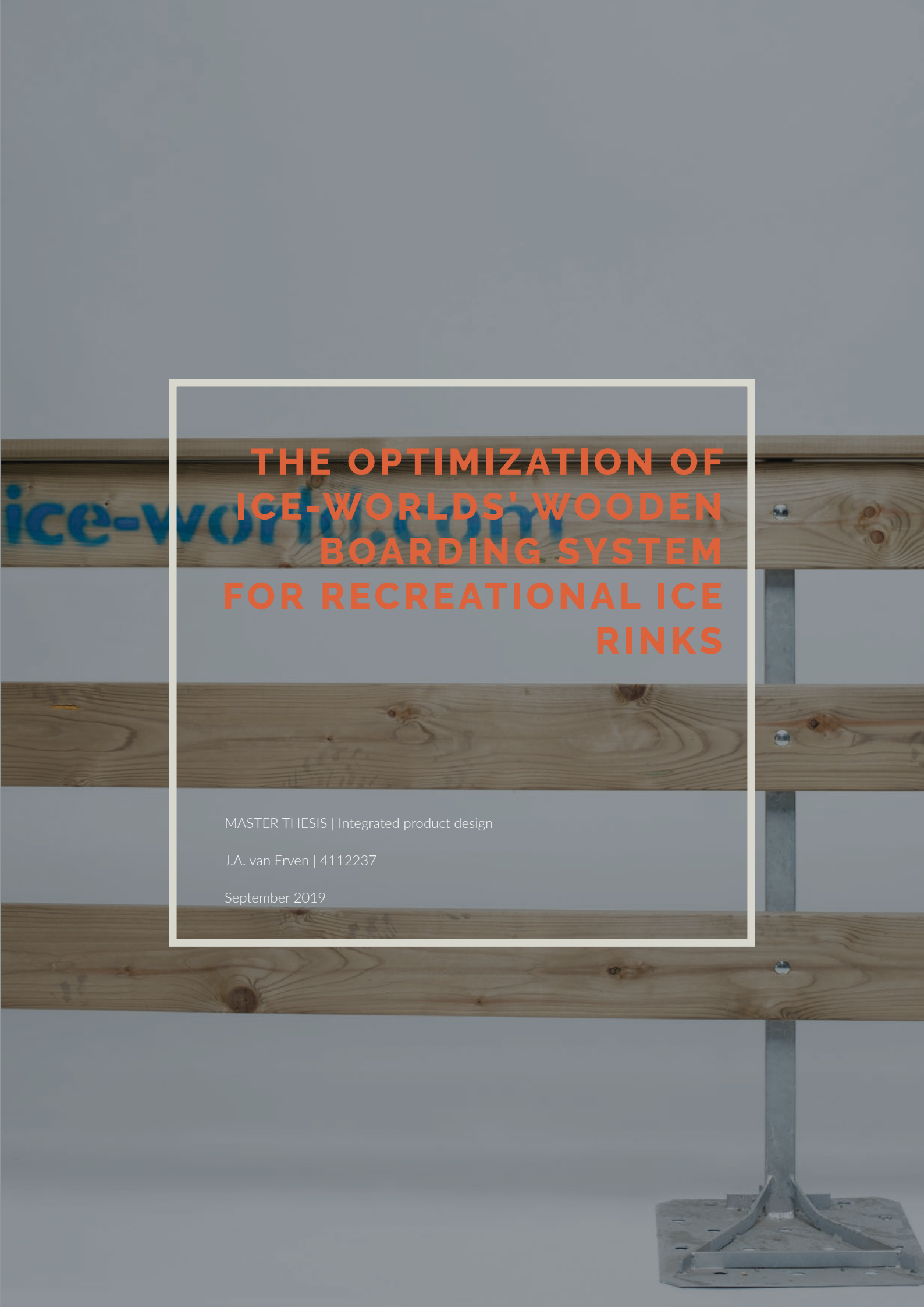

THE OPTIMIZATION OF ICE-WORLDS' WOODEN BOARDING SYSTEM FOR RECREATIONAL ICE RINKS

MASTER THESIS | Integrated product design

J.A. van Erven | 4112237

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Master thesis
Delft,

Author
J. A. van Erven
Integrated Product Design (Msc.)
Student number: 4112237
+31 (0)6 23 34 41 60
javanerven@gmail.com

Supervisory Team

Chair
S.G. van de Geer
Industrial Design
Department of Design Aesthetics
S.G.vandeGeer@tudelft.nl

Mentor
C.P.J.M.Kroon
Design Engeneering
Department of Product Architecture Design
C.P.J.M.Kroon@tudelft.nl

Company Mentors
G. W. Molenaar
Manager Research & Design
Product Development
guido@ice-world.com

K. Schonewille
Product Engineer
Product Development
karijn@ice-world.com

Company
Ice-World International
Weteringpad 7
3762 EN Soest
www.ice-world.com

Delft University ofTechnology
Faculty of Industrial Design Engineering
Landbergstraat 15
2628 CE Delft
The Netherlands
www.tudelft.nl

PREFACE

Dear reader,

Before you lies a graduation report that describes my project performed for the TU Delft and Ice-World International. This project is the final step before graduating from the faculty of Industrial Design as a Master of engineering. Within this project, all the knowledge gathered during my nine years of studying comes together and is applied to the project scope to analyse problems and create solutions.

Ice-World formulated an assignment with the objective to innovate the existing boarding systems of their ice rinks. When I first saw this assignment, it sparked my interest, because when I was young, I used to play Ice hockey. So, to say I have my fair share of experience on the ice, as in the present day, I still love to skate. My personal experience on the ice enabled me to relate to users and provided me with the confidence to create a valuable redesign of Ice-World's wooden boarding system.

This project was performed for Ice-World International, which is the current market leader in temporary recreational ice rinks in the Netherlands. Ice-World has been active since 1996 and placed their first ice rink in Belgium. Currently, around 60 ice rinks are built in the Netherlands each year. These ice rinks are usually in operation during the Christmas season for about three weeks in total. The rest of the time, the components are in storage.

Ice-World can install an ice rink within 24 hours, which is crucial, as time equals money. On average a recreational ice rink is 450 m2 and uses wooden boarding to blend in with the winter theme present around an ice rink.

Although this was an individual project, I would not have been able to finish this project without the help of certain individuals. So, I would like to take a moment to thank these people individually.

I am starting with my project chair, Stefan van de Geer. His door was always open, and whenever I would walk in, he would take the time to hear the problem and always help find a solution. Usually, these meetings would end up in hour-long sparring sessions. Stefan also took the time to come to me as my communications skills are not to write home about. Not getting tired of all my complaints and having the intention to help me through difficult times.

I want to thank my project mentor Caroline Kroon, for the help during the entire project keeping the objectives relevant and also offering perspective for all the stakeholder requests.

Both Caroline and Stefan never gave up on me during times where I would have given up on myself.

I want to thank Guido Molenaar and Karijn Schonewille, my company mentors who allowed me to do my graduation project at Ice-World — giving me the experience of working within a small design team and providing the necessary support. Guido and Karijn were always available when I had questions or needed an opinion.

I want to thank Anne van Lieren, my girlfriend, who had to hear all my problems every time but helped me keep both feet on the ground. She encouraged me to keep going and also acted as my proofreader.

I want to thank Martin and Sybille, my parents. They kept believing in me and allowed me to finish my masters. At sometimes we had the idea my studies would never end, but here we are.

EXECUTIVE SUMMARY

Ice skating is (still) very popular in the Netherlands, and it is gaining popularity across the globe. Temporary ice rinks on squares and in parks is an increasing solution in order to attract visitors in the winter and holiday season. Ice-World International, the world leader in temporary ice rinks since 1992, has experienced a significant increase in demand for temporary ice rink rental in the Netherlands. As a premium supplier, Ice-World wants to keep offering its customers high quality and innovative solutions. Therefore, Ice-World asked to explore opportunities for updating the boarding systems with a new modular boarding system that fits every rink dimension and could replace current systems.

This graduation project has resulted in a redesign of the wooden boarding system. A boarding system is used as a barrier around an ice rink to prevent ice skaters from sliding or falling off the ice. It is a modular system, as every ice rink has different dimensions. Currently, Ice- World carries two different types of boarding systems: a transparent boarding and a wooden boarding. The wooden boarding is preferred by European customers, while international customers prefer transparent boarding. Existing problems with the boarding especially relate to the wooden system. The focus of this project was set to the wooden boarding because of increasing market demand (within the Benelux), and it is the core business of Ice-World.

The wooden system of Ice-World has been used for over 15 years, without any significant changes. Ice-World pre-identified problems with the wooden boarding related to safety and aesthetics. In the research phase, observations and interviews have been done to explore additional challenges and issues across the complete product journey – from production, assembly, storage, transport, installation, use, maintenance and end of life. This product journey has been used to capture all-important use scenarios of the boarding system to create a complete list of requirements.

Challenges that were identified during the research phase include inefficient storage methods that cause deformations, excessive storage volume, insecurity about the current state of safety, etc. The most significant challenge was to design a modular system that fits the existing ice rink freezing elements. An in-depth analysis showed that the boarding system is currently not compatible with the dimensions of the ice rink system used to freeze the water – resulting in poor alignment of the panels, on site size adjustments of the panels and overall poor finish.

The research phase resulted in an extensive list of requirements and wishes used for the final design. A design vision and list of design goals were formulated to guide the ideation and conceptualisation phase. The redesign for should be a safe, modular, durable, environmental conscious boarding system that contributes to a winter atmosphere and overall better ice rink experience. In the ideation phase, solutions were developed for sub-problems of the boarding. Three concepts were designed, constructed in 3D CAD models and evaluated. The weighted criteria method was used to make a validated decision on the final concept.

Several rounds of iterations were done to optimise the selected concept. Simulations of (extreme) use scenarios were done in SolidWorks to evaluate and make iterations to the construction. The final design of the boarding systems consists of 5 different panels, a base and a corner frame. With these components, every rectangular shaped, standard-sized ice rink can be realised. The redesign is compatible with dimensions the other elements of the ice rink system. The redesign ensures perfect alignment of the panels, offers customers twice as much sponsoring surface due to symmetric design and is constructed in a way that prevents accidents from happening. The panels of the redesign are produced from Platowood - an environmentally friendly, weatherproof wood and has a longer lifespan than the current wood.

Finally, a full-scale prototype was created to validate the assumptions of the redesign further and to test the construction on strength and impact. Recommendations were put forth considering the redesign and further opportunities for Ice-World.

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Image 1: Ice rink Mexico. Source: Ice-World

1. PROJECT INTRO

This chapter start with an explanation of the problem Ice-World currently faces, then the assignment following the problem is discussed. From the problemem defenition and assignment, research questions have been created. After the research questions a description of Ice-World is given who this assignment is for. The chapter ends with the project scope and design approach.

Image 2: Ice-World ice operator. Source: Ice-World

1.1 PROBLEM DEFINITION

Ice-World has been active for over 25 years within the recreational ice-skating rink business. In these 25 years, the way ice rinks are set up has not changed much. This lack of change also affects the boarding used around the ice rink. Ice-World uses two types of boarding systems: a wooden version and transparent version (see Appendix 5). Ice-World's customers demand high quality, and as a premium supplier, Ice-World needs to live up to these quality expectations. Currently, the price/quality ratio is unsatisfactory to Ice-World and it's customers. They want to prevent customers from selecting other suppliers by enhancing the aesthetics, construction and finish of the boarding.

Ice-World considers the boarding as their trademark – it needs to represent the high-quality standards, brand and vision of the company. Ice-World identified significant problems related to the boarding. The boarding system does not fit the dimensions of the ice rink and thus on site adjustments have to be made to the panels. The boarding system consists of standard-sized components, but at almost every installation, the boarding has to be adjusted to fit the specific dimensions of the ice rink. It is essential to find the core of this problem – and to come up with a fitting solution to optimize the current boarding system. This optimization will be the main focus of the project.

1.2 ASSIGNMENT

The assignment for this project is to create a new modular boarding system that fits every rink dimension and could replace the current systems. The system should fit within the company's product portfolio, be safe and live up the quality standards Ice-World wants to achieve. A more specific lists of design goals for the redesign was formulated after the analysis phase. These design goals were used to develop a feasible, desirable and viable design.

1.3 RESEARCH QUESTIONS

Based on the assignment and problems identified by Ice-World I conclude the following main research question and sub questions:

How can Ice-World optimize its current modular boarding system so it can represent the Ice-World brand, quality standards and vision?

a. Which factors are of importance during the product lifecycle (production, installation, use, etc.) of the boarding system?

b. What are the underlying symptoms of the current problems with the boarding system?

c. What are alternative materials that can contribute to the optimization of the boarding system and match Ice-World brand, quality standards and vision?

Customer: 'You might as well use the boarding to keep cows in.' (05-03-2019)

Image 3: Ice-World wooden boarding. Source: Ice-World

1.4 THE COMPANY

Ice-World International was founded in 1992 by Wim Hoeks. Before Ice-World, Wim Hoeks was active in the swimming pool business. Here he found out that the principles used for heating the water could be used to freeze it as well. From this idea, Wim designed an ice rink freezing system that got patented eventually. The fact that it is a foldable aluminium piping system created a lot more benefits than the competitors. This freezing system enabled Ice-World to become the world market leader in the temporary ice rink industry. Ice-World started with one ice rink in Belgium, but now they are active around the globe.

1.4.2 LOCATION

The headquarters, production facility and warehouse are located in Soest, but Ice-World International has sales offices and dealers all over the world. In Soest, a staff of 30 employees keeps the company afloat.

