to assess all the factors regarding design, manufacturing and materials required in order to deliver a producible model of a PS-board made of plastic. The project's results showcase a broad quantity of options and available paths which were selected from until a final, most suitable, design remained. The multiple other paths that perhaps could have offered superior performance in terms of sustainability, mechanical properties, and weight, were most often discarded on a basis of incompatibility with the requirement of small production size due to high costs of adaptation. In spite and often because of these compromises, the outcome of this project could be regarded as feasible. However, some major uncertainties and requirements left unverified could arguably question the outcome's feasibility.

4.1 Research Questions

The first question regarding how the properties of the shape of a PS-board impacts the users experience was explored in the Shape and Design Implementation with the most important takeaways being included in the List of Requirements and Analysis of User Implications. In these chapters, the research question was answered as satisfactorily as possible given the time and resources constraints of the project. In order to explore the question further, it would be recommended to perform physical tests with users in combination with analyzing the responses of a larger number of users than in this project, which can be difficult to find when it comes to powder surfing.

The research question regarding the approaches for the optimization of environmental impact was answered by the Sustainability Investigation and Sustainability Based Concept Screening. How material selection could be optimized was also answered more specifically in the Concept Selection and Assessment, Material Screening and Literature review. One way in which the question could be answered further would be through a more thorough EcoAudit comparison between a larger amount of possible materials, as well as an analysis of methods for reducing waste in the production process.

The third research question; exploring which production processes could be suitable, was answered in several chapters. The processes which were suitable for small scale production in terms of cost and shape were analyzed and presented in the Initial Production Analysis. The environmental impacts of the production processes were assessed both through the Sustainability Based Concept Screening, where different constructions based on production processes were matched with Sustainability Strategies, and through the EcoAudits of the Concepts, which were based on the production processes.

The research question regarding which constructions could be created by the appropriate production processes was answered partially, with Concepts generated by the Morphological Matrix. It was answered further with the information in the Concept Selection and Assessment and the details in the Final Concept Refinement offering examples of how constructions could be made and adjusted in order to meet requirements for the form. Because of the uncertainties in the requirements regarding mechanical properties, Concepts could not be generated specifically to meet the required strength. Instead, the constructions offer examples, the exact strength of which could potentially be verified in future studies.

The question of which specific materials could offer desirable properties was thoroughly analyzed in the Material Analyses and complemented with information in the Literature Review. The question of how the aforementioned materials were compatible with different constructions was answered in the Literature Review, User Implications and the Final Concept Refinement. The part of the research question which remained unanswered consists of the exact values needed for the mechanical properties of materials in order for them to be considered desirable, as well as further information regarding the materials friction on snow.

The question regarding which shape modifications could be required to adapt the design to the production process was briefly touched upon in the Analysis of User Implications, to then be further analyzed in the Final Concept Refinement. The question was most thoroughly investigated for the use of Twin-Sheet Thermoforming with subsequent Foaming in Place. One way to further answer the question would be to make similar analyses on different production processes.

Several attempts were made to thoroughly answer the research question regarding which requirements existed for production files. Due to the information gathered from the potential factories giving inconclusive results on aspects such as file tolerances, the requirements of general production files could not be defined satisfactorily. However, in the Surface Modeling for Production chapter, the necessary file type was defined as an STP file, partially answering the question.

4.2 Methodology and Results

Throughout the project diverse methods were adapted, many of which used established and documented approaches, while others were adapted more quickly and in a sense invented during the course of the project. For example, during the Concept Generation a Morphological Matrix was used, which is a documented and pre-established method for generating Concepts (Bligård, 2015). On the other hand, the Concept screening method used in the following chapter, Sustainability Based Concept Screening, was mostly invented to suit the specific purposes of both sorting and selecting the best Concepts for each Sustainability Strategy. This results in a variable reliability between our different methods.

The constructed methods were most often created due to desired specificity and lack of time to research existing methods to utilize. Since they are new methods they have neither been peer tested or repeated which opens them up to weaknesses such as low means of verification and influence of biases. The different steps in the Concept Selection and Assessments exemplify this as they relied heavily on the discretion of the people involved in their execution. The desired outcome of this method could for example also have been achieved with several other selective methods such as performing multiple parallel PMI analyses (deBono, n.d.), but this might have multiplied the workload for this stage of the project by three or four times.

The way in which the program Granta EduPack has been used might also have produced some sources of error, even though it includes more established methods than our sustainability analysis. The information in the database may lack certain information, or instances of materials or production processes. One such example was noted, as there was no information regarding the composite material of Epoxy and fiber glass created by hand-lay up, instead, only pre-impregnated versions of the composite which might have different properties was available in the *Polymer Level 3 Universe*, which the analyses were made in. Another example was the lack of information on Twin-Sheet as a specialized version of Thermoforming in the database, which was only discovered in the Literature Review. This implies a risk of there being more available materials and production processes which were not considered at any point in the report, which could possibly have provided more suitable alternatives for the production of the PS-board. The way in which filtering tools in Granta EduPack have been used may also have caused sources of error, if certain suitable materials or processes were lost in user errors during screening.

One major source of potential errors throughout the project has been a lack of obtained information. This problem has been prevalent in multiple areas of the project and affected both information on production and user experience. When gathering production expertise through interviews in the Initial Production Analysis, fewer sources were identified than expected, leading to a lot of unanswered questions. Because of the limited expertise, most of the information regarding production processes was gathered from Granta EduPack and the Literature Review, making the conclusions from the Literature Review quite theoretical. Even though the Literature Review does include a wide range of production sources as an attempt to mitigate the risks, the selection and interpretation of sources has not been reviewed by any person with previous production expertise. This creates a risk of biases or misunderstandings to affect the results in the Literature Review.

In order to adjust for the lack of production expertise, contact with factories was sought in order to at least double check their specific capabilities, but in this instance too, less information was gathered than expected. The combination of these sources of error might lead to some results in the report being difficult to use for production of products. One example of this which was noted, was that the contacted factories could not produce Thermoforming components in large enough thicknesses to create a solid board, which was previously assumed. This example was identified as a problem, yet if there still exist similar unnoticed problems, they risk making some results irrelevant for future production.

When it comes to user experience, it proved difficult to gather information from users, since few users whom had tried powder surfing were identified and interviewed. Not only were no interviews obtained from asking in the online forum on the website Freeride, it was also commented by one user on the forum that the reason for the lack of information was that powder surfing was not a frequently exercised sport in the community (Gladpack, 2026). Even though two extensive interviews were conducted with Johan Olofsson to examine the user experience of powder surfing, the risk of these answers mainly reflect professional snowboarders, still remain. This risk could have been mitigated if more interviews with non-professional riders in different settings had been possible to execute.

4.3 Unattained Results

The most prominent cause of unattained results in the project has been connected to the inability to exactly determine the structural requirements for the PS-board. This has stemmed from the inconclusive results from FEA-simulations, in combination with a lack of other available methods to determine the structural load on a powder surfer board. Due to the time restrictions of the project, the simulations were not able to be refined enough to produce reliable results. There exist other possible ways to estimate which structural requirements are present for a PS-board, such as experimental studies, prototyping or proof of concept by other similar products, however none of these methods were available within the scope of the project. No experimental studies were found regarding forces or loads on snowboards in powder snow and there were no resources for prototyping with similar materials and constructions to the explored Concepts. Some similar products were identified, such as the ski components for snowracers, yet these used methods for reaching higher structural stability such as high ribs (Siga, n.d.), which was unavailable for the project due to the requirement of low snow collection.

Due to the aforementioned issues, there were no specific requirements for mechanical properties such as yield strength, flexural strength, stiffness or impact resistance to compare the explored Concepts to, nor prototypes to test or existing products similar enough to compare to. This has led to all considered Concepts, including the Final Concept, to be unverified when it comes to structural stability in their intended use. This has also limited the produced decision-making basis from exactly determining which materials and constructions would be suitable for a PS-board. Instead, the pros and cons of various potential materials, constructions, and production processes were presented as the basis for decision-making to MCS. The immediate effect of this is that all considered Concepts would require further testing before being verified as promising constructions for PS-boards. The lack of specific requirements has also affected the measurability and quality of the List of Requirements, making it less useful as a partial result of this project.

Another factor which has greatly impacted the Final Concept is the complexity of foam-sandwich composites. The inherent complexity of the different materials interacting with each other was found to produce different failure modes for different composite structures in the Literature Review, thus affecting which mechanical parameters were most critical and needed to be dimensioned for. In the found literature, the strength and failure modes of foam-sandwich composites were assessed by using physical prototypes or complex stress-analyses, which were outside the limits for this project to replicate. This has had the effect that no values of mechanical parameters were produced for the Final Concept. Due to the uncertainty of which materials in which thicknesses would be needed in order to achieve a certain mechanical performance, an accurate assessment of the structural stability of the Final Concept was in turn hindered, which leaves a notable uncertainty to aspects of the boards performance. However, even with specific values of mechanical parameters, it would be hard to assess the Final Concepts feasibility, due to the aforementioned problems with structural validation. Due to the uncertainty of the Final Concept's strength, no exact thickness of the shell or foam could be dimensioned for any mechanical requirements, which had the effect that no thicknesses could be recommended to MCS.

The last unattained result pertains to the gliding properties of different materials on snow, which is essential for the use of the product. Due to an observed gap in the literature, in combination with the constraints on time and prototyping, no assessment has been made of the snow friction of the otherwise suitable materials for each considered Concept. This has embedded an uncertainty to the feasibility of the suitable materials which could risk rendering some considered construction and production processes obsolete. The only exception to this has been HDPE, and Concepts containing HDPE, since the material had a well-documented low friction against snow.

4.4 Final Concept and Alternative Solutions

The project's ultimate result was the formulation of the Final Concept along with the production model for MCS. However, despite great efforts, some aspects of the Final Concept have been left undecided or unverified. As previously mentioned, stress values were unable to be assessed. Therefore, another reference for dimensioning was needed, for which surfboards were chosen due to similar foam composition. However, there are still differences in their constructions as surfboards are often made out of thermoset resins, with a pre-shaped foam core whereas our proposed Concept initially forms a thermoplastic shell which is then filled with expanding foam. The differences between thermosets and thermoplastics have been explored and could have been accounted for given sufficient mechanical data. However, information about the differences between pre-shaped foam components, either injection molded or shaved to size, and the foam resulting from Foaming in Place was not found and could therefore only be speculated about. There could be a difference in the binding between the foam and exterior layer, in the worst case causing the layers to separate, significantly increasing the risk of breakage. Another risk is if the Foaming in Place is incomplete and does not manage to sufficiently fill the cavity of the shell, therefore not fulfilling its reinforcing role resulting in a weaker board and leaving it susceptible to punctures and being filled with water, snow and ice. As previously mentioned these factors compound when the materials are combined into a sandwich structure. Therefore, even the reference dimensions of the surfboard could be argued to provide insufficient basis for definite dimensioning the board. During the end of the project the dimensioning was ultimately left to the discretion of MCS, provided that they were informed with all information from the results, in order for a final production file to be created. This could mean their resulting product might not meet some of the requirements from the List of Requirements, such as being able to hold for the expected load cases. There are fortunately still things that could be altered at this stage such as the density of the foam or changing material that could improve the produced product without adding further tooling costs.

The Final Concept sought to fulfill the formulated Longevity Strategy and be as durable and long lived as possible to distribute the environmental cost of production over a longer time and discourage overproduction. The Recycled Input Strategy, of using recycled materials was also meant to be implemented if possible. However, leading to the Concept finalization some concessions were made, most of which were made to prioritize factors such as price, weight and ease of production. One major concession made was not choosing a Concept that used a thermoset composite material as it would have provided superior structural integrity and strength at a comparable or even lower weight. The reason the composite materials were not used was the high price estimates which MCS received from factories for manufacturing and tooling costs. Another concession was the choice of HDPE as material for the entire outer shell. HDPE is not an especially strong thermoplastic compared to others such as fiber-reinforced PET, but other factors such as the guarantee of excellent gliding properties along with low price and availability to manufacturers also factored in the decision.

Satisfying the Recycled Input Strategy by using recycled materials could be a partial option for the Final Concept, since HDPE is a material that is available to be recycled. As of writing, the choice between virgin and recycled HDPE has been left open. Though the availability of recycled HDPE was deemed as good, it did not compare to some thermoplastics such as PET. As a material PET, reinforced with fiber glass, could very easily be sourced out of recycled ingredients, as PET was identified as one of the most recycled plastics and short length fiber glass was attainable through recycling of other fiber glass products, since mechanical shortening of fibers was acceptable. On the other hand, the reason for PET being the most recycled, as found in the Sustainability Investigation, was because it belongs to a closed loop system of beverage containers. Removing recycled PET from this closed system would increase the need to add virgin plastic back into it, since the plastic used in the board will be significantly less likely to be recycled than a beverage container. However, easy sourcing of the plastic remains an important factor to be considered, since it does not matter whether the board can be made from recycled materials or not if they cannot be sourced. A potential manufacturer for the Final Concept would need to offer Twin-Sheet Thermoforming, low tooling costs, low material and processing costs. Adding a requirement for broad material selection to the list could prove challenging.