1.4.3 ICE-WORLD'S MARKET

Ice-World specializes in different types of ice rinks:

Recreational

A recreational ice rink can vary in size, but is a single ice rink with a single function - recreational ice skating. (see image 4) **On average a recreational rink is 450 m2.**

Fun park

The fun park enables Ice-World to offer more than just a recreational ice rink. With a fun park, Ice-World tries to provide activities for both skaters and non-skaters. Activities can vary from a fun slide, ice biking or fun tracks.
(see image 5).

Sports

Ice-world does not only focus on recreational use but also provides ice rink solutions for professional use. The requirements for the ice rink and other hardware, of such professional arenas, are very different than a recreational rink. (Image 6)

Image 4: Recreational ice rink, Laren Source: Wintervillage.

Image 5: Fun Track, Beijing. Source: Ice-World.

Image 6: Speed skating rink, Rotterdam. Source: Ice-World

On average, 67% of Ice-Worlds revenue comes from renting out ice rinks. Ice-world rents out around 600 portable ice rinks every year in 23 countries. 75% of the rental is recreational ice rinks, 15% is fun parks and 10% is sports (Ice-World, 2016).

1.4.4 ICE AS A SERVICE

Ice-World provides a service – customers rent an ice rink, and **Ice-World is the one responsible, among other things, for the hardware, transport and installation.** Everything stays the property of Ice-World and Ice-World is accountable for the correct functioning of the rink during the event. How this all relates to the boarding will be discussed later on.

1.4.5 MISSION AND VISION

The clear message that shows from the mission and vision below is that **Ice-World strives for the highest quality service and being a sustainable company.** These aspects will also reflect within this project and help Ice-World in achieving this mission and vision.

Mission

*Ice-World wants to introduce everyone to the fun that people experience on an ice-skating rink. Anywhere in the world and in any conceivable location. For customers looking for that special event, we develop innovative ice concepts that use real ice and which stand out in terms of **quality and sustainability**.*
Together with our customers, we go for: "Join the ice experience", our motto, which is reflected in all facets of our business operations.
(Ice-World, 2018)

Vision

The realization and creation of the ultimate ice experience is always the starting point for Ice-World.
*In everything we do we strive to achieve the **highest quality** and perfection. Our focus is on innovation, **sustainability** and delivering added value to our customers.*
In the entire process: From idea to development, from production and logistics to installation, operation and services. A customer-focused approach and the optimal use of our expertise, knowledge and experience are central to this.
(Ice-World, 2018)

1.4.6 SUSTAINABILITY

Ice-World aims to be an environmentally friendly company. Ice-World offsets 100% of its CO2 emissions by planting mangrove forests in Myanmar. Furthermore, Ice-World compensates the energy consumption of all projects with wind energy certificates.

1.4.7 BRAND AND PORTFOLIO

Ice-World does not stop where the ice rink ends – they want to create a complete skating experience. Ice-World offers lots of accessories that can be used to improve the ice experience. Ice-World also uses these accessories for exposure, because almost every item is bright orange (see Appendix 5).

Aside from the colour, Ice-World places their name on almost every product. Again the intention is to create exposure for recognition of an Ice-World rink. **Seeing the Ice-World brand at the ice rink is essential, and the colour orange plays a significant role.**

1.5 PROJECT SCOPE

The project scope is determined based on the type of material of the boarding, the market and shape of the ice rink (see image 7). **The wooden boarding is selected for this project as the market for wooden boarding is significantly larger than the market for transparant boarding** (within the Benelux) (Wilma Hinloopen, Office Manager, 2019). Moreover, the problems and challenges that have been identified by Ice World especially relate to the wooden boarding (Koen van Dongen, Warehouse manager, 2019).

A further focus has been placed on Ice-Worlds' main market – the Dutch recreational rental market. Ice-World is market leader in the Netherlands - holding 56% marketshare.

In the Netherlands, almost all (90%) of the rinks are recreational (Ice-World, 2018) . Last year, 56 ice rinks were rented out in the Netherlands. This makes up for 20% of the yearly revenue. Dutch customers prefer the wooden boarding, as it fits with the overal christmas atmosphere that customers try to create around the ice rink. – 90% of the Dutch ice rinks are installed with wooding boarding (Steven Bottema, CEO, 2019).

90% of the wooden boarding in the Netherlands is used to create simple, rectangular shaped ice rinks (Ice-World ice rink quotes from 2018). The rectangular standard size is a cost effective shape and easiest to install. This project will therefore focus on redesigning a wooden boarding system for a rectangular shaped ice rink.

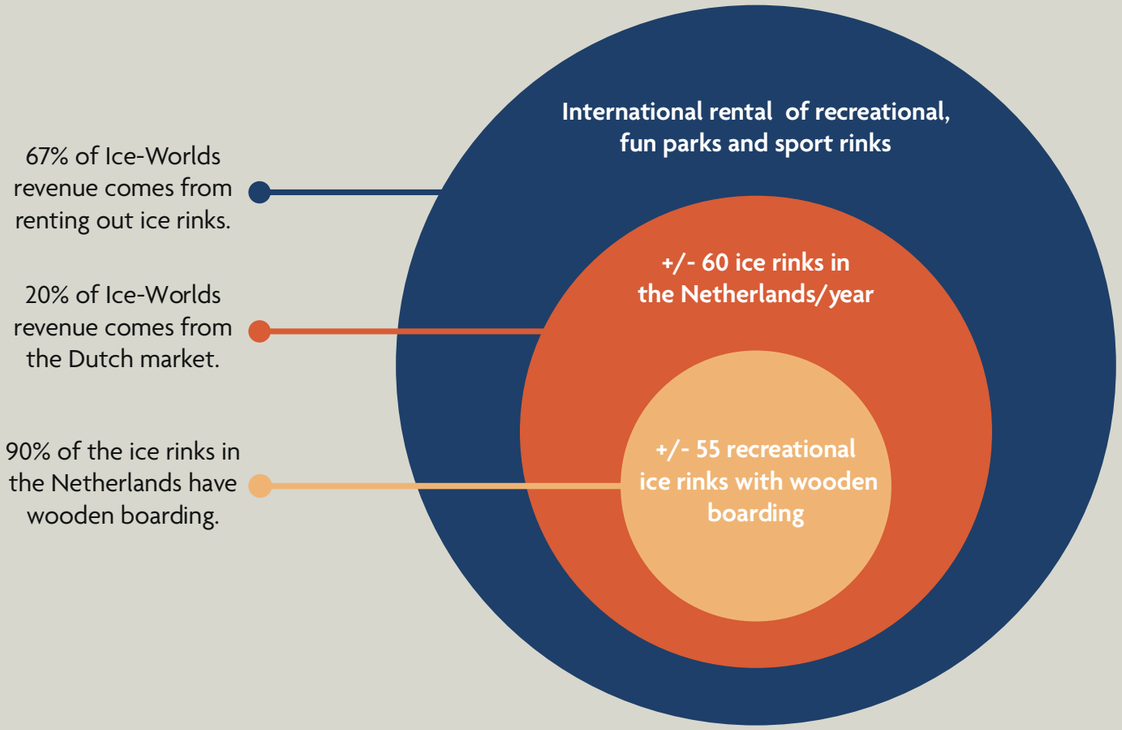


Image 7: Project scope. Source: Ice-World

Image 8: Ice rink Laren. Source: Wintervillage.

1.6 DESIGN APPROACH

The double diamond design approach (Design Council, 2005) is used in this project (see image 10). Several diverging and converging stages have been used to create a redesign of the wooden boarding.

The project started with a extensive internal analysis and small external analysis. A large part of the internal analysis was dedicated to a problem analysis along all phases of the product journey. A compelte set of requirements for the redesign was drawn up. Finally, a design vision and specific goals were formulated based on the findings of the analysis to guide the ideation process. The final concept is selected based on the weighted criterion method (Roozenburg, N.F.M. and Eekels, J., 1995). As a final step, the redesign is evaluated and detailed. The project is concluded with recommendations for Ice-World. Areas of interest have been put forth that could be used for further development.

A big part of the research phase has been field research (see Appendix 6,7,8) combined with observations. Starting this project in November (at the beginning of the season) provided the opportunity to experience the entire the entire process of installing and using an ice rink on site.

The design approach gives a general overview of the different steps taken during this project to enable a complete design process. The method is used as a guideline, but the reality, in my case, was very different. Image 9 visualises the actual process that this project went through. In the beginning, there is a lot of uncertainty, and it is easy to lose yourself in the overwhelming amount of information. It was hard for me to find focus at first, but through a lot of decision making the objective became more apparent, and a precise target was created to be able to finalise the design.

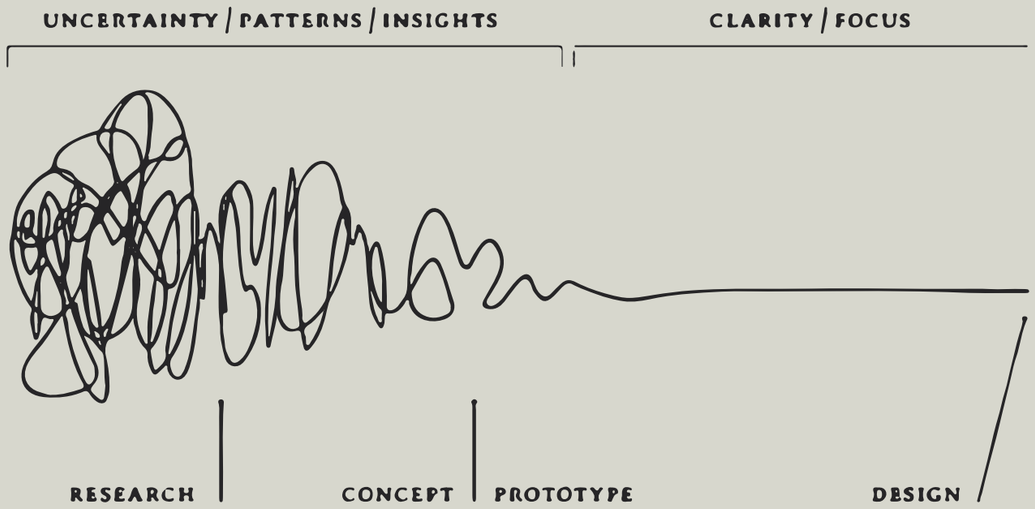


Image 9: Squiggle by Damien Newman. Source: UX Collective

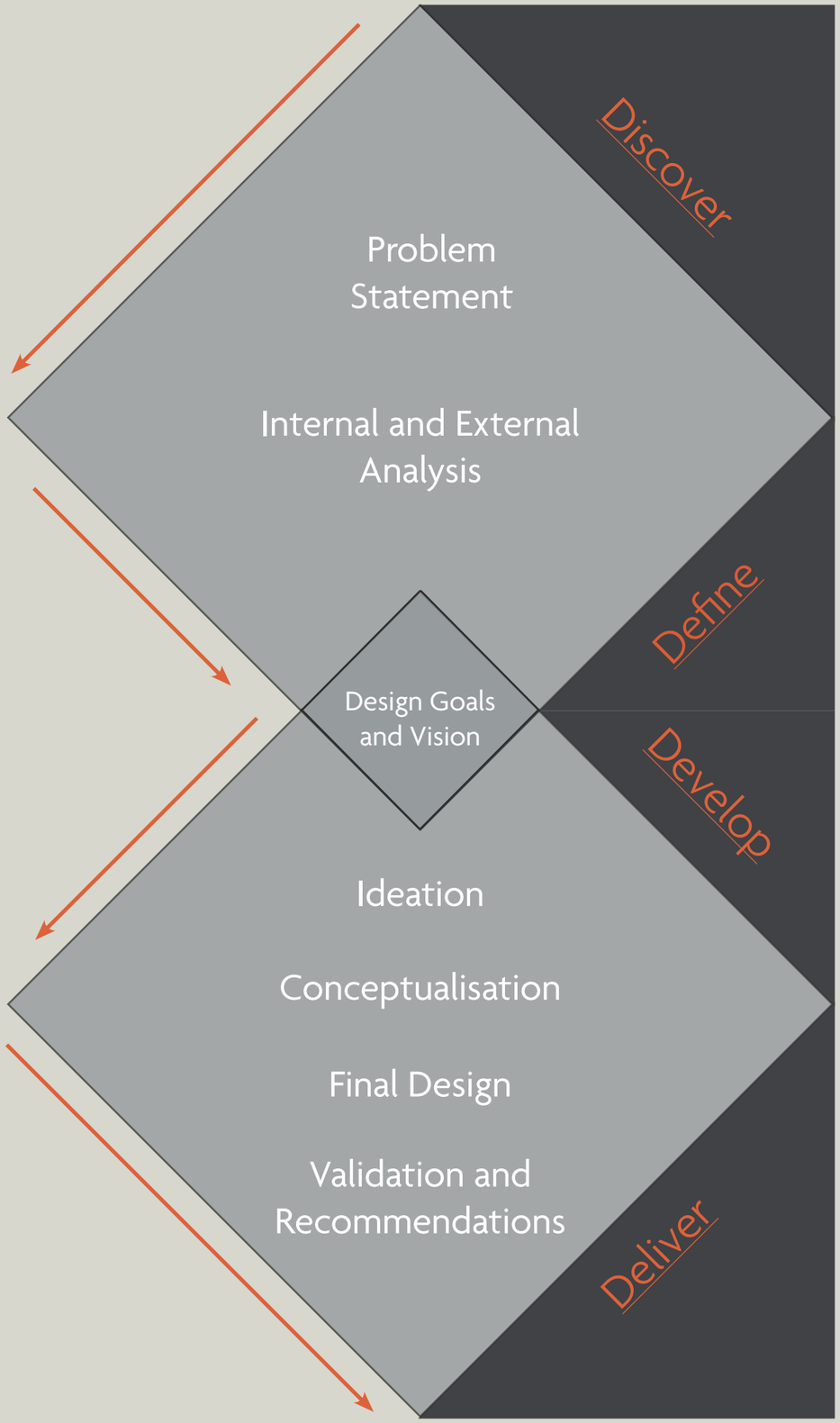


Image 10: Double diamond, Design council, 2005

Image 11: Ice-World Storage Facility. Source: Author

2. INTERNAL & EXTERNAL ANALYSIS

In the research phase, observations and interviews have been done to explore challenges and problems across the complete product journey – from production, assembly, storage, transport, installation, use, maintenance and end of life. The product journey has been used to capture all-important use scenarios of the boarding system to create a complete list of requirements. This chapter discusses the findings of this internal analysis as well as the small external analysis that was done. The findings were used to formulate a design vision and goals. For the majority of the internal analysis, observations have been done to collect all the necessary information.