As mentioned, the project's ultimate results were the Final Concept, which has been tailored to fit the requirements of MCS, however the results from the project still have potential to be applied for other purposes. The Sustainability Strategies could serve as useful guidelines for product design while working with small scale plastic production. The underlying Sustainability Investigation and our interview material can in and of itself serve as an insightful basis for more research in the area. The stages of different production and material investigations can, up until phase three of the project where MCS chose the Final Concept, be drawn upon by anyone in the process of designing a plastic PS-board. Even the Final Concept could in theory be useful to other designers with similar priorities to MCS. The User Study can also provide useful insights to other designers, as it includes both expert and hobby users and is not solely centered on the development of MCS's PS-board.

4.5 Areas for further research

For any subsequent research or analyses on the subject of feasibility for low scale production of plastic powder surfers, some recommendations have been identified through the course of the project. One potential area which could be researched is the mechanical requirements which PS-boards should be dimensioned after, which could be performed on a basis of thorough FEA-simulations of stress, or perhaps testing existing products with sensors which measure the physical load applied by the user and the snow. Another experimental approach could involve developing prototypes with varying thickness, in order to derive mechanical requirements from the material properties of the prototype. A variant of this would be to focus on foam-sandwich composites, which could also be performed by stress simulations or physical testing.

Another research subject could be to make a thorough study of the friction properties of different polymers on snow. A tribological study of the suitable materials in this report on a surface of snow could resolve a major uncertainty which affects the results in this report.

If the Concepts presented in this report are to be verified further, the recommendation left for the verifying research is to perform prototype testing in combination with more contact from factories or individuals with production expertise.

One possible implication for the user of a PS-board which has not been included in this project as described in the limitations, is the semantics of powder surfers. Further research could investigate in which ways the design of a PS-board could appeal aesthetically to potential consumers, and in which way the choice and adaptation of production processes affect the aesthetics.

On a closing note, for any other authors planning their thesis on a similar time frame to this project, a recommendation is made to limit the scope of the project significantly more than what can be observed in this report. One suggestion would be to limit a future project to simply containing a thorough study of the interactions between shape and user experience, or to only research the manufacturability of a power surfer, given the suitable production processes suggested in this report.

5. Conclusion

The shape of a PS-board has several parts which affect the user experience. The Traction pads can be designed to be large to account for varying foot positioning and to not collect snow. Channels on the underside of the board are suitable for packed snow, but not powder. The Tail of the board can be made thinner in order to make the board turn easier, or wider in order to increase grip. The thickness on the board mostly affects the rider's pivot point, the effects of which are not fully explored. The Sidecut can be concave or convex in order to prioritize stability or maneuverability respectively. The length of the Nose can be adjusted for how the board cuts into the snow, with longer Noses cutting further into the snow and shorter Noses skimming more. A Camber can be added to the board to accentuate the effects of a concave Sidecut, whilst Rocker can be added to accentuate a positive Sidecut. A Spoon Nose can increase maneuverability and a Reverse Spoon in the Tail can increase stability.

For the development of plastic powder surfers for small scale production, four different Sustainability Strategies have been identified. They can be employed in order to optimize the selection of materials and production processes for achieving a positive environmental impact, through their respective methods. The Public Recycling Strategy involves designing a board recyclable in facilities available to the user, increasing accessibility to and likelihood of being recycled. The Internal Collection Strategy involves designing a board with a tailorable recycling method in mind, increasing the yield of recycling with less material degeneration by using a third-party recycling company. The Recycled Input Strategy involves increasing the use of recycled material, avoiding the emissions from refinement of virgin material and limiting waste. The Longevity Strategy involves designing the board to have a lengthened lifetime, making the embedded impacts count to an increased total benefit for the user, dispersing the impact over a longer timespan. Concepts have been generated for which production processes, constructions and types of materials fit within the respective strategies.

Four different production processes have been identified as suitable for production of plastic powder surfers; Thermoforming, Twin-Sheet Thermoforming, Polymer Casting and Vacuum-Assisted Resin Transfer Molding. Even though they were all identified due to low cost, the actual pricing as provided by specific factories may vary, and affect whether they are suitable for small scale production or not.

Different constructions were identified that could satisfy the requirements which sometimes also had their own advantages. Constructions using foam filling, well-structure, and internal structures were explored for light-weighting thicker boards made from cheaper softer materials. For added strength exterior attributes such as stiffening ribs, increased thickness and an applied fiber glass coating could be used as well. Harder materials could make thinner boards and even be reinforced with fiber glass to achieve unmatched strength. The constructions which were deemed most suitable have been analyzed as to which production process and material group they employ and therefore which Sustainability Strategy they apply to.

There are five main families of materials which are compatible with the suitable production processes in a range of configurations; unfilled thermoplastics, fiber reinforced thermoplastics, foams and thermosets reinforced with short fibers and with fiber mats. The identified unfilled thermoplastics which may be suitable were PET, SMMA, PC, ASA, AES and HDPE. The potential fiber reinforced thermoplastics contain PET, SMA and PC, with shredded glass fibers. The possible choices for thermosets with shredded fiber reinforcement were Epoxy and PA12 with glass fiber filling. The thermosets reinforced with fiber mats which might provide suitable properties were Polyester and Epoxy combined with glass fiber mats. PU, PE and PP were identified as possible foams to use for Foaming in Place, but were not fully investigated due to the complexities of using custom foam-sandwich composites. Whilst some aspects of these suitable materials have been confirmed as desirable, little to no verification has been made regarding properties for gliding on snow and structural stability.

When using Twin-Sheet Thermoforming, draft angles may need to be included into any powder surfer, which might affect the shape of the Rails and thus the user's experience. It is possible to create a seam between the upper and lower half which does not protrude from the product, and should therefore not affect user experience significantly. Some modification might need to be done depending on which method is used for fastening the Leash. This can be done by adding depressions in the top surface through the Twin-Sheet process, or by post-processes such as drilling, and subsequently adding a beam which the leash can be tied around. There exist standard components for surfboards which might be usable for powder surfers as well. Another potential method is to use post-processing methods to create holes in the Traction Pads, although there might be issues with durability. The specific effects on user experience were not defined.

The file requirements needed for general production files from plastic production have not been completely verified. However, STP files with file tolerances to the CATIA V5 standard have been observed to be satisfactory in some instances. A CAD-file has been surface modeled in Rhino 8 to produce a STP file with the aforementioned tolerances.

There exists a feasibility for small scale production of plastic powder surfers with low tooling costs. However, without further research this feasibility does depend on a multitude of factors which are uncertain unless confirmed by prototyping, which might pose an economic challenge to small-scale production due to the tooling cost.

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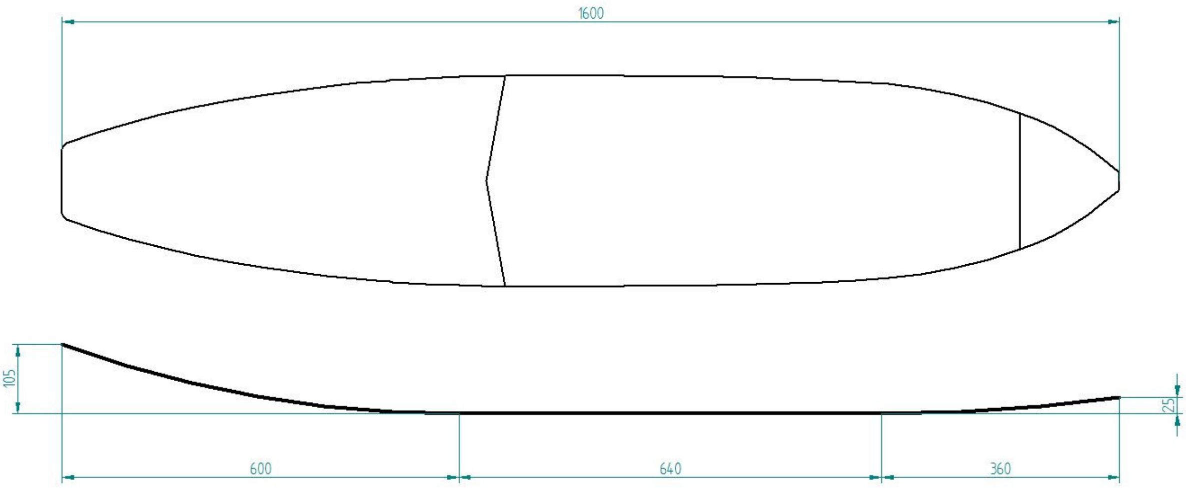
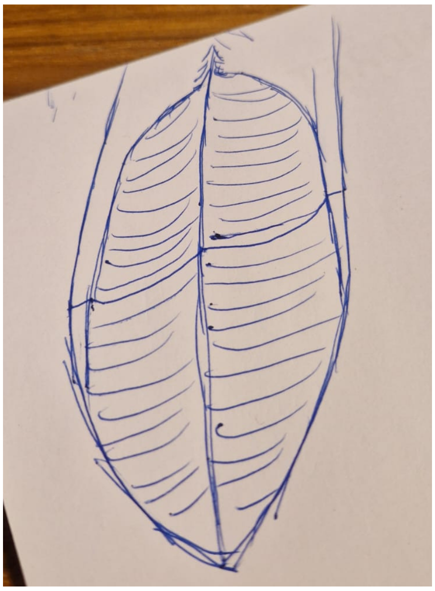
Appendix A

Received Images

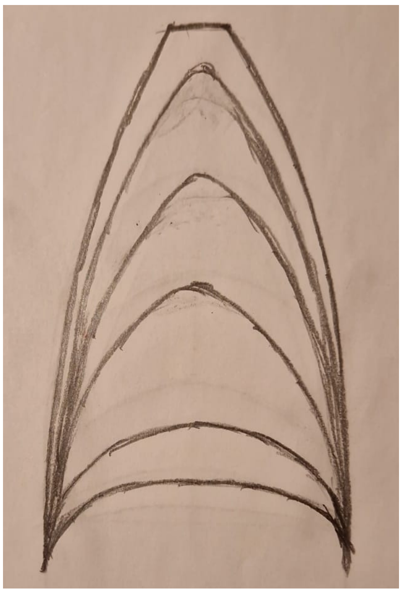
These images were received from, and were used with the courtesy of, Moonchild Snowboards and Johan Olofsson. They were used in the Shape and Design Interpretation for defining the shape of the PS-board in development and as a basis for creating the early CAD-model.



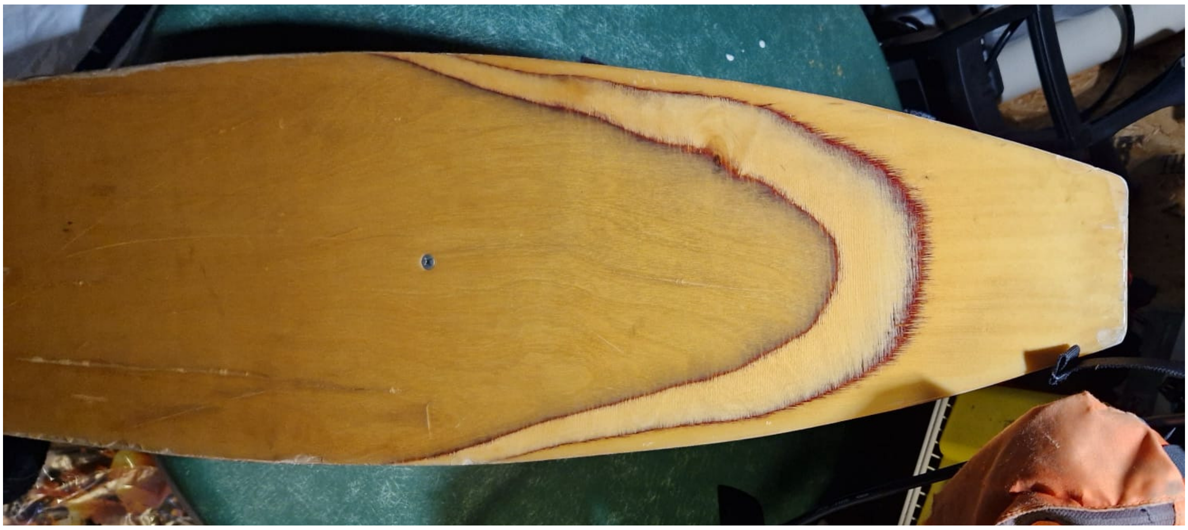
Dimensioned drawing of the top and side profiles of the board. The first received image



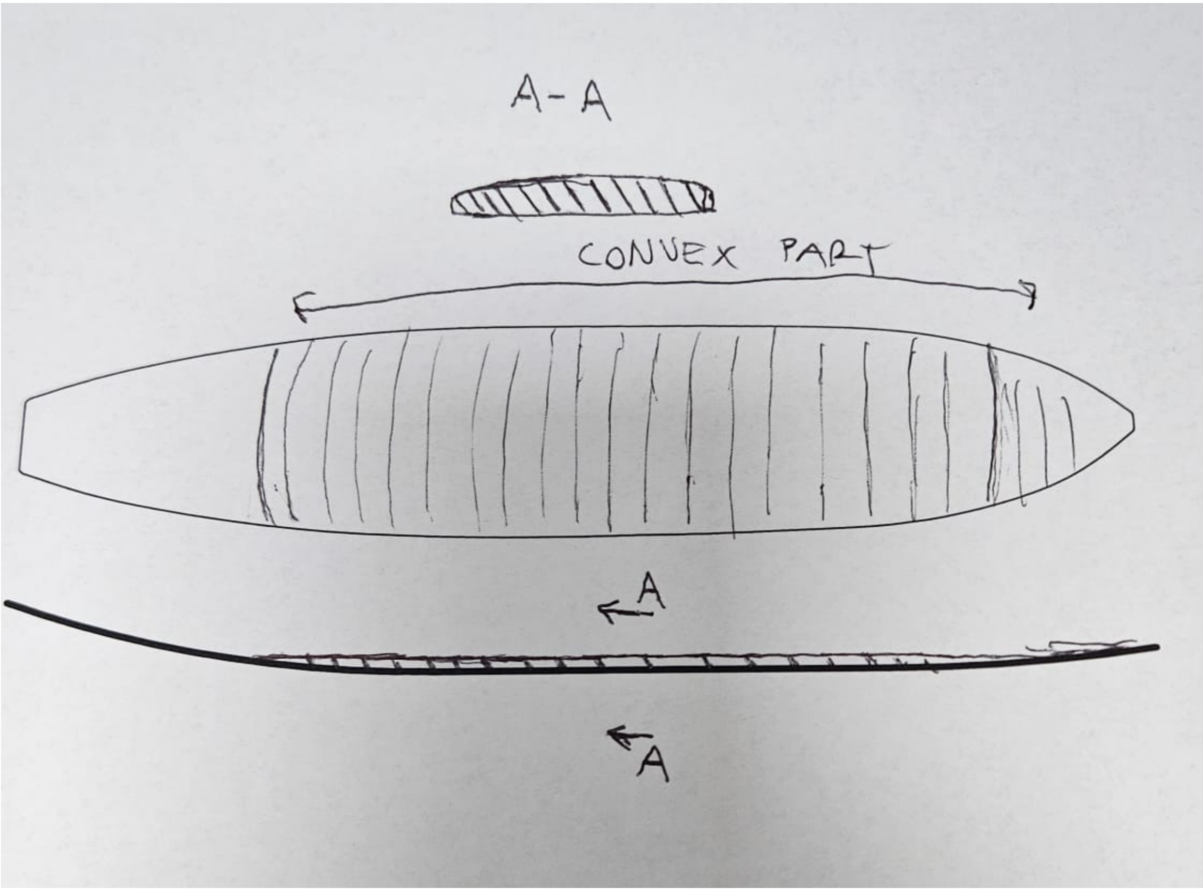
Sketch of Reverse Spoon Tail



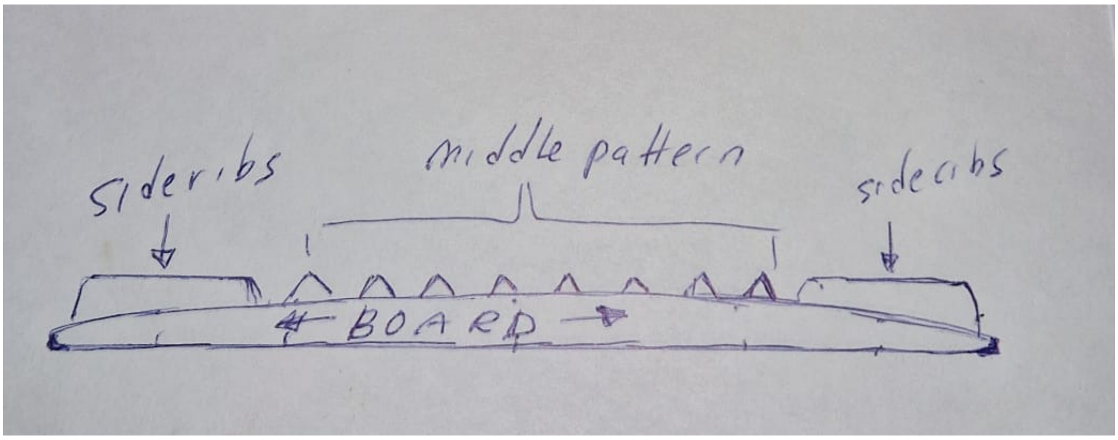
Sketch of Spoon Nose



Physical prototype with Spoon Nose design

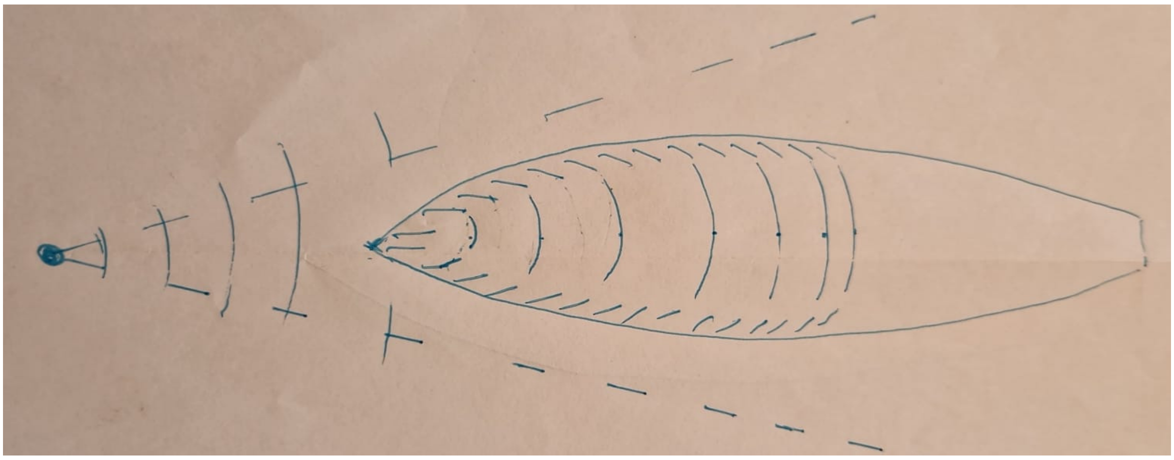


Sketch of curvature on the board top surface

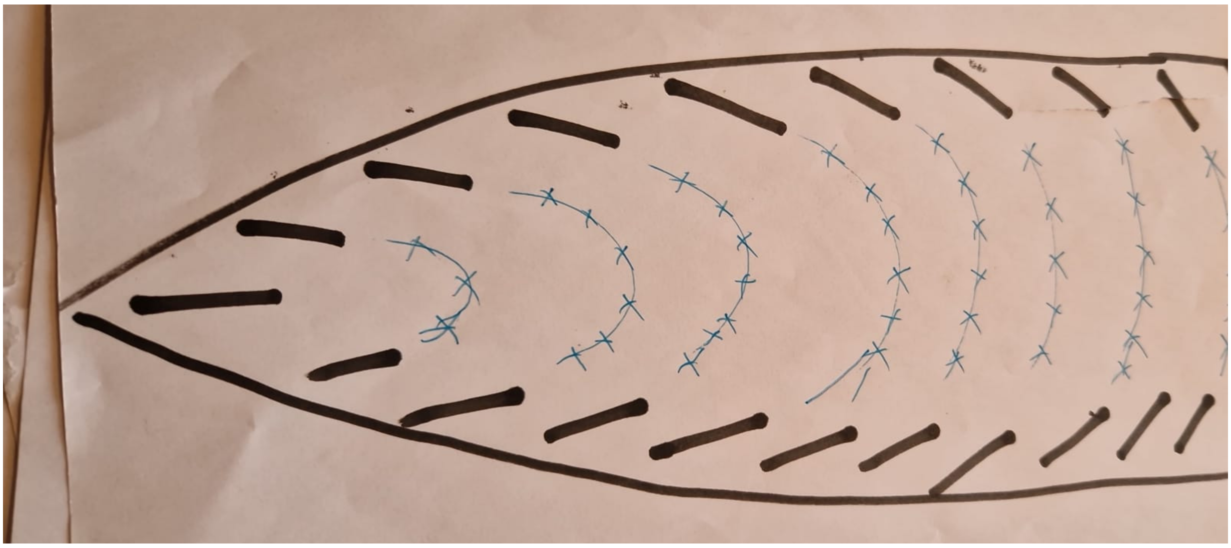


Sketch of pyramid placement along board, cross section

Handmade Traction Pads with pyramids



Sketch of radial placement of central pyramids



Sketch of central pyramid placement

Appendix B

Prepared interview questions

This Appendix contains the questions asked in the interviews or surveys in different parts of the project. The questions were asked in the Shape and Design Interpretation, User Study, Sustainability Investigation and Initial Production Analysis. In the latter two, interviews were semi-structured, entailing that some extra questions were added depending on the answers of the participant.

B1

Shape and Design Interpretation

- Kan du berätta om hur du kom fram till formen som finns idag?
- Hur kommer det sig att nosen är så pass lång och smal?
- Hur kommer det sig att tailen ser ut som den gör?
- Hade du någon särskild tanke om rocker-profil?
- Föredrar du tjock eller tunn powder surfer?
- Spelar tjockleken på kanterna någon roll?
- Kan andra former än platta traction pads vara bra?
- Hur stora krafter utsätts en powder surfer för?
- Hur har du tänkt kring grafik?
- Vad är skillnaden på positiv och negativ sidecut och hur påverkar det åkningen?
- Har man nånsin camber i en powder surfer, eller alltid rocker?
- Brädan vi jobbar på har en lång och smal nos, hur fungerar andra varianter av nosar?
- Hur påverkar spoon och reverse spoon åkningen?

B2

User Study

- När upptäckte du powder surfing?
- Var det kul redan från början eller först när du hade åkt powder surfer ett tag?
- Kan du beskriva upplevelsen av att åka en powder surfer?

- Finns det saker du kan göra med en vanlig snowboard som du inte kan göra med en powder surfer?
- Finns det saker du kan göra med en powder surfer som du inte kan göra med en snowboard?
- Hur stora traction pads du vill ha på en powder surfer?
- Finns det något du saknar när du åker på en powder surfer?
- Finns det något du saknar när du åker snowboard?
- Har du haft några dåliga upplevelser med powder surfers? Varför?
- Vart på brädan upplever du att du placerar trycket på en powder surfer när du svänger?
- Är det viktigt för dig att effektivt kunna överföra tryck till kanten?
- Påverkas upplevelsen av flexen hos powder surfern?
- Vad tycker du är viktigast när du väljer traction pads?

B3

Sustainability Investigation

- Återvinns hårdplaster oftare än mjukplaster?
- Är det skillnad på hur mycket mekanisk och kemisk återvinning som används?
- Vi har hittat information om att ABS går att återvinna, men vi har inte hittat någon aktör som gör det, känner du till någon?
- Hur påverkar additiv återvinningen?
- Görs det idag produkter av återvunnen förpackningsplast?
- Vart får företag tag på återvunnen plast?
- Har du råd till företag som skapar nya plastprodukter?
- Vilka är de främsta anledningarna till att vissa inlämnade plastprodukter inte går att återvinna?
- Är infrarött ljus vanligt som sorteringsmetod?
- Tar ni emot plastprodukter utan märkning på vilken plast det är? Vet ni om andra länder gör det?
- Om man gör produkter av återvunnen plast, går de ofta att återvinna en andra gång? Varierar det mellan plaster? Hur är det för HDPE, ABS, PET eller PLA?

- Om man har en komponent som till mesta del består av en återvinningsbar plast men har silikon fastlimmat på sig, går det att separera och återvinna enkelt via t.ex. mekanisk nedbrytning? Eller måste alla olika material kunna tas isär för hand?
- Blir det någon skillnad på egenskaperna hos en återvunnen plast beroende på vilken nedbrytningsmetod som använts i återvinningen?
- Går det att återvinna en komponent som består av en enda plast, men som har variationer i färg och/eller tillsatser?
- Har ni fler råd till oss designers på hur vi bäst kan skapa plastprodukter som går att återvinna?
- Vilken förändring hade du velat se i dagens återvinning av plast?
- Finns det särskilt dåliga additiv?
- Vilka plaster fungerar bäst för återvinning?
- Vilka plaster går oftast till materialåtervinning istället för energiåtervinning?
- Hur kan man arbeta med hållbarhet in i kompositproduktion?
- Vilka utmaningar finns det med att återvinna kompositer?
- Slits tillverkningsverktyg fortare om man använder återvunna termoplastkompositer i dem?
- Hur kan man arbeta med hållbarhet in i kompositproduktion?
- Känner du till några fibrer som potentiellt skulle funka i produkter där hållbarheten är viktigare än prestandan?
- Hur stor andel av den inlämnade plasten ni får går till nytt material?
- Här i Sverige har vi bra återvinning, men vet ni hur mycket plaståtervinning i resten av världen som faktiskt blir till nya plaster och inte bara bränns för energi?
- Vet du hur den mekaniska prestandan förändras för plaster som återvinns?
- Har ni någon data på hur olika återvunna plasters egenskaper (såsom styvhet, smältpunkt, osv) skiljer sig från nyproducerad plast av samma sort? Eller vet ni vart det går att få tag på?
- Finns det någon anledning till att återvunna plaster skulle vara sämre än nyproducerade i tillverkningsprocessen av en ny produkt? t.ex. att dess viskoelastiska egenskaper förändrats.