2.1 BUILDING AN ICE RINK

The boarding is related to the rest of the ice rink. To get a good picture of the context of the boarding, first, the installation of an ice rink is analysed. **Building an average ice rink of 450 m2 takes around 24 hours** (Ice-World brochure, 2018). The process consists of 7 steps. Starting with the foundation and ending with frozen water. The steps are shown in image 12.

What is interesting to see is that the boarding is not connected to the ice rink other than the frozen water. What effect this could have on the entire operation will be discussed later on in this chapter.

Step 1: Foundation
To be able to provide a smooth skating surface, a foundation or platform is needed, which is a level surface. The foundations ensure that the water will freeze evenly. Usually, the floor will be constructed from wooden panels.

Step 2: Waterproof
On top of the foundation, a plastic foil is placed. This will create a waterproof basin in which the water can be sprayed.

Step 3: Cooling system
The aluminium pipes are placed on top of the plastic foil. At the same time, the pipes are connected to create a closed system.

Step 4: Creating a basin
Aluminium profiles are placed on the outside to create a standing edge. This edge prevents water from flowing elsewhere.

Step 5: Boarding
The wooden or plastic boarding sections are placed around the rink, on top of the system. The boarding stands will freeze into the ice floor.

Step 6: Filling the rink
The closed cooling system of the ice rink and cooling installation is filled with the refrigerant and then tested for leaks. The basin is then filled with water, and the chiller is turned on.

Step 7: Freezing the water
The chiller is running at full capacity to freeze the water. The ice layer grows around the aluminium tubes. Depending on wind and outside temperature, the water basin will change into an ice floor of 7 centimetres thick within 12 to 24 hours.

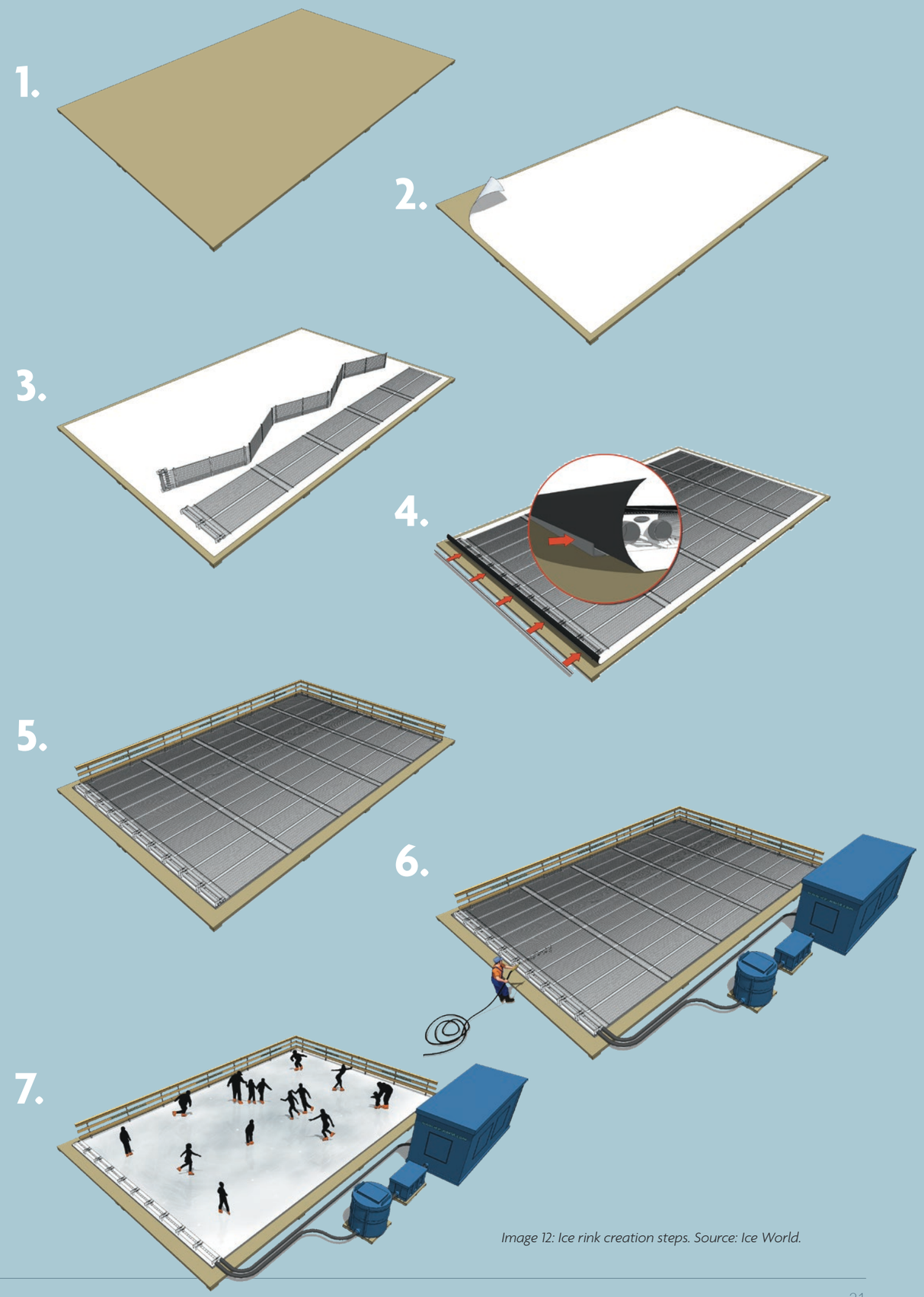


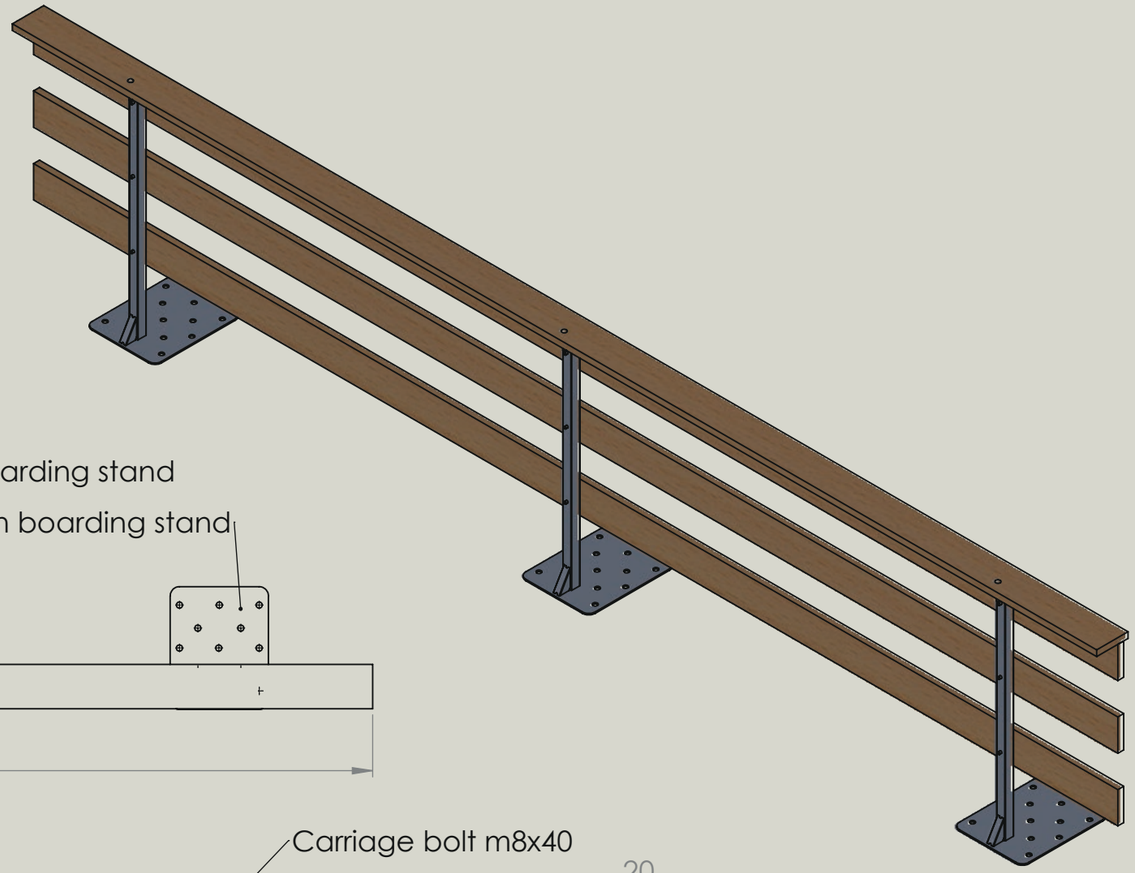
Image 12: Ice rink creation steps. Source: Ice World.

2.2 CURRENT WOODEN BOARDING

How does the current wooden boarding of Ice-World look like?

Mentioned before is that **the current wooden boarding is unchanged for at least 15 years.** A small overview of the different aspects of the existing wooden boarding is given, to show the current construction (see image 13).

The boarding consists of 4 wooden planks of five-meter that have been impregnated with chemicals to withstand weather influences. These planks are attached to three boarding stands of galvanised steel. The overall height of the boarding is one meter. Other lengths are two and a half meter and one meter. The entire functioning of the boarding within context like installation will be dicussed later on. An extended overview of other aspects of the boarding like rental price and weigth can be found in appendix 4.



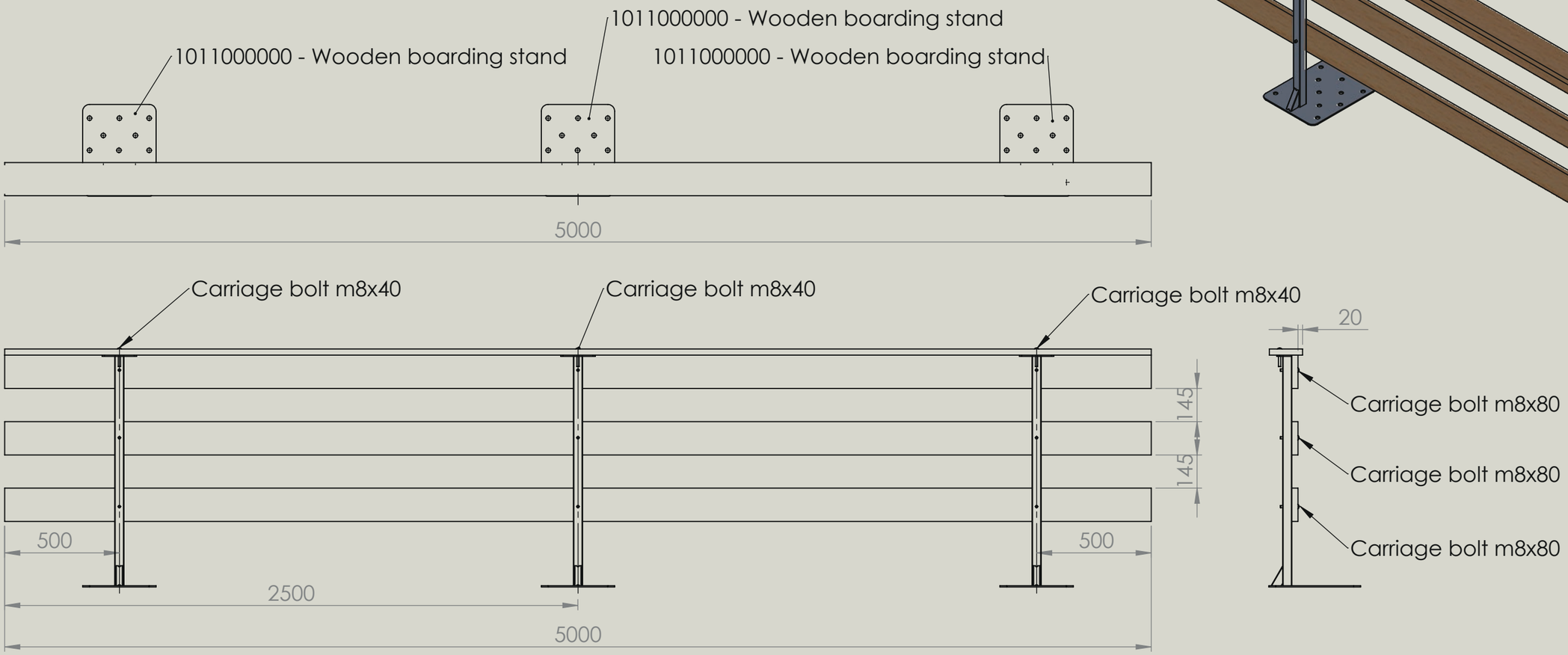


Image 13: Current wooden boarding. Source: Ice World.

2.3 THE ALUMINIUM COOLING SYSTEM

One of the identified problems is the boarding needed to be cut to size when installing the ice rink. An analysis has been done on the aluminium ice rink system used by Ice-World to create the ice to discover the exact measurements of the system so that the new boarding can be a perfect fit.

The cooling system consists of four main components:

- Startheader
- Rubber hoses
- Aluminium pipes
- Endheader

The four components are assembled to create a foldable cooling element (see image 12 and 53). **These elements have a standard width of 1m and can be scaled with 5m long pipes to a maximum length of 55m** (Wibe Kramer, Acount manager Ice-World, 2019). Every 5m rubber hoses are placed where the elements can be folded for storage. In the final assembly, the start headers are always placed outside of the skating area as they cannot be submerged in water. The elements can be adjusted in length but not in width to accommodate custom-sized rinks. **Standard ice rinks are always multiplied by one in width or five meter in length.**

But the aluminium system construction can be quite misleading in its total length. This is caused by the rubber hoses adding ten centimeters every time the systems is lenghtened with 5m. This is also why Ice-World uses gross and net lengths when communicating with their customers. But these gross and net length do not stand for the actual length of boarding needed. This is caused by the specific placement of the boarding on top of the system. When placing the boarding top of the system the sides without the headers see the base of the boarding placed against the edge. On the header side the boarding stands are placed against the hoses at the start header and at the end header the stands are placed at the height of the bleeder valve. this valve needs to stay accessible when the system is filled with coolant. This placements leads to the final length and width available for boarding (see Appendix 19). This can be described with the following formula:

L = 4,85m+5,10m •
Number of cooling elements -1

W = 1m •
Number of cooling elements

The analysis showed that fitment problems occur mainly in the scaling in lenght, not so much the width. This analysis also showed that a different solution was needed on the header side (which scales exactly with one meter) and the non header side (which scales with 5,1m). This will translate into the length for the non-header side boarding being derived from 5.1m and the header side from 1m. How this translates into the final dimensions will be described in the final design.

Header side

Non-header side

Image 14: Startheader Source: Ice World.

Image 15: Rubber connection hose. Source: Ice World.

Image 16: Ice rink system componenst. Source: Ice World.

Image 17: End header. Source: Ice World.

2.4 PRODUCT JOURNEY

For the analysis of the operation of the boarding a product journey has been drafted (see image 18). This product journey shows all the important steps that the current boarding goes through during its entire life span. The product journey has been used to capture all the important use scenario's to ensure a complete overview of all the functions the boarding has to fullfill and problems in the current situation. De-installation, transport and storage occur a second time when the event is finished, these steps are similar to the storage transport and installation before the event starts, but the operation takes place in opposite order. For this reason they are kept out of the product journey shown below.

There are nine steps:
1. The boarding is produced by third party manufactures
2. The boarding parts are assembled by Ice-World
3. Ice-World then stores the boarding.
4 The boarding is taken out of storage and transported to the event location.
5. A team of builders from Ice-World make sure the rink is installed.
6. The ice rink is used for the rental period.
7. The boarding returns to Ice maintenance and repairs take place.
8. The final stage of the life cycle is the end of life in which the boarding is taken apart and discarded.

Storage, transport, install, use and maintenance are part of a continuous cycle, as the boarding system is a rental product.

2.5 STAKEHOLDERS

Before diving into the journey an overview was made of the different stakeholders in relation to the different phases (see image 19). What stakeholder is present in which phase and what role and interest does the stakeholder have. These factors will be analysed in the comming chapters.

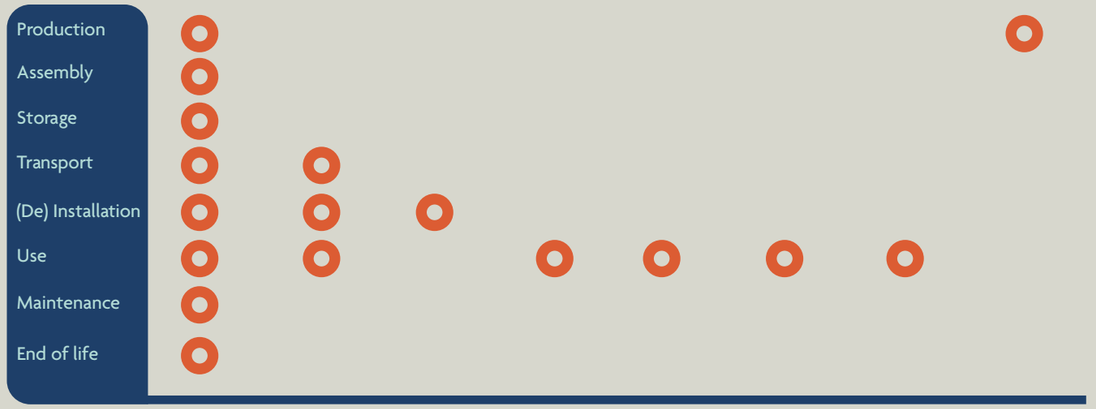


Image 19: Stakeholder overview. Source: Author

Image 18: Product Journey. Source: Author

2.6 PRODUCTION & ASSEMBLY

Ice-World uses third parties to manufacture the parts needed to create the final boarding systems, only the final assembly is done at Ice-World.

2.6.1 BOARDING PRODUCTION

Ice-World has a vast network of part manufacturers and part suppliers. **Ice-World does not have the need or facilities to produce parts and entire products themselves.** This also shows from the company portfolio, it contains a lot of different in house designed products of different materials and construction, but these are all manufactured elsewhere. **For the new boarding, parts will be manufactured by a third party, as Ice-World does not own manufacturing equipment and is not intending major investments.** This also relates to pre- and post-production, such as coatings.

Image 20: Assembly rig used by Ice-World. Source: Author

2.6.2 COST PRICE

The wooden boarding is less expensive to produce and to rent (see Appendix 4) .**Customers expect the wooden boarding being the less expensive option compared to the transparent boarding.** This relation should be kept intact with the redesign.

2.6.3 ASSEMBLY FACILITIES

Ice-World does not have access to advanced assembly facilities. The assembly of the boarding is done by hand - with a special assembly rig (see image 20). For the final assembly Ice-World makes use of electric and non electric hand operated tools such as a drill and a ratcheted socket to assemble panels. The assembly process needed for the new boarding should also allow the assembly workers to deliver a consistent build quality. **Currently a five meter panel is assembled within 20 minutes** (Koen van Dongen, Production Manager, 2019). Sometimes extra boarding is needed in a rush and Ice-World needs to produce extra boarding in a very short timeframe, this means easy final assembly is desirable.

Requirements Production & Assembly:

Requirement: Part production is done by existing third party manufacturers. (2.3.1)

Requirement: Final product costs should be lower then the transparent boarding. (2.3.2)

Requirement: Final assembly should be possible with the current Ice-World facilities. (2.3.3)

Requirement: Final assembly of one panel needs to be possible in no more then 20 minutes (2.3.3)

Wish: Parts should be constructed from standard purchase parts as much as possible. (2.3.2)

Wish: Final assembly needs te be as easy as possible. (2.3.2)

2.7 STORAGE

From assembly the boarding goes into storage, awaiting the moment it will be used. Ice-World has a storage facility with a capacity of 7600 square meters and this space is fully used during off season. The high season for is from November to January. So, **on average the boarding is stored for 9 months in a row**. Main aspects in the 'Storage' phase are the volume, securing, storage stability, storage impact of the panels.

2.7.1 STORAGE VOLUME

The wooden boarding is stored with 8 panels of 5m on a single pallet (see image 21, 22). **Of the total package 89% is air and can be considered as 'lost' space** (see Appendix 2). The boarding stands remain installed during storage which prevents the panels to be stacked efficiently. Currently around 7000m wooden boarding is stored – resulting in a large amount of unused storage space.

The storage space of Ice-World is at the limits of the capacity. More efficient storage is necessary when the company keeps growing. Ice-World is already building extra levels in their warehouse to accommodate for extra storage space, as Ice-World is currently not looking to expand it's facilities, but optimize it's current storage first. (Guido Molenaar, Manager R&D, 2019).

Image 21: Stacked pallets with boarding. Source: Author

Image 22: Current storage situation. Source: Author

2.7.2 SECURING THE PANELS

The boarding is strapped down with 2 clamping straps. The boarding is deforms through these clamping straps, because of the force needed to secure the panels (see image 23). As the boarding is stored for 9 months these deformations become permanent, this has a negative influence on the lifespan and appearance of the product.

Image 23: Clamping straps deform the boarding construction. Source: Author.

2.7.3 UNPROTECTED SIDES

The sides of the boarding are exposed during storage and transport. As the panels are quite large and impractical to move around, the sides of the panesl are quite vulnrable. **When a side impact happens the boarding is prone to have chips and splinters created,** causing unsafe situations and a decrease in lifespan. With the new design it should be prevented.

2.7.4 STORAGE STABILITY

Another problem the was found through observations is that **the boarding cannot be placed on a pallet in a stable and safe manner.** The boarding is positioned on the pallet in upright position, causing instability (see image 24). As boarding can easily tip over it requires two people in the operation. The stacking of the boarding is a slow and unsafe process.

Image 24: Instable boarding and moving a pallet with boarding. Source: Author

Requirements Storage:

Requirement: The storage volume of 40m of the new boarding should be less then 40m of the current wooden boarding. (2.4.1)

Requirement: The boarding panels should be stackable on top of each other. (2.4.1)

Requirement: The boarding should be able to be stored at least 4m high (2.4.1)

Requirement: The boarding must not plastically deform when in storage. (2.4.2)

Requirement: Stored boarding should have no parts sticking out. (2.4.3)

Requirement: Storing the boarding may not decrease the lifespan of the system. (2.4.3)

Requirement: The boarding should not be able to slide around during storage. (2.4.4)

2.8 TRANSPORT

The ice rink is not permanent, so the components get shipped to and from an event many times. Transport is an important step in the process. In this chapter important factors that will be discussed are: Method of transportation and package dimensions.

2.8.1 TRANSPORT VOLUME

For the transport currently one trailer fits an average ice rink (see image 25), so normally a customer only pays for the transport of one trailer. The boarding influences the layout and volume of the ice rink within the trailer. When the boarding occupies less volume, more room becomes available for other components or accessoiries – making the transport more efficient and creating more transport possibilities. Having a lower transport volume will only be interesting for the cases that normally needed multiple trailers as the minimum amount of trailers used to transport an ice rink is one.

2.8.2 STORAGE TO TRANSPORT

At the start of the ice rink season, the components are prepared to be loaded up for transport. **On average five rinks are loaded per day for about a week.** During this timeframe the workload is high and the operation has to go smoothly to prevent delays. This is why the boarding is stored the same way as it is transported, so that the loading process to be as fast as possible. Another factor that enables a smooth loading process is that the amount **different parts needed for an entire ice rink boarding needs to be kept to a minimum, to lower the chance of parts being forgotten or wrong parts being transported** (Koen van Dongen, Warehouse Manager, 2019).

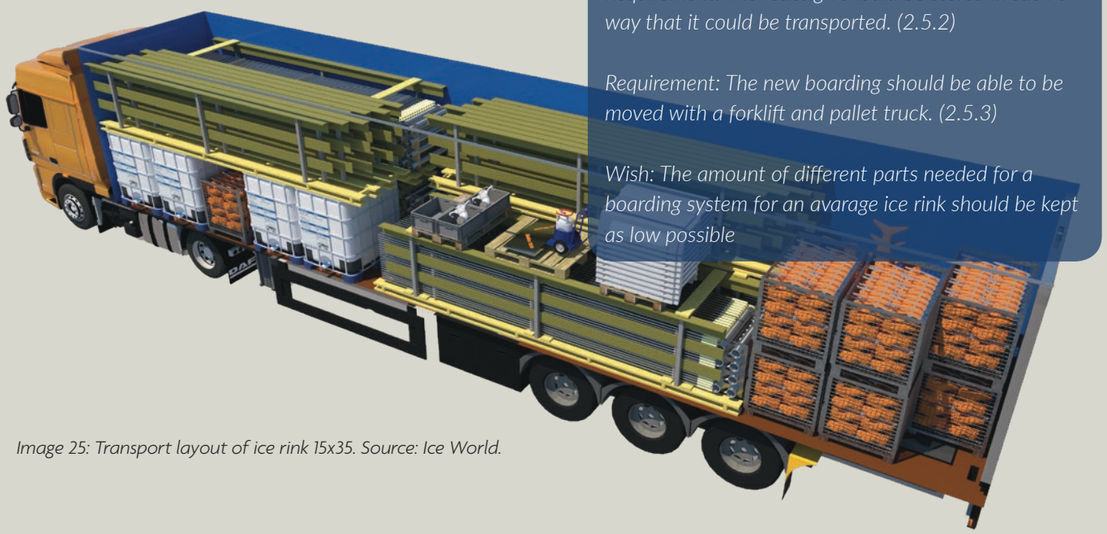


Image 25: Transport layout of ice rink 15x35. Source: Ice World.

2.8.3 MOVING THE BOARDING

At location and in the warehouse the **boarding is moved with a forklift or a pallet truck.** It should not be possible for the boarding to fall off when it is moving normally.