B4

Initial Production Analysis

- Vår form kan i stora drag beskrivas som ett tunt avlångt rätblock (ca 4*30*150cm). Om denna tillverkas via Rotomolding, kommer tjockleken och kvaliteten av plasten variera mycket inom komponenten?
- Blir det olika egenskaper i Rotomolding i "ändarna" på rotationsaxeln?
- Funkar Rotomolding bra på helt massiva komponenter utan håligheter?
- Hur ordnar sig polymererna inuti plasten om man gjuter dem via t.ex. Rotomolding?
- Om Thermoforming används för att forma en extruderad plast, kommer fiberriktningen att behållas och kan det ge några fördelaktiga materialegenskaper?
- Kan man variera tjockleken på komponenten genom Thermoforming även om man börjar med ett jämnt extruderat ark?
- Om inte, kan man variera tjockleken genom att börja med ett ark med varierande tjocklek, eller finns det bättre metoder för detta?
- Kan man utföra Thermoforming och stansning i ett steg? Blir det billigare?
- Hur kan ett byte till återvunnet material påverka produktionen för Rotomolding, Thermoforming, extrudering?
- Vilka egenskaper är viktiga hos en plast för att funka med Rotomolding, Thermoforming, extrudering?
- Brukar man kunna blanda olika färger vid gjutning eller extrudering av plaster för ett "tie-die" mönster?
- Har vi missat någon lämplig produktionsmetod för små serier?
- Skiljer sig de mekaniska egenskaperna hos en plastkomponent mycket beroende på produktionsmetod?
- Brukar man använda en och samma extruderare, rotomoldmaskin, etc. för produktion av flera olika plaster, eller vill man särskilja vilka maskiner som kommer i kontakt med olika polymerer?
- Kan det bli problem i produktionen om man kör återvunna plaster i samma maskiner som vanliga plaster?

Appendix C

Setup of programs

Below are the descriptions of the setups used in different computer softwares in order to obtain results for the Initial Production Analysis, Material Screening and Concept Selection and Assessment.

C1

Production Analyses - Granta EduPack

The analysis of thermoplastic production processes used the filtering tool *Limit* on batch sizes between 100 and 1000, as many processes for thermoplastics were adapted to significantly larger batch sizes and therefore had excessively high initial costs. The upper limit of 1000 units was chosen to include additional production processes than would otherwise not have been taken into account, due to a shortage of suitable processes presented. An additional *Limit* was set for a maximum unit price of 50 euro to exclude specialized processes designed for high-performance plastic components. It was set to 50, even though the specified requirement for production cost was 30 euro, since there was a chance of possible processes just outside the specified range. Lastly, a graph was created showing the initial *Capital Cost* and *Relative cost index (per unit)* for production processes across the respective batch sizes using *Chart/Index*.

The analysis of thermoset production processes used a batch size *Limit* of less than 100 units to exclude methods suited for larger batch sizes and higher initial costs. A chart was then created using a *Chart/Index* to plot the initial C*apital Cost* and *Relative cost index (per unit) of* production processes. Afterwards the production processes with the most favorable characteristics were selected based on the information from the graphs, as well as which ones were deemed capable of producing the product's form, according to the information sheets for each production process.

C2

Material analyses - Granta EduPack

The analysis was conducted on the materials the database considered suitable for the production process of Thermoforming, Polymer Casting, and Vacuum-Assisted Resin Transfer Molding (VARTM), with the goal of identifying the materials with the most optimal mechanical properties for each process. For Thermoforming, two analyses were performed to cover both fiber-reinforced and unfilled thermoplastics. For the analysis of unfilled thermoplastics, the *Tree* tool was first used to filter the materials in the database to include only thermoplastics, after which the *Limit* tool was set with the *Polymer Thermoforming* setting to exclude plastics not suitable for the production process. *Limits* were also set to restrict the maximum price to 50 SEK/kg, minimum young's modulus to 0.3 GPa, minimum fracture toughness to 1 MPa*m^0.5, minimum toughness to 1 kJ/m^2, maximum minimum service temperature to -20 degrees Celsius, water resistance to the values *Acceptable* and *Excellent*, and UV resistance to the values *Fair*, *Good*, and *Excellent*. To ensure no fiber-reinforced thermoplastics were included, a *Limit* was set with the *Polymer* setting at a minimum of 100%. For the analysis of fiber-filled thermoplastics, the same *Tree* and *Limits* as above were used, with the exception of the *Limit* on *Polymer* set to a minimum of 0% to allow for fiber filling, and a *Limit* restricting the minimum tensile strength to 100 MPa.

The analysis of materials for Polymer Casting began with a *Tree* using the *Polymer Casting* setting to filter out materials that were not suitable for this production process. *Limits* were set to restrict the maximum price to 50 SEK/kg, minimum modulus of elasticity to 6 GPa, minimum fracture toughness to 1 MPa*m^0.5, minimum impact toughness at 23 degrees Celsius with a notch to 1 kJ/m^2, maximum minimum service temperature to -20 degrees Celsius, water resistance to *Excellent*, and UV resistance to *Fair*, *Good*, and *Excellent*.

For the VARTM analysis, *Tree* was used with the *Vacuum-assisted RTM* setting to filter out materials that did not work for the production process. *Limits* were set to restrict the maximum price to 50 SEK/kg, minimum modulus of elasticity to 6 GPa, minimum fracture toughness to 1 MPa*m^0.5, minimum impact strength to 1 kJ/m^2, maximum minimum service temperature to -20 degrees Celsius, water resistance to *Excellent*, and UV resistance to *Fair*, *Good*, and *Excellent*.

For all analyses, graphs were created using *Chart/Index* to compare the parameters *Density*, *Price*, *Yield Strength*, and *Young's Modulus* for the materials that had not been filtered out. The remaining materials were then grouped by their primary polymer type, such as HDPE, SMMA, etc. This was done by removing all instances that, according to the graphs, did not possess the most favorable properties within their polymer type, via the *Remove from subset* function. Then the primary polymer types with the most favorable properties were selected, based on the information from the graphs. Some of the selected materials were also filtered out due to their well-known environmentally hazardous properties, or inability to be used in the researched production process. Finally, the analyses produced a collection of suitable materials for each production process.

C3

EcoAudit - Granta EduPack

The EcoAudits were performed by selecting the most suitable materials available in Granta EduPack for the Concepts representing each production process. To perform the EcoAudit, the weight of the different components of the Concepts was needed as an input. However, the weights could not be calculated until a final CAD-model had been created, which would only be done for the Final Concept. Thus, only approximations of weights could be used for comparison. The Polymer Casting and Thermoforming Concepts were likely to be heavier since they were made with solid thermoplastic which need more mass to achieve the same strength as thermoset constructions. The VARTM Concept on the other hand was made from thermosets, which would reduce the required material use significantly, in turn lowering weight. The Twin-Sheet Concept included foam between its outer thermoplastic layers, which is produced to achieve a very low density. The foam would help with adding leverage and therefore strength to the construction, with a reduced weight of material used. The Twin-Sheet Concept would therefore likely have a lower weight compared to Polymer Casting and Thermoforming, but the same or somewhat higher weight than the VARTM Concept. The approximations of weight used were: Twin-Sheet was given a total weight of 2.5 kg, Thermoforming a weight of 3 kg, and VARTM and Polymer Casting were both given a weight of 2 kg.

Appendix D

Lists of Insights

This Appendix contains the insights which were compiled from the information gathered from interviews conducted in the Shape and Design Interpretation, Sustainability Investigation and Initial Production Analysis.

D1

Shape and Design Insights - Olofsson

- A large traction pad allows for a broad range of foot positioning, which is useful for weight redistribution during riding. They can be useful when placed anywhere on the board apart from on top of the nose.
- Snow must not get caught in the Traction Pads, it needs to be easy to remove during riding. Neither water must be absorbed into the pads because it will freeze.
- EVA foam is often used for the Traction Pads but it gradually begins to absorb water with age. Traction pyramids are another solution, which can be made with silicon.
- Channels are concave shapes on the bottom of a PS-board which are similar to the Reverse Spoon, but exist along the entire edge of a board. They are useful for handling packed snow, but become more restrictive for the user in powder snow.
- For riding in powder snow applying pressure along the rail becomes less desired. It can however be desirable for passing through sections of worse quality snow.
- Flexure in the board is not necessary when surfing. The PS-board can even be mostly stiff.
- A leash between the rider and board is useful for not allowing the board to continue gliding down the hill if the rider falls off the board or dismounts it. During a fall, it is important that the leash is long enough to allow the board to continue traveling and create a safe distance so a rider does not hurt themselves by colliding with the board.
- A pintail shape allows for easier turning as it reduces contact with the snow at the rear of the board, whereas a fishtail increases the grip of the board.

- The thickness of the board affects the center of gravity and changes the pivot point while turning. The precise effects of the thickness are not well explored but could relate to the transfer of force during turning.
- A negative side-cut is primarily used to angle into and cut through the snow and is characterized by grip and stability whereas a positive side-cut is used to surf and flow on top of it, which allows it to easier change direction in a “looser” manner.
- A longer thinner board nose makes it more inclined to start turning gradually, whereas a shorter, broader nose is better at skimming on top of the snow.
- A camber is an upwards lift in the center of the board, that is used in combination with a negative side-cut to accentuate the cutting force with the help of elastic flexure of the board, whereas a rocker is an upwards lift in the nose or tail which accentuates the properties of a positive side-cut.
- A Nose Spoon profile reduces resistance from the snow by redirecting it outward while a Reverse Spoon accentuates it by directing it inward. The resistance can be used for increased stability, enhanced steering or reducing friction depending on where on the length of the board it is positioned.

D2

Sustainability Insights - Granström

- Property adjacent collection and local recycling stations in Sweden are designed exclusively to handle packaging, since it is financed by the extended producer responsibility (EPR). The rest of the plastic waste is a municipal responsibility. Thus, municipal recycling centers are designed for all other types of plastic waste.
- A lot of Municipalities in Sweden send waste from the municipal recycling centers to incineration and energy recovery facilities instead of recycling the plastic into new material, due to a variety of reasons.
- Some of the biggest challenges with managing recycled plastic are not whether it is possible, but whether it is financially practical for the relevant actors. There are a lot of different factors which affect the cost of choosing recycling.
- There are chemical and mechanical recycling methods, but only mechanical recycling is currently used in a large scale. Mechanical recycling is simpler but causes defects in

the recycled material, while chemical recycling is similar to manufacturing virgin material and is therefore more energy-intensive but produces higher-quality results. Both methods require feedstock of high quality, and prior sorting is thus necessary to exclude materials with insufficient quality.

- Additives in the plastic which do not disappear during re-melting cause contamination in the recycled material; dirt also causes contamination but can be removed by washing, at the cost of shortening the chain length of the polymers and lowering the quality of the output. Therefore, the choice of washing feedstock is a balance between cleanness and degradation. Warm washing with chemicals removes more contamination, but also causes more degradation whilst cold washing without chemicals is more lenient, but works worse with severely contaminated plastic.
- Recycled plastic from packaging is one of the largest sources for recycled plastic since packaging is one of the material's primary applications. Therefore, packages are effective to regulate and collect through extended producer responsibility.
- Using recycled plastic from packaging for other products is usually a form of downcycling compared to recycling/upcycling from a systemic perspective, since food packaging especially must meet strict requirements and a high quality.
- Recycled packaging can consist of 100% recycled materials in some cases, whilst other cases might require some virgin plastic to be added in the mix of polymers, for example as a surface layer in contact with the product or in order to improve mechanical properties.
- If one wishes to use recycled material in a product, one can use post-consumer recycled material (PIR), but these are difficult to source and may be contaminated. Alternatively, one can use post-industrial recycled material (PIR), but in that case there might also be a question of whether it is more sustainably beneficial for the industrial process to be streamlined, so less waste is produced to begin with.