Requirements Transport:

Requirement: One unit of boarding can have a maximum length of 2.4m; a width of 1,2m; and a height of 2,65m. This will ensure the most effecient layout possible within the trailer, as other components are related to these number as well. (2.5.1)

Requirement: The boarding should be stackable in transport.
(2.5.2)

Requirement: The redesign should be stored in such a way that it could be transported. (2.5.2)

Requirement: The new boarding should be able to be moved with a forklift and pallet truck. (2.5.3)

Wish: The amount of different parts needed for a boarding system for an avarage ice rink should be kept as low possible

2.9 INSTALLATION

Once the ice rink components have arrived at the specific location the installation of the ice rink begins. **On average five to six installers build the ice rink of which two Ice-World representatives and the rest are hired temporary workers.** The main aspects in the 'installation' phase that will be discussed are the placement, aligning, connecting, securing and size adjustments of the panels.

2.9.1 INSTALLATION TIME

Ice-World promises to build an avarage ice rink in 24 hours. **Around 90m of boarding is needed for an average ice rink.** Placing the 90m of boarding takes around three hours, this comes down to around two minutes per meter.

Renting an ice rink is not cheap. **On average the customer pays around 115000 euros.** A part of this budget is influenced by the ice rink and boarding respectivaly. **The personell to install the ice rink is payed by the customer. So the longer it takes to install the higher the bill for the customer. (with a minimum of four hours), but overall this is only 2,5% of the total rink cost (for four hours)** (quotations Bussum). When a shorter or longer build time is achieved this will have a marginal effect on the overall costs, so a faster installation time will not be a requirement, but a wish.

2.9.2 BOARDING HANDLING

The boarding is taken out of the lorry and placed on the ground. From there the large panels are carried separately by two persons to the final location. **A boarding panel is 5m long and 44kg in weight. At least two persons are needed to carry this panel.** There are also smaller panels of two and a half and one meter long, but are not used often.

2.9.3 BOARDING PLACEMENT

Currently the boarding is placed on top of the cooling system and frozen into the ice. This means that a part of the ice cannot be used for ice skating. When visiting the installation of the ice rink in Bussum, **the customer wanted to maximize the ice available.** The customer requested for the boarding to be placed on the outside of the ice rink at the end header (see image 26). This meant extra effort was needed to adjust the boarding in such a way that is was usable on the outside of the rink. This placement also shows the importance of the relationship between the ice system and the boarding to be able to create the desired final product.

Image 26: Boarding placed on the outside of the rink. Source: Ice rink Noordwijk.

2.9.4 PANEL ALIGNMENT

Between the different panels there is a lot of deviation present, mainly caused by storage and assembly. This means that a smooth transition between the panels at the ice rink is not guaranteed (see image 28, 29). Also, because of the overall large size and weight of the panels, getting the panels in a straight line is a difficult task. At this moment aligning the panels needs two persons as moving one side of a panel usually moves the other side as well, as the panels are not yet connected. **The difficulty with allignment increases the installation time.**

2.9.5 CONNECTING THE PANELS

After placing the panels on the system, the panels are connected to each other. This is done by attaching a metal plate on the back of the boarding where the two separate panels meet (see image 29). **This method creates a very poor finish to the final product in combination with the wooden planks not alligning.**

2.9.6 SECURING THE PANELS

When the rink is finished the stands will be frozen solid into the ice, but before the ice is formed the panels are still quite unstable and fall over easily. To prevent this from happening the holes in the base of the stand enable the panels to be secured with screws to the wooden floor (see image 27) where the ice rink is placed on top off. When ice has formed, it is impossible to place fallen over boarding back upright. **So, boarding stability previous to ice formation is essential.**

Image 27: Base secured to the floor with a screw. Source: Author.

Image 28: Installation of the ice rink. Source: Author

Image 29: Current boarding connection. Source: Author.

2.9.7 USED TOOLS

A part of the installation process are also the tools needed to install the boarding. For many years the installation process has been the same and the installers are used to a certain method. Below an overview of the different tools used during installation:

- Cordless drill.
- Wrenches
- Handsaw
- Angle grinder

2.9.8 CUSTOM ICE RINKS

The majority of the ice rinks placed are comprised of the standard ice rink system, but sometimes a standard size just does not fit the location (see image 30). When this is the case the system is cut to a custom size. This also means that the boarding has to be cut to size to fit the ice rink dimensions. Ice-World wants to be able to serve every wish of the customer so it is in Ice-Worlds best interest when the boarding can be cut to size easily.

Image 30: Adjustments made to the boarding dimensions. Source: Author.

Requirements Installation:

Requirement: Installing the boarding with two persons should take no more then two minutes per meter. (2.6.1)

Requirement: Seperate parts should not weigh more then 50 kg. (2.6.2) (http://www.euronorm.net/content/template2.php?itemID=7)

Requirement: Boarding must not be stacked higher then 1,8m (2.6.2) (https://www.arbocatalogus-tg.nl/brancheafspraken/fysieke-belasting/tillen-en-dragen/)

Requirement: Installing a boarding section should be possible with a max. of two persons. (2.6.2)

Requirement: The boarding must fit every standard ice rink without any adjustments needed. (2.6.3)

Requirement: The boarding must be able to place on the outside of the ice rink to maximize ice surface.

Requirement: The seperate panels should be able to be alligned easily. (2.6.4)

Requirement: The seperate panels should be able to be connected to each other. (2.6.5)

Requirement: It should be possible to secure the boarding to the wooden floor boards. (2.6.6)

Requirement : Installation should be possible at the event with hand operated tools. (2.6.7)

Wish: To accommodate for divergent lengths in ice rinks, the boarding should be able to be adjust by size, without compromising the final quality. (2.6.8)

Wish: Installing the boarding with two persons should take less then 2 minutes per meter. (2.6.1)

2.10 USE

When the boarding is installed and the ice rink is ready, the event is ready to take place. At such an event lots of visitors come to ice-skate, but also come to watch the skaters. The primary function of the boarding in the 'use phase' is to create a save barrier between the ice-skaters and the spectators. The five main aspects in the 'use' phase that will be discussed are the behaviour of skaters and spectators, safety, sponsoring, maintenance of the ice and look and feel of the ice-rink.

2.10.1 VISITOR BEHAVIOR

During an ice-skating event the ice-skater and spectator use the boarding in several ways. The behaviour that is relevant for the redesign of the boarding are discussed below.

1. **Provide support to ice-skater**

Support is needed when an (unexperienced) skater moves around, but is scared to fall and therefor holds on to the boarding for a sense of security. The current boarding has a very stiff construction and a solid wooden plank on top that is used as a handrail.

2. **Sitting on top of the boarding**

As ice skating can be an exhausting undertaking, people seek places to rest in between rounds. There are in most cases no designated places to sit inside the rink. Therefore, skaters use the boarding as a seat (see image 31).

3. **Spectating**

People that visit an ice-rink also like to watch and see what is happing on the ice. Parents want to watch their children for example. Spectators lean against the boarding with their full weight.

Image 31: Visitors sitting on top of the boarding. Source: Ice World.

2.10.2 SAFETY

As ice skating uses sharp metal blades to move around, safety is a big factor when it comes to ice skating events. **Ice-World is expected to supply a safe product. If an accident would happen and Ice-World is to blaim it can have a large negative impact on the brand image and could cause a loss of customers.** There has been an incident where a little boy fell of the ice rink and dropped 1,5 meters (Guido Molenaar, 2018). This happened, because the boy was able to slide underneath the wooden boarding. This created the suspicion that the current boarding was not safe. **Analysis showed that there were no safety regulations or guidelines for the market.** To create a safe boarding this meant looking at other markets with similar use cases. To ensure a safe boarding the following safety issues have been considered:

1. **Creating a barrier between skater and spectator**

The majority of the skaters on the ice rink are not experienced skaters and are often unable to stop on their own. When they want to stop they use the boarding as a 'brake'. The boarding needs to be capable of resisting the impact, so that the skater does not collide with the spectators. Also, the boarding needs to be the right heigt to prevent skaters from falling to the other side.

2. **Preventing skater from sliding of the ice rink**

As mentioned an accident happened with a young boy fell off the ice rink. This must not happen again and so the boarding needs to account for this safety hazard.

Image 32: Vistitors placing drinks onto the boarding. Source: Wintervillage

3. **Sharp edges**

Currently the boarding is constructed in such a way that the transition between planks is not as smooth as it should be (see 2.6.5) It is possible for skaters to hurt themselves on these edges that are sticking out, these should not be present.

4. **Using the boarding to place drinks**

Catering is usually present around an ice-rink and spectators are allowed to take their drinks anywhere around the ice-rink. People place their drinks on top of the boarding (see image 32), as this is a flat surface. The (hot) drinks can be spilt or glass can fall onto the ice rink. Broken glass will freeze solid onto the ice, which is dangerous and difficult to remove.

2.10.3 MAINTENANCE OF THE ICE

It is very important that the ice is properly maintained throughout an ice-skating event. When skaters move around on the ice, snow is formed and creates an insulating layer on the ice. This snow layer makes it more difficult to move with ice skates. The snow also melts and subsequently freezes on the ice, adding an extra layer on the ice – resulting in higher energy consumption of the ice rink. This also happens when it rains. **It is important to enable drainage possibilities to remove snow and rain from the ice, to ensure a good skating experience and a lower energy bill.** Image 33 shows how Ice-World solves this with their transparent boarding, which normally is a closed design.

Image 33: Special boarding with drainage. Source: Ice World.

2.10.4 SPONSORING

Sponsoring is a big part of the revenue of a skating event. Around 50% of the revenue is created by the sponsoring. This is why most of the events cover the boarding almost entirely with sponsoring of different materials (see image 34). Currently sponsoring is only placed on the inside of the ice rink as the attachment on the outside of the boarding is difficult. **Sponsoring panels commonly have a size of 2m long – this does not fit on the outside of the boarding as the distance between the stands is to small.** Sometimes customers use banners to cover the boarding on the inside of the boarding, but this method is not preferred. Mentioned in customer interviews, customers seek to increase sponsoring capacity.

Image 34: Boarding covered with sponsoring. Source: Ice World.

2.10.5 LOOK & FEEL

Look & Feel is very important when organizing an ice skating event. Analyzing multiple ice skating events a specific atmosphere can be identified. **The customer wants to create a winter and christmas like look & feel.** Looking at Christmas markets and architecture in skiing resorts (see image 35) it proves why wood is used so often at these skating events (see image 35). This also explains why every competitor still offers a wooden boarding next to a more modern plastic one. For the new boarding to be succesfull the customer needs need to be taken into account.

Image 35: Collage atmosphere ice rinks comparison ski resort architecture. Source: Multiple

Requirements Use:

Requirement: It should be possible to hold on to the boarding as a skater. (2.7.1)

Requirement: The boarding should have a rigid construction and grasping posibilities should be between three and five cm wide. (2.7.1) (https://inspectapedia.com/Stairs/Handrail_Graspability.php)

Requirement: The boarding should be able to withstand inappropriate use by children that use the boarding as a seat. The new boarding system should not deform under a vertical load (on top of the boarding) of 2000N. (This is based on five p95 nine year old children of 40kg). (2.7.1) (dined.io.tudelft.nl)

Requirement: No sharp edges should be present and transition areas between panel should be smooth. (2.7.2)

Requirement: Guidelines from construction and building regulations were consulted in order to determine a safe height for the boarding. Building regulations for fences state that a height of 1 meter is required (https://q-netics.nl/nieuws/de-hoogte-van-balustrades-en-hekwerk-welke-regels-geleden-er/). Taking into account the extra height from the largest skates the required safe height should be 110 cm, measured from the ice surface. (2.7.2)

Requirement: Gaps within the new contruction can not be larger then 89 mm. (2.7.2) (Rolf Winter, 2019)

Requirement: The boarding cannot deform plastically under extreme loads. As an example, a p50 adult male of 80kg (dined.io.tudelft.nl) is skating at 15 km/h into the boarding. This comes down to a horizontal force of 1667N (2.7.2)

Requirement: The new boarding should not allow for drinks to be placed a drink on top of the boarding. (2.7.2)

Requirement: To ensure the ability of proper ice maintenance the redesign should have at least as much drainage surface area as the transparent boarding. On average four of these panels are placed on an ice rink. This comes down to a total minimal surface area of 1920800 mm2. (2.7.3)

Requirement: It should be possible to place trespa sponsoring panels of two meter long on one side of the boarding. (2.7.4)

Requirement: The boarding should fit the theme the customer of Ice-World wants to create at its event. (2.7.5)

Wish: It should be possible to place trespa sponsoring panels of two meter on both sides of the boarding. (2.7.4)

Wisht: The boarding should contain as much open space to maximize spectating possibilities. (2.7.1)

Requirement: The boarding should not corrode when used outside. (nog een stukje over scenario)

Requirement: The boarding must not plastically deform due rain, wind or heat. (nog een stukje over scenario)

2.11 MAINTENANCE

When the ice rink components return to Ice-World they are inspected and parts are replaced when needed (see image 36). This ensures that the components are ready next season before returned to storage. During this stage employees have been observed. Factors that are of importance are the return frequency, cleaning and repairs of the boarding.

2.11.1 RETURN OF THE RINKS

The high seasons in the Netherlands runs from the end of November to the midst of January. At the end of this season all the rink components return to Ice-World to be repaired, cleaned and stored awaiting the next season. The majority of the returns happen in one weeks' time. **During this week on average eight ice rinks a day arrive back at Ice-World. This relates to around 720 meters of boarding that has to be unpacked, checked, repaired and cleaned and then packed again for storage.** This creates a very high workload that hinders a proper repair and maintenance process.

The current construction of the boarding allows for easy replacement of the planks, where the planks are only attached to the stand with a nut and bolt. **So, when a five meter plank needs to be replaced this only takes a short amount of time, around ten minutes performed by one person.**

2.11.2 CLEANING

When the boarding returns, it has been outside for several weeks. The boarding could get dirty due to the use and environmental impact. When this is the case the boarding is cleaned by hand. It is important that the boarding can be cleaned easily before going back into storage, so that at the next event there is no dirt present.

Requirements Maintenance:

Requirement: Maintenance should to be possible with at Ice-World with the current facilities. (2.8.1)

Requirement: One plank can be replaced in a maximum of two minutes per meter. (2.8.1)

Requirement: The boarding can be cleaned with soap and water. (2.8.2)

Wish: Maintenance needs to be as easy as possible to prevent operational delays. (2.8.1)

Image 36: Boarding maintenance. Source: Author

2.12 END OF LIFE

There comes a moment during the life cycle of a product where the product does not function anymore and has to be discarded, repurposed or recycled. This is also the case with the wooden boarding. Some parts are able to be reused and others need to be discarded.

2.12.1 LIFESPAN

At Ice-World the current boarding systems has an intended lifetime of five years. This lifetime is currently not achieved (Erik Verzijl, Controller of Ice-World,2018). There are no clear guidelines that indicate when to replace a part – when it is not broken but only damaged by the impact of ice skaters or due to the transport. The repairs are thus opinion based, resulting in different levels of appearance, as planks are replaced at different times. The boarding is also known to splinter and deform due to transport and storage – contributing to an overall shorter lifetime.

The current wooden boarding consists two materials with different lifespans – galvanized steel and impregnated wood. Galvanized steel has a longer lifespan then the wooden planks. The stands are able to be reused multiple times as the damaged wooden planks can be replaced. Wooden boards that are only damaged on the sides are able to be shortened and reused as a different length panel.

2.12.2 BEING A SUSTAINABLE COMPANY

Ice-World tries to become a more sustainable company. The internal analysis showed that they are putting (some) effort into this by using solar energy and biodegradable cooling fluids. The boarding can become more sustainable and contribute to the overall goal and marketing of being more sustainable. Currently the materials used by Ice-World for the boarding are not focussed on sustainability, especially the wood used. This impregnated wood cannot be recycled or burnt, but has to be discarded in a particular way.

Requirements End of life:

Requirement: The lifespan of the boarding should be at least 5 years (2.9.1)

Wish: The lifespan of the redesign should be as long as possible. (2.9.1)

Wish: The materials used for the redesign should be fully recyclable. (2.9.2)

2.13 EXTERNAL ANALYSIS

Besides the internal analysis, an small external analysis has been done aswell. This analysis includes factors like competitors and the customer needs.

2.13.1 COMPETITOR ANALYSIS.

A condensend competitor analysis has been performed to explore the current trends and product offerings in the market. This analysis shows the market offerings and possible opportunities within the market.

The main competitors of Ice-World are:

- Satellite
- Delta Temp
- Ijsgarantie
- AST
- Industrial Frigo

The collage (image 37), shows the different boarding systems used by the competition. Besides the collage, the company brochures have been consulted. From this analysis, there are two key insights:

- **Every competitor offers a wooden boarding and plastic boarding with no additional features and similar looks**
- **There is only one competitor, AST, that offer ice rink boarding with integrated lighting.**

Within the current market, it is difficult for Ice-World to differentiate. Every competitor has somewhat of the same offer, but this means that there is lots of room for Ice-World to innovate.

Image 37: Collage wooden boarding from competitors. Source: Multiple

2.13.2 CUSTOMER NEEDS ANALYSIS

An analysis around the customers' job to be done was carried out to understand how a new boarding system can deliver additional value (see image 38). This analysis is based on customer interviews, observations and trend reports.

As Theodore Levitt said, "people do not want a quarter-inch drill, they want a quarter inch hole." This is also true for customers of Ice-World. Customer buy a services from Ice-world to get jobs done. This notion is at the heart of jobs-to-be-done theory. The theory was used to explore all the customer's needs around a boarding system and determine which are unmet.

Customers jobs to be done start with an desired outcome (level 1) that describes the desired end-state on an abstract level. We can subsequently break down a desired outcome in a Job To Be Done (level 2), related activities (Level 3) and products and services used in that activity (level 4).

After the overview was completed, several business opportunities, both for short and long term, have been identified. Besides the opportunities for Ice-World as a business, possible search area's have been selected.

Customer: 'Next year we are placing led lighting in the ice.' (05-03-2019)

2.13.2.1 QUICK WINS

Ice-World has a broad range of accessories that can be used for activities on the ice besides ice skating. The need for activities on the ice is increasing, as the visitor looks for an enriched experience. (Oomes, M., 2014). **For Ice-World, it is essential to keep developing accessories as it can act as a differentiator from the competitors.** Accessories are within the core business of Ice-World and therefore identified as a quick win. For the ice rink itself it could improve on seating options for the skaters as skaters often look for a place to rest during ice skating.

2.13.2.2 LONG TERM OPPORTUNITIES

The identified long term opportunities could be used in a broader sense than just the boarding. These opportunities will be discussed in the recommendations. The search areas below the long term opportunities are related to the boarding and will be discussed next.

2.13.2.3 SEARCH AREA'S

Games

The first search area relates to providing products and services that enable customers the ability to included games and other activties on the ice. Curling is already a populair game on the ice. It could be interesting to explore how the boarding system can contribute to this trend. Could the boarding incorporate game elements? .

Event dressing

The next search area's revolves around the winter atmosphere of an ice rink and how the boardig could play a bigger role in the context setting of an ice rink. Think of boarding that could look like it is made of ice or lighting solutions that are incorporated in the boarding system.

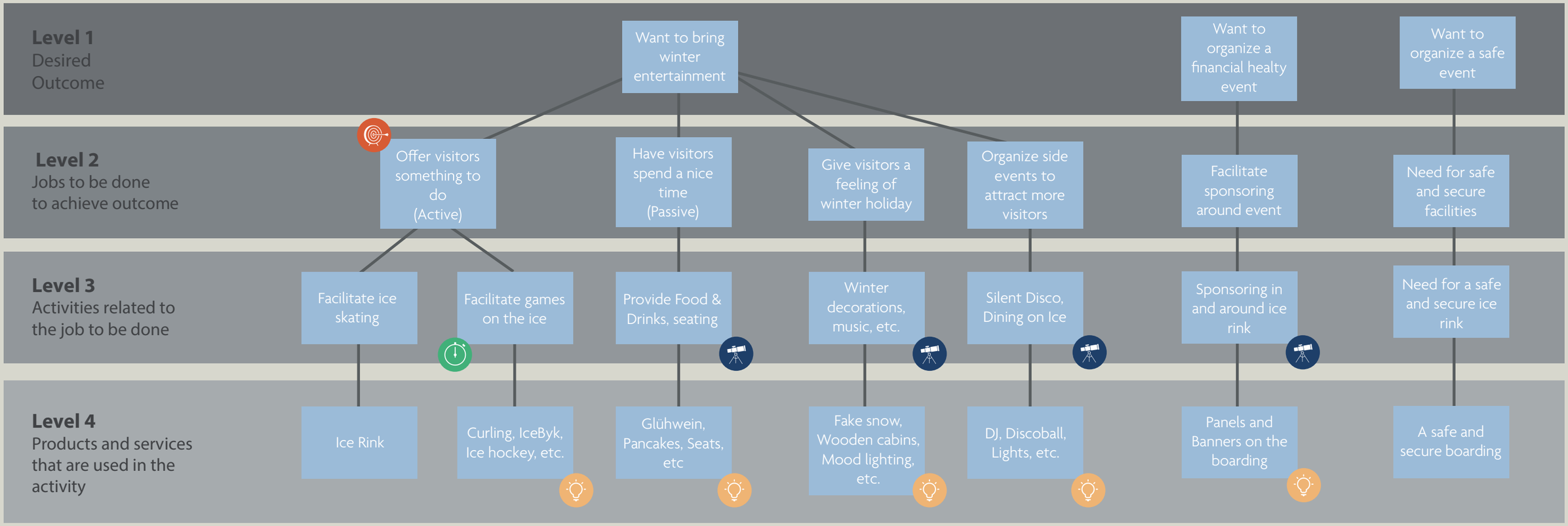


Image 38:. The customers' desired outcomes related to the ice rink and the influence of Ice-World. Created by Author

Activities
The third search area looks into opportunities for the boarding related to activities on the ice besides is skating that are not games. Like disco's. How could the boarding play a role as disco lighting for example.

Sponsoring
The fourth search area is related to the sponsoring of an ice skating event. around 50% of the ice rinks income comes from sponsoring (Wibe Kramer, Account manager, 2019). Currently, the sponsoring does not add to the atmosphere of the ice rink. It could be interesting to look for ways to integrate the sponsoring in a more professional manner and with improved aesthetics.

Seating
Skater and visitors interact during a skating event, you would see skater standing still against the boarding talking to spectators. These spectators and skaters are often acquainted. This experience could be improved by creating a bar like setting around this interaction, by placing a couple of bar like tables on top of the boarding for instance.

2.14 DESIGN GOALS AND VISION

2.14.1 DESIGN GOALS
The design goals have been created to use as design guidelines in the next phase. These goals are the outcome of the research done. During the process ideation and research was done paralell to each other. This meant some prelimenary ideation was done into the search area's that resulted from the customer jobs to be done, Only later it was conclusde that a sound foundation was needed as the general construction of the new boarding, then after this was done value can be added like lighting.

The vision statement gives a global direction for the end result. The design goals are more detailed and provide specific guidelines:

Design a...

- safer boarding.
- boarding that fits every commonly used rectangular shaped ice rink with a minimum size of 1x5m
- a boarding that is better recyclable
- a more efficient storage.
- a more efficient transport.
- a more efficient installation.
- boarding that is easy to maintain and has a long lifespan.
- boarding that fits the customers and Ice-Worlds' aesthetic needs.
- boarding that optimizes ice skating surface area.

2.14.2 DESIGN VISION
Based on the design goals a design vision has been generated.

VISION

A wooden boarding system that is safe, modular, durable, environmental concious, fits rink specific needs and contributes to the winter atmosphere, creating an overal better ice rink experience.

Image 39: Installing ice rink system. Source: Ice-World

3. DESIGN DEVELOPMENT

This chapter provides a short overview of the concept development, concept decision and final selection. This chapter only shows a small overview of the three concepts and decision. See appendix 12,13 and 14 for more details about the concepts, like cost estimation, stiffness simulation results and extra images. Ranking the criterion was done with the pairing method (Roozenburg, N.F.M. and Eekels, J., 1995) (see Appendix 16)

3.1 IDEATION

The concept development process consists of an ideation and conceptualization phase. First the ideation phase will be discussed followed by an overview of the concepts that are developed. At the beginning of the ideation phase an exploration into lighting has been done (see Appendix 9,10), but it became clear that the first priority had to be the overall construction, so the search area's from the customer jobs to be done were put on hold.

3.1.1 IDEATION

The ideation phase was about creating lots of different ideas and finding solutions to sub-problems of the boarding - like minimizing storage volume. These small ideas were combined to create more elaborate ideas. The ideas are subsequently translated to concepts that solves several problems or challenges. All concepts fulfil the list of requirements.

The ideation phase started with the deconstruction (1) of the boarding system. By deconstructing the boarding in different elements and functions a complete and profound understanding of all the different sub-problems was created. The sub-problems formed the starting point for idea generation. With the 'How can you' technique many different solutions for sub-problems were explored. These 'How can you's were discussed and elaborated on in a brainstorm session (2) with Ice-World employees. Thirdly, an overview of all the problems (3) found in the analysis were brought to the table and ideas were created to try and solve these problems. Finally, other markets (4) were explored to find existing solutions and inspiration.

3.1.2 SUB-PROBLEMS

When the ideation started it became clear that generating ideas for a new system as a whole was not very effecient. To enable a more specific ideation, questions around sub-problems were created, for example:

- How do you make sure a construction stays upright?
- How could you connect panels to each other?
- How could you allign panels to each other.
- How do you create a barier?
- How do you create effecient storage?

These subquestion were used create for an individual brainstorm, but also used in the brainstorm with Ice-World employees. The sub questions were also used to find solutions within other, adjacent markets, like construction.

3.1.3 INSPIRATION FROM COMPETITION

From the competitor analysis, it could be concluded that every competitor uses a different boarding concept for its recreational ice rinks. To generate additional idea's and inspiration for possible an proven constructions. The boarding of the competitors have been looked at to find interesting solutions for problems like the connection method.

Image 40: Brainstorm with Ice-World employees. Source: Author

3.1.4 BRAINSTORM SESSION

A brainstorm session was held with 4 Ice-World employees. 2 people from R&D, 1 from Operations and 1 from customer relations. The goal of the brainstorm was to find possible solutions concerning installation, ambiance and sponsorship. These questions followed from the field research, customer needs and the analysis of the current product life cycle.

Procedure

The brainstorm started with a short introduction of the current problems concerning the 3 subjects. Per subject several how to's were formulated and through different strategies the questions were answered. After each subject the solutions were discussed and the most relevant and interesting solutions were selected. From this selection the ideas were elaborated. These ideas were collected and show the main insights of the brainstorm session. Most of these insights are recommendations as they are outside of the project scope.