D3

Sustainability Insights - Juntikka

- Composites are primarily used for and developed with a focus on high-performance and low weight. Sustainability is a difficult aspect to integrate into composites, which requires a holistic thinking throughout the entire life cycle of such materials.
- EOL is a challenging area for composites, as many materials are mixed, in both thermoset- and thermoplastic based composite products.
- For high-performance composite material, thermosetting resin matrixes are used along with high performance fibers, and in such cases, recycling the fibers is usually the only viable option. The fiber materials, such as carbon fiber, can be separated from the surrounding thermosetting resin through methods such as chemical recycling or pyrolysis; the latter also serves as a form of energy recovery for the thermoset part.
- Glass fiber based thermoset composites can, in terms of recycling, primarily be broken down and used as filler material for other material manufacturing, typically in the construction industry.
- Thermoplastic composites can primarily be recycled into lower-performance composites with shorter fiber lengths after, for example, size reduction followed by re-melting and extrusion.
- For composites, modularity is a useful tool for improving sustainability, as damaged components are usually difficult to repair. By applying modularity, they become easier to replace.
- For composites, sustainability improvements during use are also beneficial, especially as light-weighting in the transportation sector. Examples include reduced operational emissions or extended service life.
- Composites can be produced from a single base material as both fiber and matrix, but this requires highly specialized processes, facilitating the subsequent recycling.

D4

Sustainability Insights - Jansson

- The business model matters as the ownership of the product affects how much it is used across its lifetime. A seasonal product like a snowboard owned by a single person is only used during that season. Whereas a distributed ownership model like hiring allows for a greater extent of use during the season. Another way of increasing the use of the product is to facilitate second hand use.
- What governs the number of times the polymers can be recycled is the purity of the polymers. The purity of the polymers can be affected by additives to the plastic which lose their properties as they are diluted when mixed with other plastics during recycling. Damage, dirt or degradation the plastic is exposed to through use also lowers the molecular chain lengths and purity. Under good conditions plastics can be recycled between ten and fifteen times. However, the reheating that occurs during recycling causes molecular denaturing caused by free radicals formed in the plastic. This can be counteracted with the addition of antioxidants which can increase the number of remanufacturing cycles to upwards of twenty times, at which point the quantity of reacted antioxidants itself makes the polymers unusable.
- PET is a plastic with a very successful closed recycling loop for drink bottles, because it retains qualities for food safety. Which means it can be a poor material choice when sourcing recycled plastics for other products.
- Most products that don't have extended producer responsibility, unlike packaging, batteries, vehicles and electronics are exceptions to this, aren't covered by regulations as to what extent they need to be recycled. Then it usually becomes the responsibility of regional governments in which case there is no guarantee the waste will be recycled.
- Components that contain multiple plastic types can sometimes be separated, i.e. by putting them in water baths so that materials that float can be sorted from materials that sink.
- An efficient way to ensure a high degree of recycling for a product is for the company to collect the products at EOL and create a dedicated recycling process. This way a high amount of oversight into additives and material purity can be maintained which

results in high quality recycled materials that can be reused to directly produce new products.

D5

Production Insights - Almefelt

- PP has the properties of becoming brittle during sudden impact, whereas PE does the opposite. Rubberizing additives can decrease brittleness while lowering its stiffness, which makes PP a viable material for manufacturing car bumpers.
- The material can be reinforced. Carbon fiber might not be suitable for environmentally friendly production as they are an energy intensive material. Glass fiber will also increase the impact resistance, although with high adhesion the material will become more rigid and strong, whereas lower adhesion conversely raises the impact resistance even higher.
- Longer fiber lengths generally increase impact resistance.
- Using fiber glass makes separation of material and recycling very problematic.
- PE and PP should glide well on snow
- Rubberizing PP will make recycling difficult. HDPE will require geometry adaptations in order to achieve equivalent stiffness.
- Adaptations in geometry for torsional stiffness can in its simplest form consist of ticks in the surface. Rails can be placed in the material, which should be manufacturable with Thermoforming. Diagonal placement will give the most torsional stiffness.
- Foam normally adheres well to some polymers, especially fat polymers. The receiving surface can also be prepared to adhere better to the foam.
- By injecting expanding PP-foam into a PP shell, it should be possible to produce a mono-material with varying density.
- Pre-cut foam blanks could work well with a thermoformed shell, but it would not adhere as well as injected foam.
- By Thermoforming extruded sheets, it is possible to choose the grain direction, unlike molding processes.
- It is possible to thermoform several sheets into different shapes and weld them together, i.e. with vibration welding.

- By using two tools, an extruded sheet can be thermoformed with varying thickness, creating different shapes on the top and bottom side. The shape in this project does not seem to have enough deviations in shape for Thermoforming.
- It is possible to thermoform several extruded sheets together to create a result with increased thickness.
- The thicker a component created with Thermoforming or Rotomolding is, the higher risk of warping.
- When mechanically recycling polymers, the chains are shortened, which makes the resulting plastic more brittle.

D

Production Insights - Xu

- Polymer casting can be problematic for fiber reinforced composites due to critical risks caused by defects.
- Short-fiber composites exist in spray form, where fibers and unhardened resin is applied to the exterior surface of a component via spray and then left to harden. This works well to achieve complex geometry.

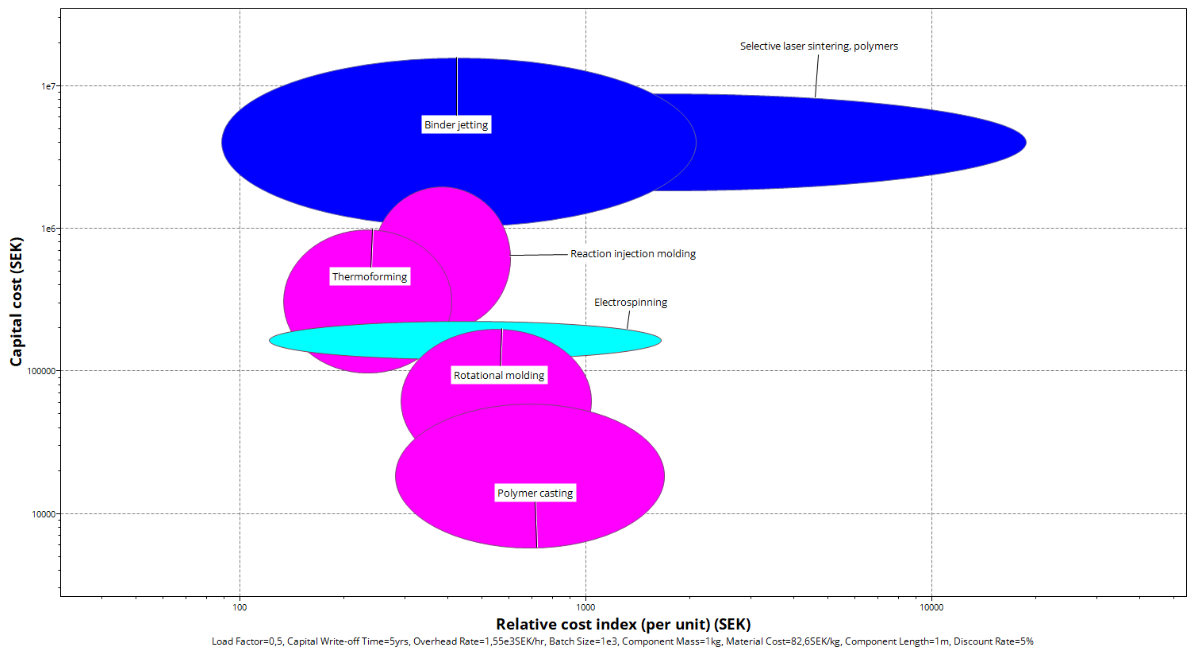
Appendix E

Results from programs

This Appendix contains the results from the simulations and analyses performed in different computer softwares, the setup of which are described in Appendix C. These softwares were used in the Initial Production Analysis and Material Screening. The results from the software used in the Concept Selection and Assessment are present under the Results chapter.

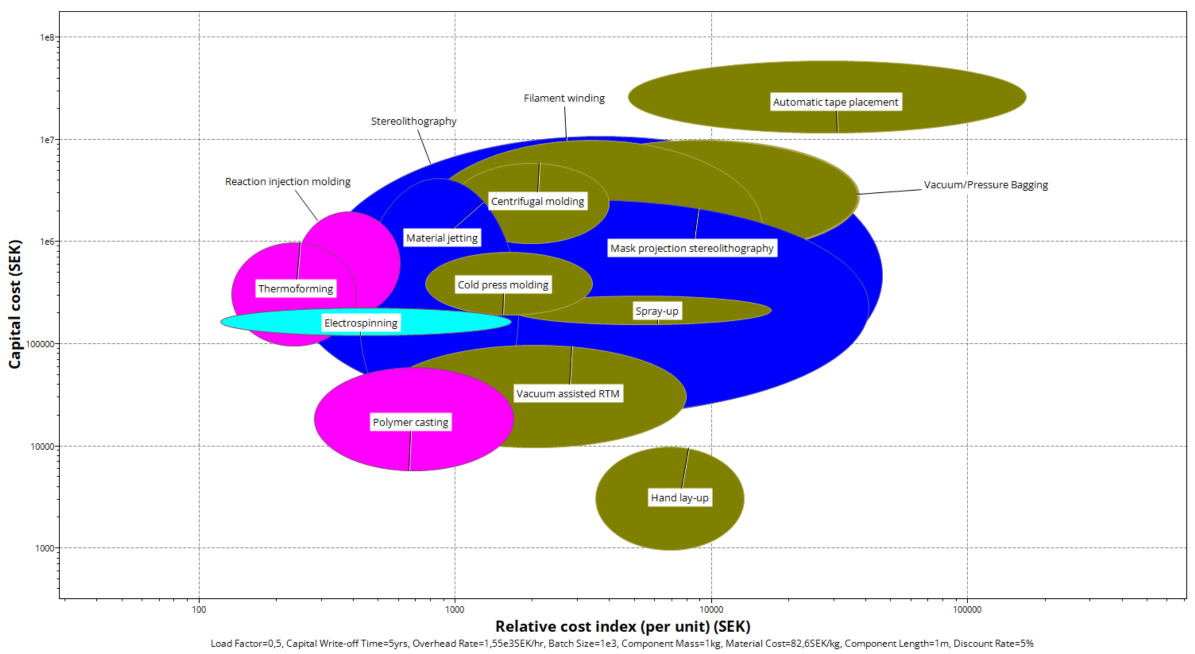
E1

Production analysis - Granta EduPack



Graph of available thermoplastic production processes

Images used courtesy of ANSYS, Inc.

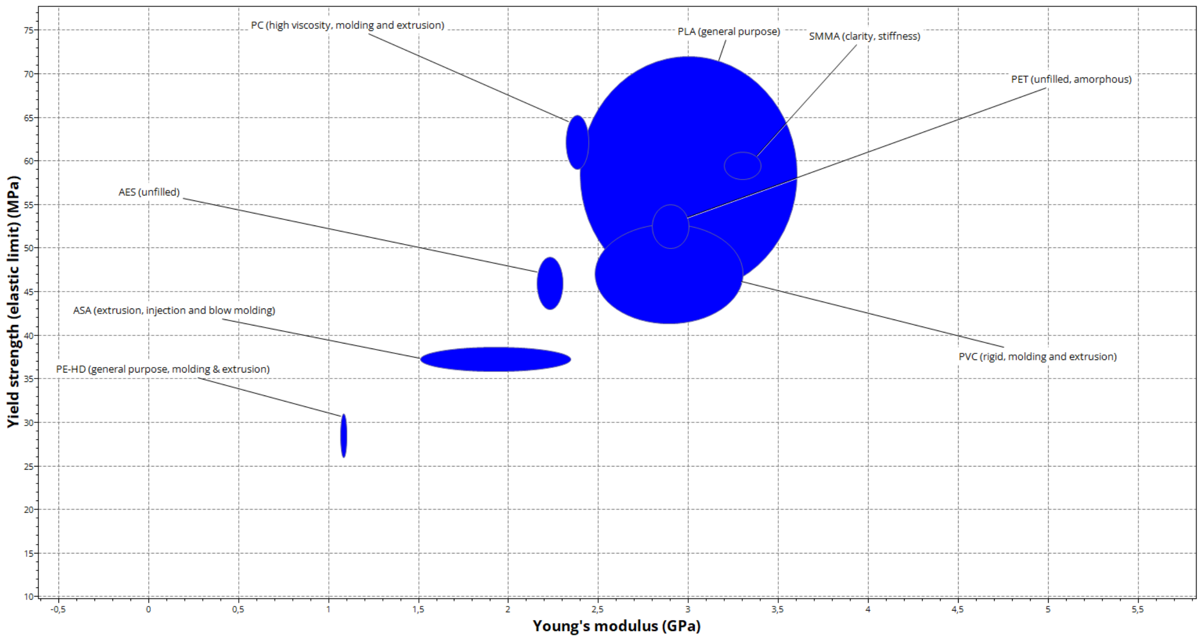


Graph of available thermoset production processes

Images used courtesy of ANSYS, Inc.