Main insights of brainstorm session:

- Placing advertisement onto the boarding in not beneficial for the appearance of the ice rink, other solutions for advertisement and the possibilities of placing it elsewhere besides the boarding could be an interesting area to explore.
- Placing the boarding stands underneath the ice rink system could have several benefits and needs to be incorporated in the redesign.
- Integrating multiple rink components (such as the stand and corner profile) could have several benefits and could ensure less building actions.
- The stands could be used to house flags or torches to increase the functionality of the stands.
- Integrating lights into the boarding is seen as an opportunity – to enhance atmosphere.
- Connecting multiple boarding sections without screws can benefit the overall finish and build time of the boarding in total.
- Instead of adjusting the boarding to size - the entrance of the rink could be adjust to fit the rink.

3.1.5 EXPLORING OTHER MARKETS

Adjacent markets were explored to find inspiration from existing solutions (see image 40). Existing solutions around boarding in construction, professional sports, sport events, event production and kettle farming were reviewed. solutions for support, material use and connection methods were explored.

Image 40: Images of construction solutions in other markets. Source: Multiple

3.1.6 BOARDING PLACEMENT EXPLORATION.

The research into customer needs showed the customers wanting to maximize the ice that is currently provided. In some cases, this meant the boarding had to be placed on the outside of the ice rink system. The current boarding system is designed for this purpose. An analysis has been done on different boarding configurations possible that place the boarding underneath the ice. The goal is to offer the customer 'more' ice, but on the other hand, Ice-World requested to keep the number of different parts needed for the entire boarding system to a minimum.

There are only two options that are possible without over-complicating the boarding construction (see image 41). The grey area's in the images are the headers present in the ice rink system. The start header is not submerged in ice during use, which currently makes it too impractical to develop a system that could be placed on the outside of the rink in its entirety. So the two options left are:

Option one:
The boarding on the header sides is placed on top of the ice rink system.

Option two:
The boarding is placed underneath the ice rink system, but only the start header side is placed on top of the ice rink system.

Placing the boarding underneath the ice rink system will increase the overall height of the system, which will be the main difference between option one and two for the end header boarding. The ice rink system analysis showed the width of the system is not scaled the same way as the length of the systems. This will affect the length and width of the boarding system, respectively. The effect this has on option one is that the boarding used on both header sides can be the same construction, as well as the boarding on the non-header sides. For option two, this means that the start, end and non-header sides all have a different combination of height and length, creating an overall more complicated construction. Option one is chosen for further development.

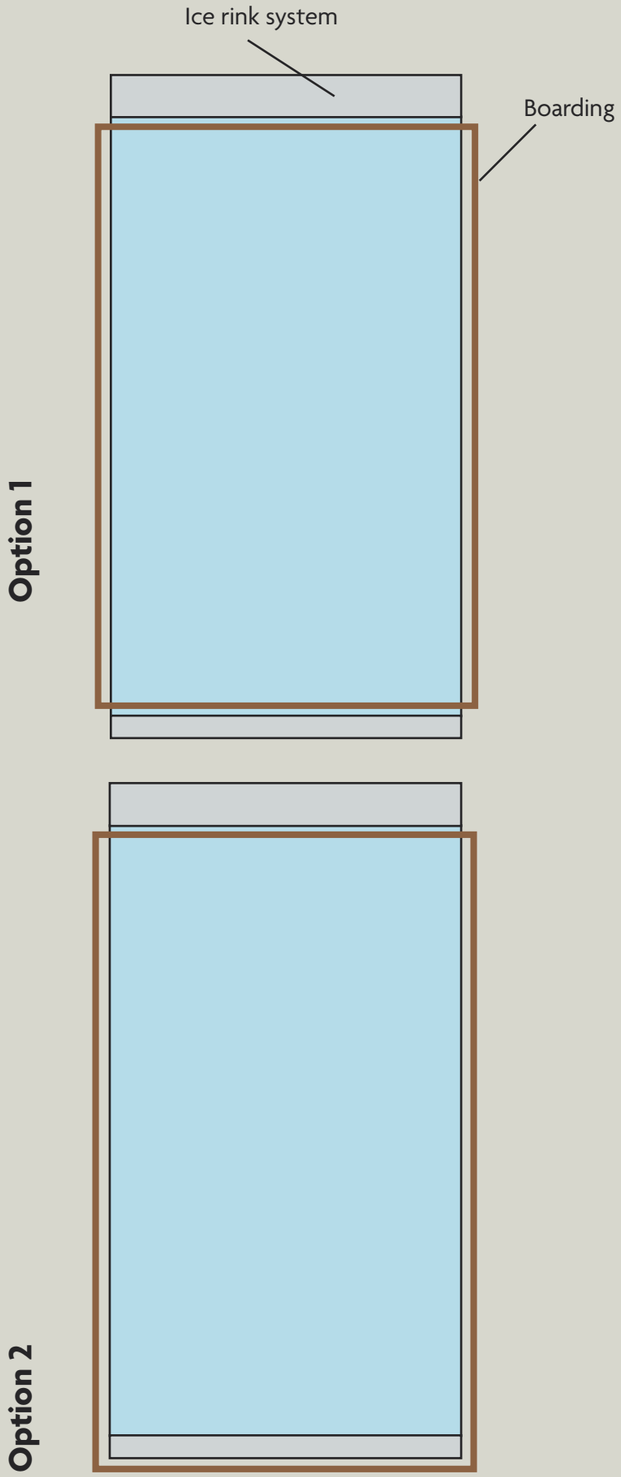


Image 41: Boarding placement options. Created by Author

3.2 THREE CONCEPTS

From the ideation phase, three concepts were created, in this chapter these three concepts will be explained in short.

3.2.1 CONCEPT 1 – MINIMAL

This concept consists of 4 wooden boards that are pre-assembled in between 2 galvanized steel frames, here the frame also acts as the support.

Having the base separate from the support and the support integrated into the panel optimizes storage volume, where this is a core problem of the current wooden boarding. Each panel only needs one base and the side without a base rests on the next panel.

A hook on the top of one side of the panel connects to the next panel and ensures that the panels align, without the need of additional parts. At the bottom one additional bolt is used to connect two sections together and takes away any play that might occur between the panels.

The handrail is an extrusion profile that is added to the panel at IW. This handrail is quite similar to the handrail the transparent boarding uses, this also creates a detail that connects this concept to the IW identity.

Image 42: Concept ! panel and base. Source: Author

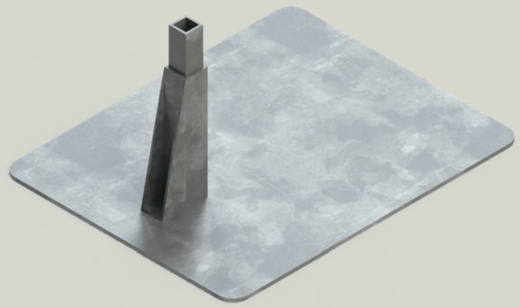
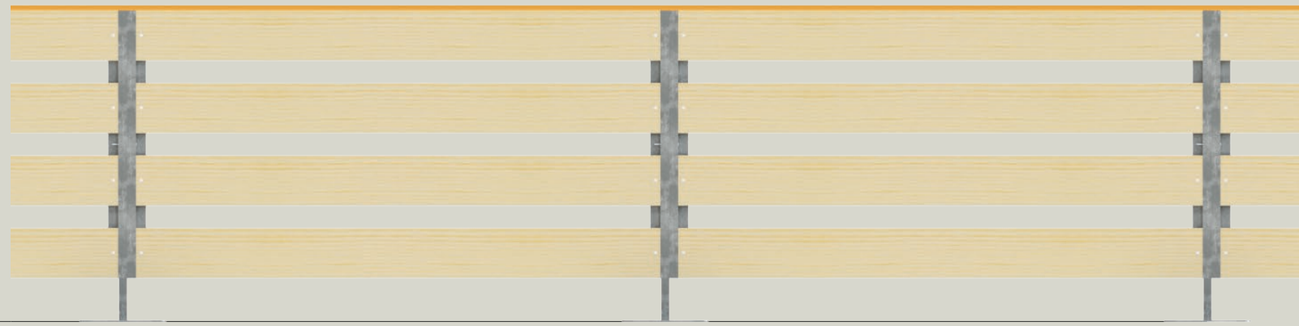


Image 44: Concept 1 base. Source: Author

Image 43: Concept 1 combined. Source Author.



3.2.2 CONCEPT 2 – CLOSED UP

This concept consists of 5 wooden boards that are placed in between 2 galvanized steel I-profiles.

The planks have a special profile that eliminates any horizontal play between the planks. The planks and stands are stored and transported separately and are installed at the location of the ice rink. This makes it possible to store and transport the wooden boards as efficiently as possible.

The profiles provide alignment in between the wooden boards as they fall into place one at a time. Here the feet are attached to the profile as there is no need to separate these. When all the boards are stacked on top of each other a final bolt in the top board ensures that all the boards are fixed within the frame at that they cannot be taken out of the frame without tools.

The board that is placed last has a handrail already installed onto it. This handrail also is an extruded plastic piece and can be screwed into the board.

Image 45: Concept 2 panel and support. Source: Author.

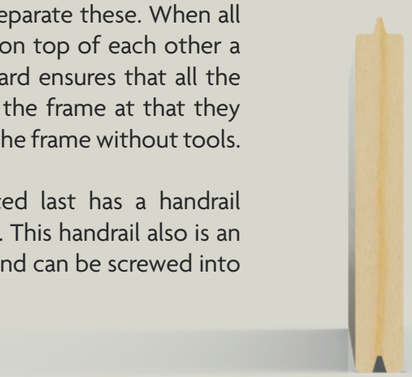


Image 46: Concept 2 plank with special profile. Source: Author.

Image 48: Concept 2 support. Source: Author.

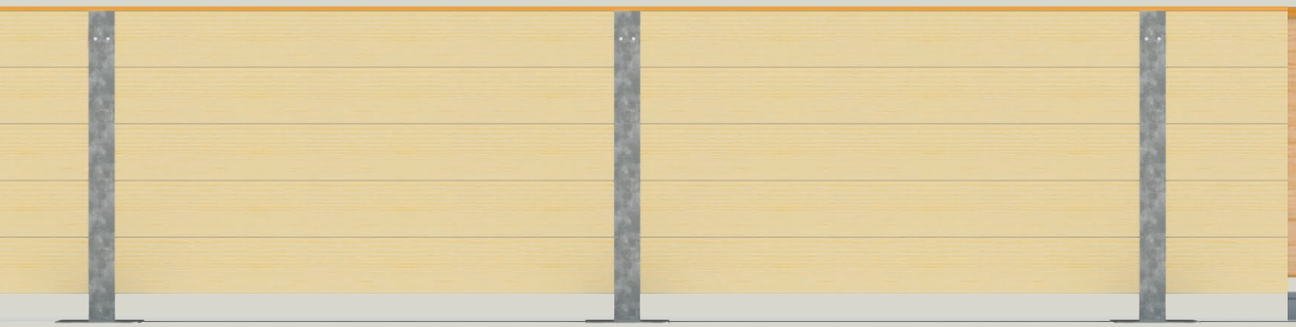


Image 47: Concept 2 combined. Source: Author.

3.2.3 CONCEPT 3 – PROFILE

This concept tries to integrate the corner profile used to create the water basin into the support of the panel. The section consists of a tubular frame where a panel of wood is placed on top of.

The frame creates the required stiffness and safety to stop the wooden panel from breaking on impact. The frame extends underneath the wooden panel to create the ability for the panel to be placed into the support.

The support acts as a rails, so when the panel is placed inside the support the panel whill automatically be alligned. The frame on the backside of the wooden panel does make it more difficult to place sponsoring on both sides of the panel.

Image 49: Concept 3 panel and support. Source: Author.

Image 50: Concept 3 panel rear view. Source: Author.

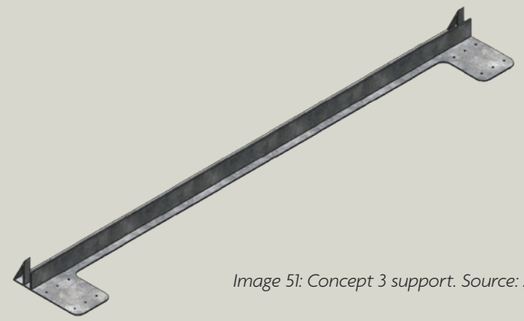


Image 51: Concept 3 support. Source: Author.

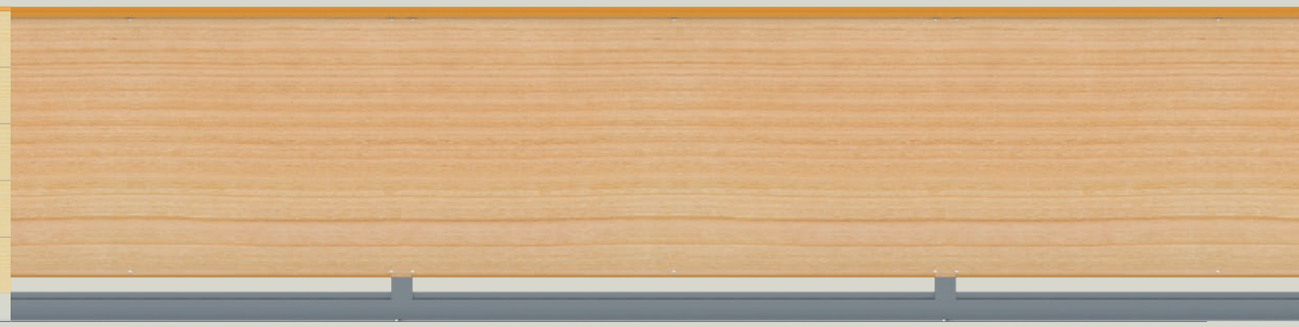


Image 52: Concept 3 combined. Source: Author.