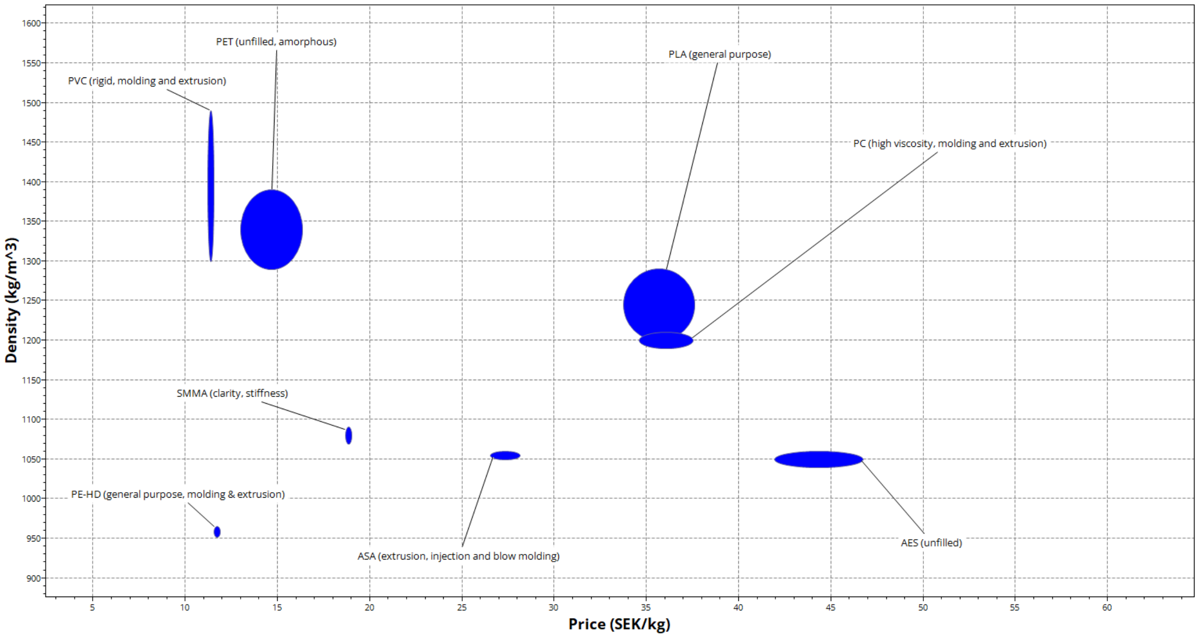
E2

Material Screening - Thermoforming - Granta EduPack



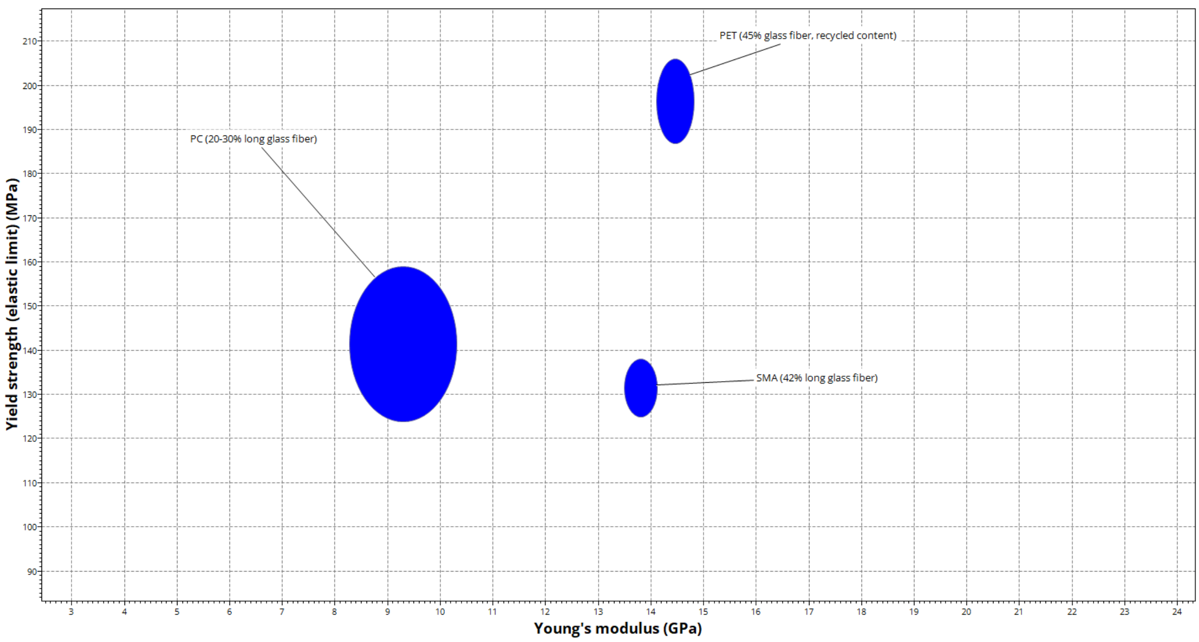
Final graph for unfilled thermoplastics for Thermoforming, measured by Yield strength and Young's modulus

Images used courtesy of ANSYS, Inc.



Final graph for unfilled thermoplastics for Thermoforming, measured by Density and Price

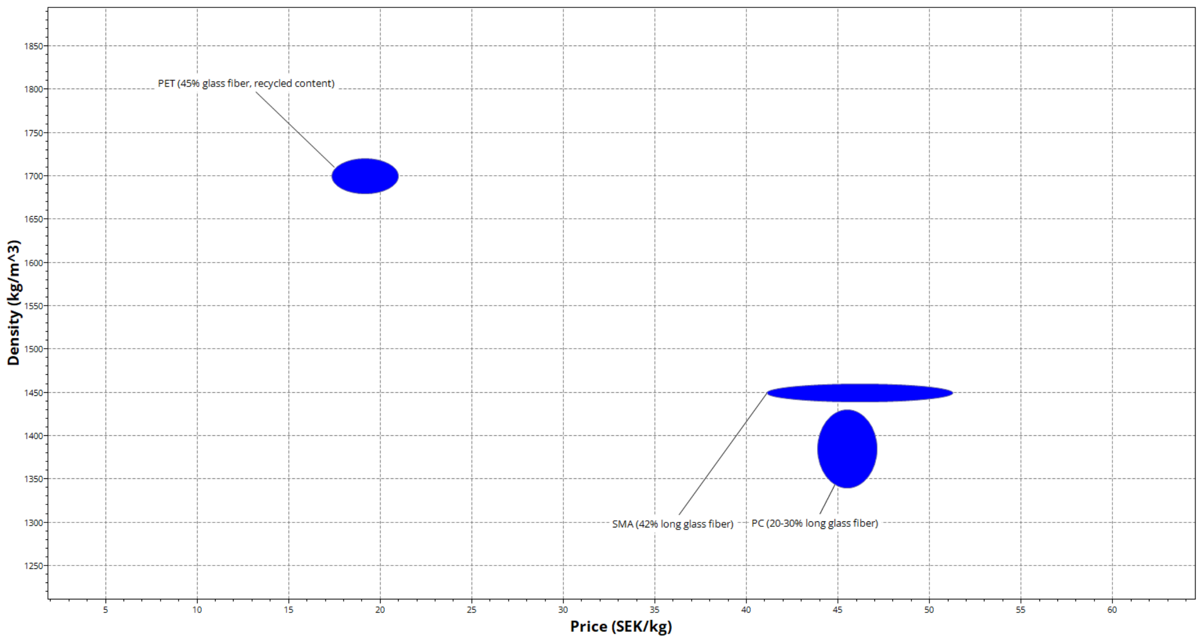
Images used courtesy of ANSYS, Inc.



Final graph for fiber-reinforced thermoplastics for Thermoforming,

measured by Yield strength and Young's modulus

Images used courtesy of ANSYS, Inc.

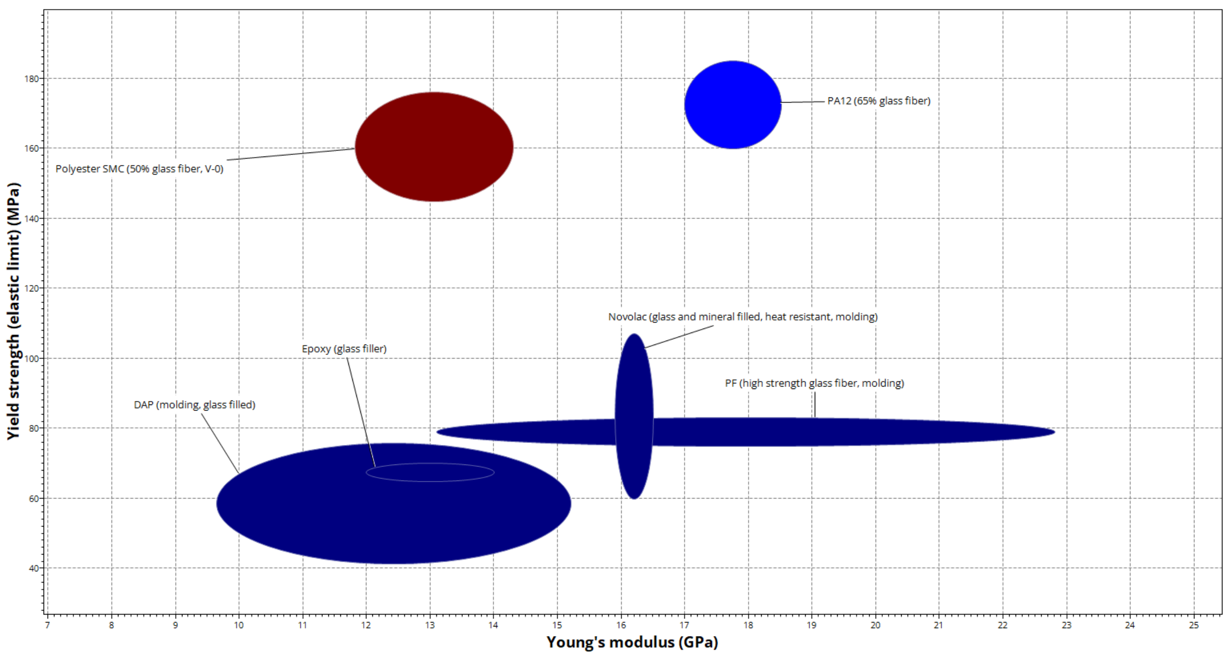


Final graph for fiber-reinforced thermoplastics for Thermoforming, measured by Density and Price

Images used courtesy of ANSYS, Inc.

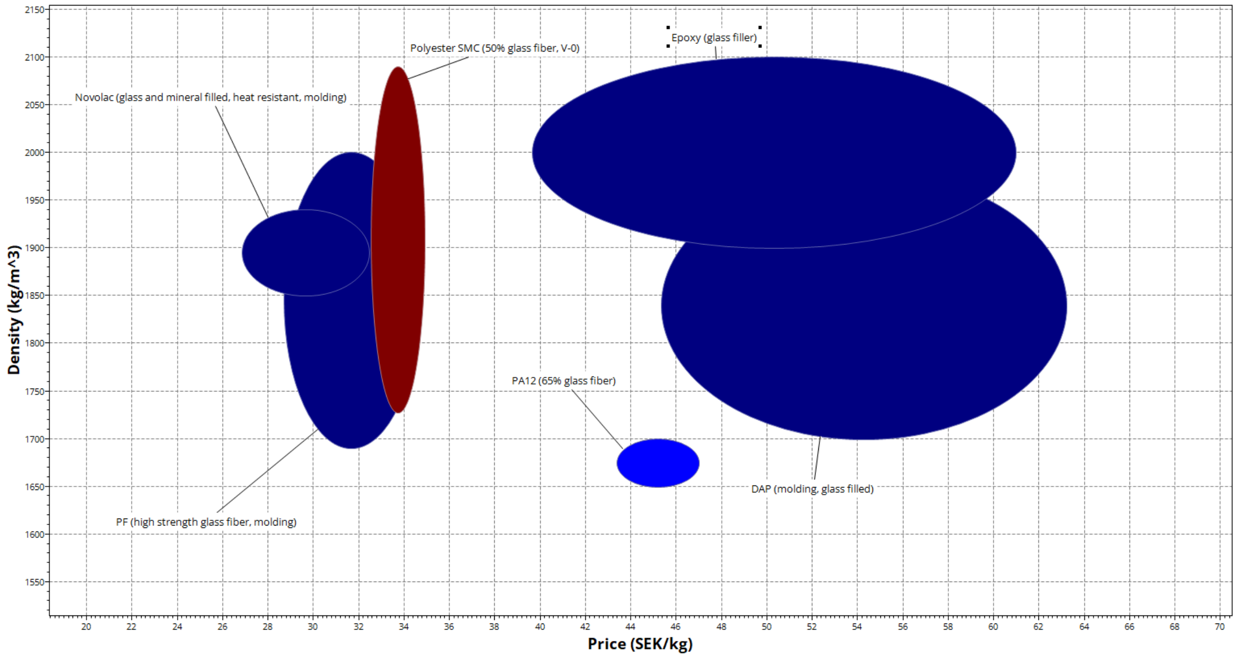
E3

Material Screening - Polymer Casting - Granta EduPack



Final graph for Polymer Casting, measured by Yield strength and Young's modulus

Images used courtesy of ANSYS, Inc.

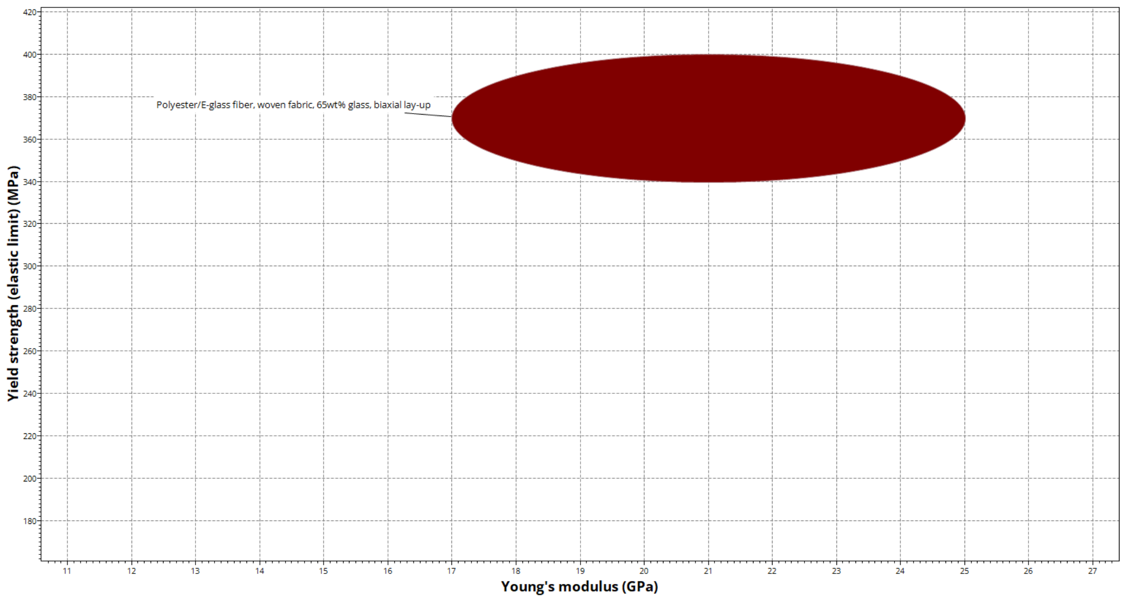


Final Graph for Polymer Casting, measured by Density and Price

Images used courtesy of ANSYS, Inc.

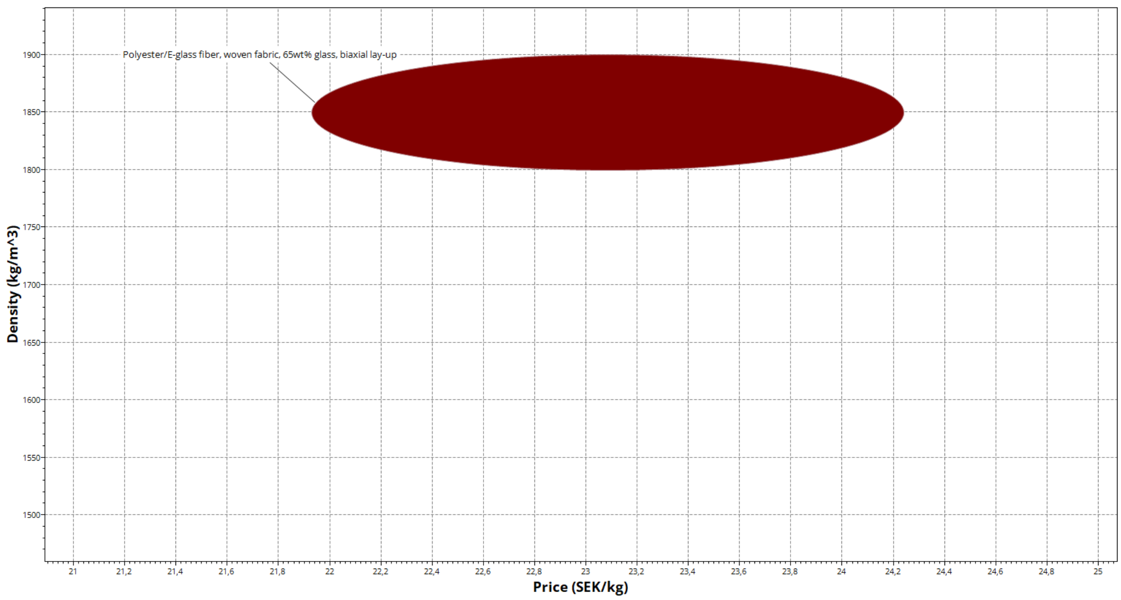
E4

Material Screening - VARTM - Granta EduPack



Final graph for VARTM, measured by Yield strength and Young's modulus

Images used courtesy of ANSYS, Inc.



Final graph for VARTM, measured by Density and Price

Images used courtesy of ANSYS, Inc.

Appendix F

List of Concepts

This Appendix includes the List of Concepts generated through the use of the Morphological Matrix.

Create Shell	Create stabilizing interior	Outer reinforcement	Joining method	#Process Steps	Included Material Types
Rotomolding	Foaming in place	Outer Fiber Reinforcement	Resin	3	Thermoplastic, Foams, Fiber glass, Resin
Rotomolding	Foaming in place	Outer Ribs	Without joining method	2	Thermoplastic, Foams
Rotomolding	Foaming in place	Extra Thickness	Without joining method	2	Thermoplastic, Foams
Rotomolding	Foaming in place	Silicone Bumpers	Glue	4	Thermoplastic, Foams, Silicon, Glue
Rotomolding	Foaming in place	Without Reinforcement	Without joining method	2	Thermoplastic, Foams
Thermoforming in two halves	Foaming in place	Outer Fiber Reinforcement	Plastic Welding, Resin	5	Thermoplastic, Foams, Fiber glass, Resin
Thermoforming in two halves	Foaming in place	Outer Ribs	Plastic Welding	4	Thermoplastic, Foams
Thermoforming in two halves	Foaming in place	Extra Thickness	Plastic Welding	4	Thermoplastic, Foams
Thermoforming in two halves	Foaming in place	Silicone Bumpers	Plastic Welding, Friction	6	Thermoplastic, Foams, Silicon
Thermoforming in two halves	Foaming in place	Without Reinforcement	Plastic Welding	4	Thermoplastic, Foams
Thermoforming in two halves	Pre-shaped Foam	Outer Fiber Reinforcement	Plastic Welding, Resin	5	Thermoplastic, Fiber glass, Resin
Thermoforming in two halves	Pre-shaped Foam	Outer Ribs	Plastic Welding	4	Thermoplastic
Thermoforming in two halves	Pre-shaped Foam	Extra Thickness	Plastic Welding	4	Thermoplastic
Thermoforming in two halves	Pre-shaped Foam	Silicone Bumpers	Plastic Welding, Friction	6	Thermoplastic, Silicon
Thermoforming in two halves	Pre-shaped Foam	Without Reinforcement	Plastic Welding	4	Thermoplastic
Thermoforming in two halves	Well-Structure through Thermoforming	Outer Fiber Reinforcement	Plastic Welding, Resin	5	Thermoplastic, Fiber glass, Resin
Thermoforming in two halves	Well-Structure through Thermoforming	Outer Ribs	Plastic Welding	4	Thermoplastic
Thermoforming in two halves	Well-Structure through Thermoforming	Extra Thickness	Plastic Welding	4	Thermoplastic
Thermoforming in two halves	Well-Structure through Thermoforming	Silicone Bumpers	Plastic Welding, Friction	6	Thermoplastic, Silicon
Thermoforming in two halves	Well-Structure through Thermoforming	Without Reinforcement	Plastic Welding	4	Thermoplastic

First half of the List of Concepts generated using the Morphological Matrix

Thermoforming in two halves	Two halves with internal structure	Outer Fiber Reinforcement	Plastic Welding, Resin	4	Thermoplastic, Fiber glass, Resin
Thermoforming in two halves	Two halves with internal structure	Outer Ribs	Plastic Welding	3	Thermoplastic
Thermoforming in two halves	Two halves with internal structure	Extra Thickness	Plastic Welding	3	Thermoplastic
Thermoforming in two halves	Two halves with internal structure	Silicone Bumpers	Plastic Welding, Friction	5	Thermoplastic, Silicon
Thermoforming in two halves	Two halves with internal structure	Without Reinforcement	Plastic Welding	3	Thermoplastic
Thermoforming solid	Solid Thermoforming / Polymer Casting	Outer Fiber Reinforcement	Resin	2	Thermoplastic, Fiber glass, Resin
Thermoforming solid	Solid Thermoforming / Polymer Casting	Outer Ribs	Without Joining Method	1	Thermoplastic
Thermoforming solid	Solid Thermoforming / Polymer Casting	Extra Thickness	Without Joining Method	1	Thermoplastic
Thermoforming solid	Solid Thermoforming / Polymer Casting	Silicone Bumpers	Glue	3	Thermoplastic, Silicon, Glue
Thermoforming solid	Solid Thermoforming / Polymer Casting	Without Reinforcement	Without Joining Method	1	Thermoplastic
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Outer Fiber Reinforcement	Resin	2	Thermoplastic/Thermosets, Fiber glass, Resin
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Outer Ribs	Without Joining Method	1	Thermoplastic/Thermosets,
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Extra Thickness	Without Joining Method	1	Thermoplastic/Thermosets,
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Silicone Bumpers	Glue	3	Thermoplastic/Thermosets, Silicone, Glue
Polymer Casting solid	Solid Thermoforming / Polymer Casting	Without Reinforcement	Without Joining Method	1	Thermoplastic/Thermosets,
Vaccuum RTM	Layers of fibreglass	Outer Ribs	Resin	1	Thermoset, Fiber glass, Resin
Vaccuum RTM	Layers of fibreglass	Silicone Bumpers	Resin, Glue	2	Thermoset, Fiber glass, Resin, Glue
Vaccuum RTM	Layers of fibreglass	Without Reinforcement	Resin	1	Thermoset, Fiber glass, Resin

Second half of the List of Concepts generated using the Morphological Matrix

Appendix G

Literature Review

This Appendix contains the Literature Review and the Concepts based on Twin-Sheet Thermoforming which were appended to the List of Concepts after the production process was discovered.

Friction coefficients of plastics on snow

To better understand the implications of the lowest layer of material on the gliding properties of the PS-board, sources were sought regarding which parameters affect friction on snow. Unfortunately, the found literature almost exclusively focused on friction of sliding objects on solid ice with, varying conclusions. One study refuted a previous common belief that self-lubrication from water content in snow is not the main culprit for low friction, but instead that small grains were broken from the snow crystals by abrasion which then acts like a rolling layer (Lever et al., 2019). Another study completely excluded mechanical deformation of the snow and instead found that friction coefficient of the snow was dictated by a thin water film, both varying with the temperature and speed of the object sliding on top of the snow (Makkonen, 2014). On the other hand, variations in friction coefficient can be attributed to at least five different mechanisms, depending on the load case. An article in a science magazine compiling results from different studies on ice friction also confirmed that no scientific consensus was yet to be reached on the topic (Rowińska, 2025). The previously mentioned studies mainly used materials which were not polymers as representation for the object sliding on the ice, so a study regarding ice friction of polymers was identified, which also found that the mechanism of ice friction varies with the speed of the sliding object, attributing it to three different mechanisms in their respective range of velocity (Stamboulides, 2012). In summary, it was inconclusive exactly which mechanisms govern the sliding properties of snow, which complicated the optimization of material for decreased friction on snow. However, one study noted that a lot of polymers can absorb lubricants which lower their friction on snow as long as they do not degrade the polymer (Lawrence, 2024). Another attribute of the plastic which could potentially impact friction is the surface roughness, which might vary with production process. Unfortunately, one study proclaimed that the correlation between surface roughness and friction coefficient is not simple, since higher roughness increases the friction but decreases the area of contact at the same time (Ebnesajjad, 2014). A more specific study examining the effect of surface roughness on the friction of skis found that in certain microscopic ranges, the friction could be lowered by raising the surface roughness of the material in certain patterns by using grinding methods (Kalliorinne, 2023). This was supported by another study on polymeric materials' friction on snow, which found that some surface roughness of hydrophobic materials showed lower friction than flat hydrophilic materials at some temperatures. It specifically found that a surface roughness between 0,5μm and 1μm provided the lowest friction regardless of the chemical composition of the sliding object (Giesbrecht, 2010).

One property relevant in the choice of materials which did show clear signs of affecting friction was whether or not the polymers were fiber-reinforced. Even though no study was identified which examined the tribological properties, which are the wear and friction properties (Sciensedirect, n.d.), of fiber-reinforced plastics on snow, some studies experimentally evaluated the friction against other materials such as steel and ice. One study which examined the tribological behavior of fiber reinforcement polyester resin, found that increased short fiber content in thermosets increased the friction of the composite against steel (Bahadur, 1990). Another study on the subject found that adding protruding glass fibers to thermoplastics in tires could increase friction on ice at temperatures near the melting point (Rizvi, 2015). Even in lower pressure applications such as footwear, adding fiber content to thermoplastics was found to increase friction on ice by one study (Bagheri, 2019).

Thermoforming Plastics

Thermoforming is a widely established production process with broad academic and industry documentation. The method is based on heating large sheets of plastics and shaping them by pressing them against molds (BMG, 2024). By using Thermoforming, a surface roughness of 0,3μm - 1,6μm can be achieved as found in Granta EduPack. The process can be customized in a variety of ways to meet specific ends. Examples of customizations include utilizing male-, female- or matched molds, cutting or trimming at various stages, vacuum or pressure forming, rotary layout and Twin-Sheet forming. Twin-Sheet Thermoforming may be specifically suited for this process as it forms two sheets and welds them in one step, which allows cheaper production of hollow components, multi-material components and simplified addition of reinforcement materials or components (BMG, 2024). The discovery of Twin-

Sheet was deemed significant enough to warrant appending the List of Concepts with new Concepts utilizing its specific possibilities. Since it is a variant of Thermoforming, the same possible materials which were identified for regular Thermoforming were also deemed suitable for Twin-Sheet. In addition to this, Twin-Sheet can be used with different thermoplastics in the top and bottom sheet, without compromising the weld between them (Associated Thermoforming Inc. 2018).

PET

Its foremost advantages are clarity, processability and strength (BMG, 2024). It can be combined with glass fiber reinforcements for markedly improved mechanical properties, as found in Granta EduPack. But as previously stated the fibers would have had implications on friction and gliding properties.

SMMA

Foremost used for applications where transparency is required, it is generally classified as a subtype of PMMA. It has high strength but low impact resistance and is prone to cracking under load (SpecialChem, 2026). The low impact resistance meant it might be unsuitable for the project.

ASA/AES

These are variants of ABS, which has excellent mechanical properties in strength and impact resistance, but improve on ABS's weakness of poor UV-resistance. The major difference between ASA and AES is that ASA has properties better suited for color clarity and surface finish whereas AES maintains better impact resistance at lower temperatures (Xinyite Plastics, 2025). For our project, it may have been appropriate to prioritize mechanical performance over color clarity, especially considering the Sustainability Strategy chosen by MCS.

HDPE

Is widely used and offers impact resistance, rigidity and chemical resistance which makes it suitable for outdoor use (BMG, 2024). It is currently broadly used for winter sports applications, for example the variant Ultra High Molecular Weight Poly Ethylene (UHMWPE) which is the current standard for snowboard bases (Lawrence, 2024). However, since HDPE had somewhat lower stiffness than other plastics, it might have been unsuitable for a mono-material construction.

PC

Is a high performance thermoplastic, specialized for strength (BMG, 2024). PC also exists in a fiber filled version for improved mechanical properties as found in Granta EduPack, with the aforementioned consequences for friction.

Foaming in Place

Foam is a useful material type for taking up space with low added weight, providing rigidity to hollow parts and adding shock absorption. Foaming in Place is a process where expanding foam is injected into the interior cavities of parts, allowing the foam to take up all the previously unoccupied space (Buitenhuis, n.d.). Foams can be categorized in a number of ways, their structure can for example either be closed- or open-cell, which means the hollow cavities are separated from each other, providing excellent thermal and moisture isolation, or interconnected, increasing the flexibility and sound absorption, respectively (Buitenhuis, n.d.). For the PS-board, closed-cell foams would have been an appropriate choice because of its moisture isolation, which would stop the PS-boards from absorbing water, making it heavier, if the foam were to come into contact with melted snow. Although Foaming in Place offers added rigidity, it also introduces a lot of complexity to the product's mechanical properties. The use of foam between sheets of other material types creates a sandwich construction, which has many structural benefits, but also many different failure modes depending on load cases and the individual mechanical properties of the constituent materials (Hazizan, 2022). This complexity would likely have made the failure state of the PS-board hard to predict without extensive prototyping or complex FEA simulations, which would in turn have made material selection based on mechanical properties and dimensioning of thicknesses problematic. However, when used in similar products like surfboards, weaker kinds, for example poly styrene foams, are often paired with harder outer materials, like epoxy composites (Wyve, 2023).

PU

The material in foam form has excellent flexibility and toughness and is, for example, often applied to offer shock absorption and cushioning for sports equipment (Buitenhuis, n.d.).

PE

PE is a well-established material for use in industry for Foaming in Place as it balances strength, shock absorption and cost (Buitenhuis, n.d.).

EVA

The material has excellent flexibility and impact resistance and is broadly used for sports equipment and footwear (Buitenhuis, n.d.). However, it does pose some safety concerns as it becomes toxic under certain specific conditions, such as heating, chemical dissolving and decomposition. Another cause of toxicity can be low quality production conditions as that can leave dangerous residue in the material (FoamOrder, 2024). Studies have also shown that substantial inhalation or ingestion in turn can lead to health negative effects (Agency for Toxic Substances and Disease Registry, 2024).

PP

The material is specialized for durability, resilience, energy absorption and long lifespans. It is commonly used for components meant to be reused (Yun-Lun Packaging Materials Co. Ltd., 2025).

Polymer Casting

Polymer Casting is a method for creating polymer components shaped after relatively cheap molds at atmospheric pressure. It is executed by inserting a liquid thermoset or thermoplastic with or without short fiber reinforcement into the mold, as found in Granta EduPack. The data sheet in Granta also showed that it is possible to create components with this process which result in a surface roughness between 0,5µm - 1,6µm. Since it was concluded in the interview with Almefelt in the Initial Production Analysis that material contents used in Polymer Casting are distributed and oriented at random throughout the component, using fiber-reinforced polymers would likely have caused both polymer chains and the short grains of fiberglass to be oriented at random. This implied that there is a significant probability that fibers would be present at the surfaces of the component, or perhaps even protruding from it. As previously mentioned, the presence of fibers could have the effect of significantly increasing the friction of the material. Another possible issue with fibers present at the surface of the product was the degradation of polymer-fiber composites in water, which occurs through capillary action in micro gaps between polymers. This occurs due to imperfections in the adhesion between fibers and the polymer (Venkatesha et al., 2021).

Epoxy – Fiber glass (short fiber)

Epoxy is a thermoset resin which was found in Granta EduPack to be used both with and without fiber-reinforcement. It is used very widely in the ski manufacturing industry as a binder between different materials in sandwich constructions due to its mechanical and water-resistant properties as a thermosetting resin. In that case, it is used in its unfilled version, and becomes a composite first when it is applied to the other materials in the construction, such as fiber glass sheets (Cuppone et al., 2020). Despite its frequent usage, there is one study which suggests that being exposed to epoxy at worksites which creates composites, involves a risk for contracting Allergic Contact Dermatitis (Pinheiro, 2026). Another potential downside to epoxy is the emissions related to it, since resins release a significant amount of greenhouse gasses, with 58% of emissions from the entire lifecycle occurring in production (Chaudhari et al., 2022). Another study reinforced that the total environmental impact of epoxy resins used in a cryogenic applications lifecycle could be lowered by choosing environmentally generated power for transport and electricity usage, as well as switching to a bio-based epoxy (Krzak et al., 2024). This was supported by another LCA study, which found that switching to bio-epoxy and more sustainable energy generation could improve the emissions related to epoxy significantly (Faroque et al., 2025).

The friction of epoxy on snow depends on the specific type of epoxy used, one study found that some epoxies had a low coefficient of friction, similar to steel, whilst others showed higher friction than concrete (Bekker et al., 2024). Since steel is commonly used in the base of skis (Cuppone, 2020), these findings implied that there exists epoxies with satisfactory friction against snow, but that it might not be every type of epoxy.

PA12

PA12 is also known as Polyamide12 or Nylon12 and is a thermoplastic which was found in Granta EduPack to be used in components with or without fiber-reinforcement and commonly found in automotive applications and consumer electronics. PA12 is a fossil based compound and entails greenhouse gas emissions in the production stage, but there are alternatives. One LCA study showed that polyamides which have a high content or starch in them shows promise for lowering the greenhouse gas emissions of the material significantly, whilst still providing favorable mechanical properties (Äkräs, 2024). Whilst no studies were found analyzing the snow friction of PA12, adding layers of another type of polyamide (PA6,6) to the base of skis have been experimentally found to significantly increase the friction against snow (Giesbrecht, 2010), which could have been detrimental if PA12 is found to behave in the same way.

Vacuum-Assisted Resin Transfer Molding

VARTM is a process in which dry sheets of fiber reinforcement are placed and fixed in a mold, before the resin is pulled through the mold by a vacuum pressure, thus creating complex shapes of fiber-resin composites. Commonly, only a bottom mold is used, with a vacuum bag restricting the components thickness, as illustrated in Grata EduPack. It is possible, however, to use an upper and lower mold (Sciencedirect, n.d.). VARTM can in some cases be compared to hand layup, but generally produces a better surface finish and involves less risk for internal voids, which gives improved flexural, tensile and impact properties (Roopa, 2015). The surface finish produced can usually vary between 0,1μm and 2,4μm according to the data sheet in Granta EduPack, although the shrinkage of resins whilst curing could pose a risk of adverse effects on the surface finish (Heider, 2007).

Since the process used fiber-reinforcements, there could have been issues with high friction if the fibers were present at the bottom surface of the PS-board, as previously mentioned, unless it would be possible to leave a gap at the bottom of the mold for only resin to fill. No sources confirming or denying this possibility have been found. There is one recent study examining the sliding properties of snowboard bases where the bottom surface is made of fiber composites, with the fibers normal to the direction of movement. This structure does show some initial promise of creating snowboards without a layer of polymers beneath. Their results were comparable with UHMWPE, but reviews were mixed, with athletes describing uneven sliding of the board. The composite investigated in the study was also used carbon fiber as filler (Lawrence 2024), was found to be significantly more expensive than glass fiber in Granta EduPack.

Epoxy – Fiber glass (sheet)

As previously mentioned, fiber glass sheets covered by epoxy are already used in both skis and surfboards, but is also in use in snowboard production (Borsellino, 2005). The composite has a shrinkage in molding which is usually under 2% (Sciensedirect, n.d.). The same potential workplace hazards and environmental concerns applied as mentioned for Polymer Casting.

Since the composite is very similar to the epoxy-fiber glass used in Polymer Casting, a risk of degradation in water through capillary action might be present. One study found that epoxy - fiberglass composites created by hand layup which were soaked in water for 10 weeks showed a decrease in flexural strength of 14-17%, with water absorption increasing most dramatically during the first and second week. After re-drying the composites, they were found to have regained strength to more than 90% of their original value, but not to 100% (Kini, 2023). It is unclear if the same effects would have been present for composites created by VARTM to the same extent. As previously mentioned, VARTM creates less internal voids than hand layup, yet a study on internal voids in epoxy – fiber glass produced by resin transfer molding still found some cavities to be present, even if there were ways of minimizing them (Pupin, 2017).

Polyester – Fiber glass (sheet)

Polyester - fiberglass is an alternative to epoxy - fiberglass which is considered cheaper and easier to use in manufacturing by one commercial source (Fiberglass Warehouse, 2022), which also claims that polyester creates surface tack which increases friction significantly. A gelcoat or wax can be added to polyester resin, which might reduce or eliminate the surface tack scoring to the commercial source. No sources were found examining the friction of polyester resin on snow or ice. The Concept of adding wax or lubricant might be supported by polyester coatings exhibiting porous structures (Vortney, 1967). Even though polyester resin usually exhibits a shrinkage of less than 3% (Sciencedirect, n.d.), higher shrinkage up to 4,8% has been observed for polyester-fiberglass components in RTM in one study (Kim, 2002). The observed shrinkage varied between parts of the study's sample with both polymers and fibers, and parts with only polymers, which was found to be a potential cause for warpage of the material. When it comes to water affecting mechanical performance, polyester - fiberglass manufactured by Vacuum Assisted Resin Injection with cut exposed fibers and no gel coat, showed some degradation according to one study (Huang, 2007). The study found a slight decrease in tensile properties, but an increase in flexural properties after submersion in water for 21 days.

Like epoxy, polyester resins give rise to some workplace hazards in production regarding skin contact (Bourne, 1963). When it comes to impacting the climate, a LCA study found that choosing bio based resin decreased emissions, resource use, ozone depletion and non-renewable primary energy drastically (Shahid 2024). There are also recent developments in creating more types of bio-based polyester resins, even though they do not currently hold the same mechanical properties as fossil based resins (AbdulRahman, 2025). Another potential way to affect the sustainability in production is using recycled fibers. According to one experimental study, recycled fibers in polyester resin produce a composite with the similar hardness as virgin fibers, and a similar tensile modulus and elongation at break for composites consisting of a 30% weight ratio of fibers or less (Araujo, 2006). The same study did however find that recycled fibers showed significantly lower tensile modulus at 40% weight ratio of fibers, and several times lower impact strength for most weight ratios.

DEPARTMENT OF INDUSTRIAL- AND
MATERIALS SCIENCE
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2026
www.chalmers.se

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