3.3 SELECTION

The weighted criteria method was used to make a validated decision on the final concept. Ten criteria have been ranked based on importance. All concepts are scored on the different criteria and multiplied based on their ranking. Most of the scores are based on assumptions, like ease of install and expected lifespan, but aspects like cost price estimation, storage volume and installation time have been calculated and can be found in appendix 15 and 18.

3.3.1 SCORING THE CONCEPTS

Each concept is scored on a 10-point scale (1-10) for all nine criteria. This score is then multiplied by the multiplier of that criteria to get the final number. Then the scores are added up to get the total for each concept. See table below. Concept 1 has the highest overall score and is the preferred concept, but strong aspects from other concepts might be usefull to combine with concept 1. Ease of install for example.

Criteria	Value	Concept 1	Concept 2	Concept 3
Storage Volume	21	9	7	5
Look and Finish	18	7	6	3
Product Cost	15	6	6	6
Ease of Install	10	6	9	7
Maintenance cost	8	9	8	4
Expected Lifespan	6	9	4	6
Handling	5	8	6	7
Size Adjustability	4	7	8	1
Installation Time	3	6	4	8
Total	90			

Table 1: Concept scoring. Source: Author.

Criteria	Concept 1	Concept 2	Concept 3
Storage Volume	189	147	105
Look and Finish	126	108	54
Product Cost	90	90	90
Ease of Install	60	90	70
Maintenance Cost	72	64	32
Expected Lifespan	54	24	36
Handling	40	30	35
Size Adjustability	28	32	4
Installation Time	18	12	24
Total	677	597	450

Table 2: Concept final scoring. Source: Author.

4. DETAILING & VALIDATION

To get to the final design, the chosen concept needs further development, this chapter discusses the steps and iterations that follow from the development of the concept to final design, from first itterations, prototyping and design validation.

Image 53: Ice rink system. Source: Ice-World.

4.1 FIRST CHANGES

First the concept went through some design changes, mainly to simplify the installation process and use a slimmer connection method betweed the wood and the metal stands.

4.1.1 CHANGES TO THE BASE

Changes to the overall installation functionality can be found in the base and the frame of the boarding. The base of the final concept supported only a single side of the panel and the connection and allignment of the panels relied on a hook on the top of the support that interlocked with the next panel. A simplification step to the construction was done to improve the installation simplicity.
The new base now connects and alligns the panels at the same time and also the panels done not rely on each other for support anymore. (see image 54,55)

4.1.2 CHANGES TO THE FRAME

The frame has been simplified as the connection and allignment functionality has been moved to the base instead. (see image 56, 57)

4.1.3 CHANGES TO THE ASSEMBLY METHOD

To create a sleaker looking panel, the connection method used to fix the planks to the frame has been changed to a screw connection instead of the bolt connection, that is also currently used by Ice-World. This means that also the back side of the panels has no more parts sticking out.

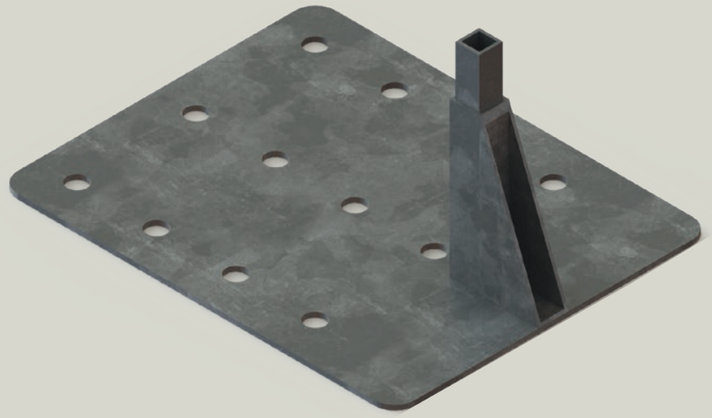


Image 54: Base Concept 1. Source: Author.

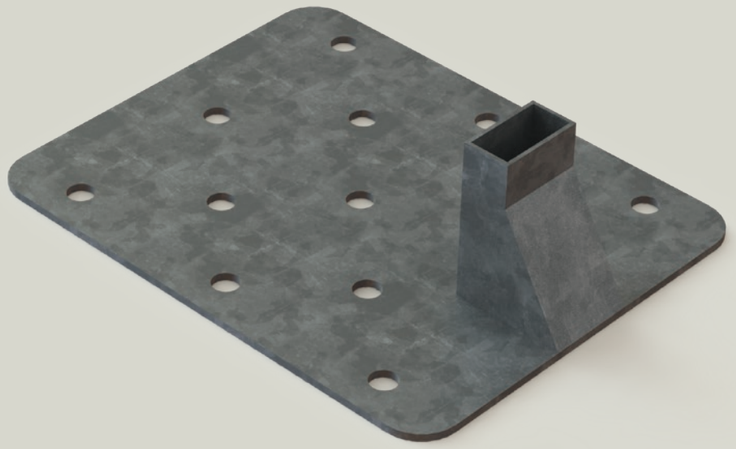


Image 55: Base Final design. Source: Author.

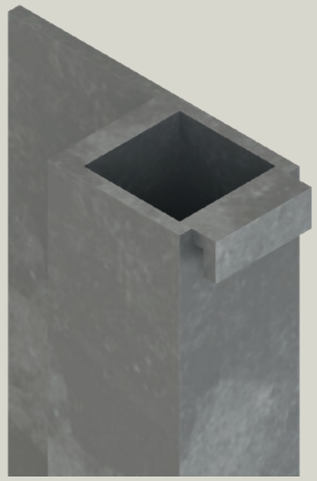


Image 56: Right side frame Concept 1. Source: Author.

Image 57:. Right side frame Final design. Source: Author.

4.2 SIMULATING IMPACT

The boarding is subjected to impact forces during an event. We have taking an extreme situation as the requirement to test the viability of the design. A person of 80 kg who is unable to slow down crashes into the boarding at 15 km/h. This creates an impact of 1667N. The following 2 situations are tested during a simulation:

- The impact is directly onto the top of the support.
- The impact is in the middle of the top plank of the largest panel.

4.2.1 APPROACH

Solidworks simulations was used to simulate the two scenarios. First, the 3D-models of the different parts were created and assembled. The simulation provides insights into the internal stresses and deformations of the construction and can be used to determine if the construction will fail or not. The parts have been simulated separately and as an assembled construction (see image 58) – to get a realistic view on the influence of the impact on the boarding.

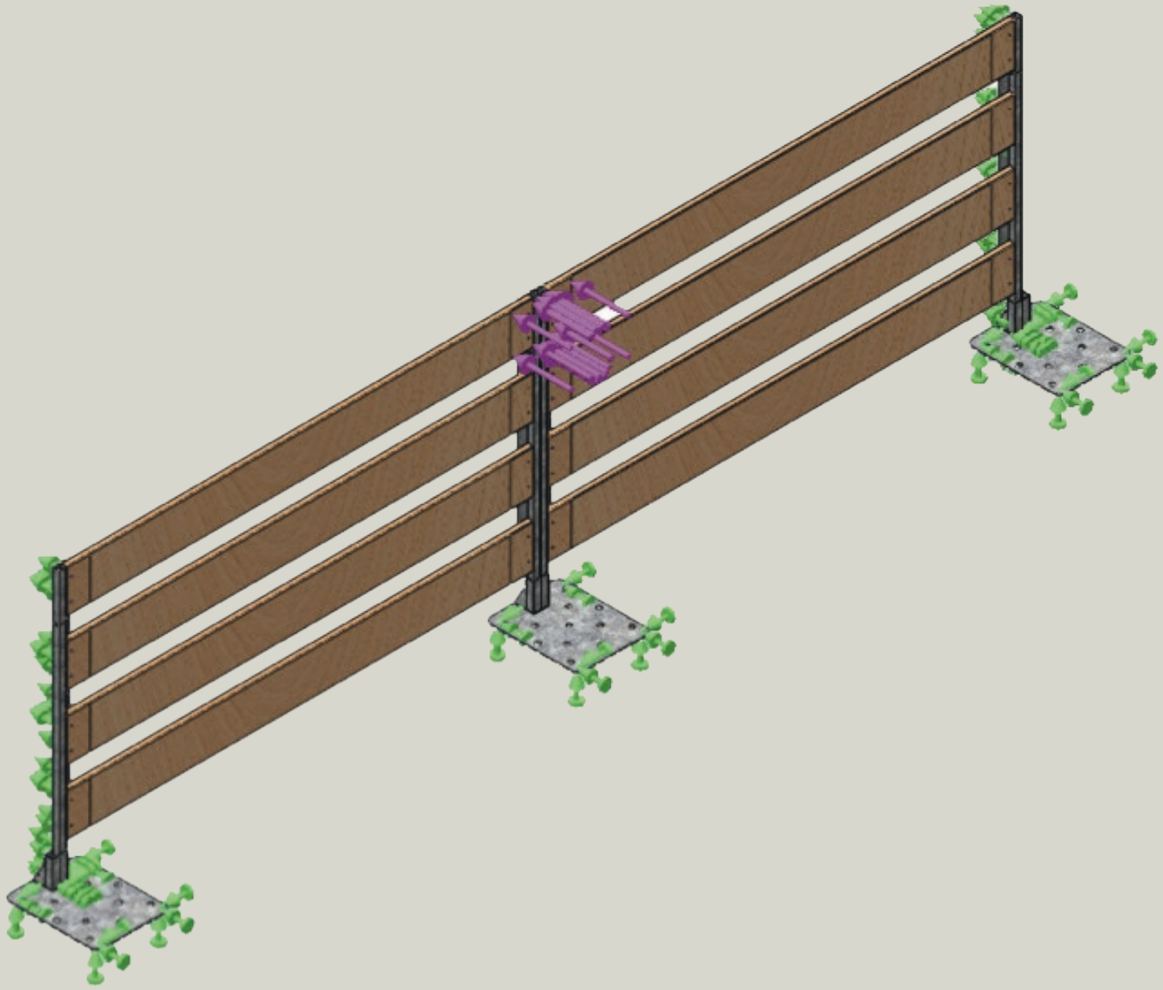
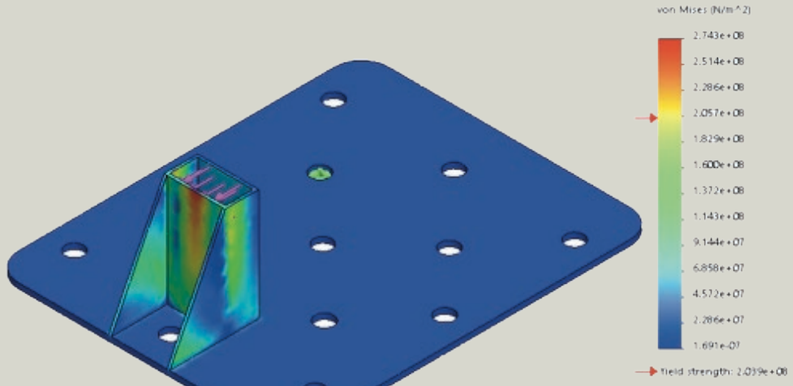


Image 58: Setup of the solidworks simulation for the entire construction. Source: Author.

4.2.2 ITERATIONS

The simulations have been used to improve the final design and optimize the construction. E.g. the support and the base have been subjected to several variations. To illustrate the iterations an example of the base is provide below.

Image 59 shows internal (Von Mises) stresses of 274MPa in the base. Based on a first simulation, an iteration to the design was made. The internal stresses have been reduced to 147MPa and this does not exceed the yield strength of 235 MPa. The overall dimensions have been kept the same but the support ribs have been placed closer together. In the final design the ridges have been closed of from a safety standpoint (see image 63).



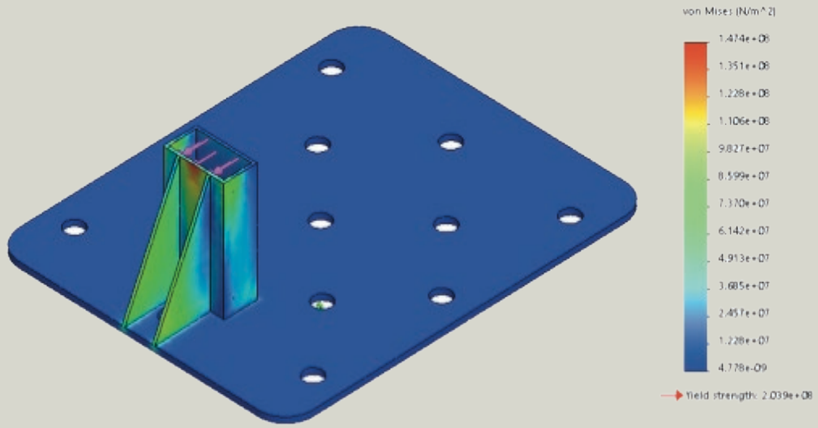


Image 59: Simulation results for two previous base versions. Source: Author.

4.2.3 RESULTS

In the simulation a comparison of the internal stresses (Von Mises) and the yield strength have been made. The yield strength is the point where the material goes from elastic, meaning it can bounce back to its initial shape, to plastic, where the material is permanently deformed. So, it is important that the stresses present in the construction stay below the yield strength. Image 60 shows the internal stresses of the entire construction. Images 62, 63 and 64 show the stresses in the different parts. As expected, the highest stresses are located in the base and the support. However, none of the simulations exceed the yield strength.

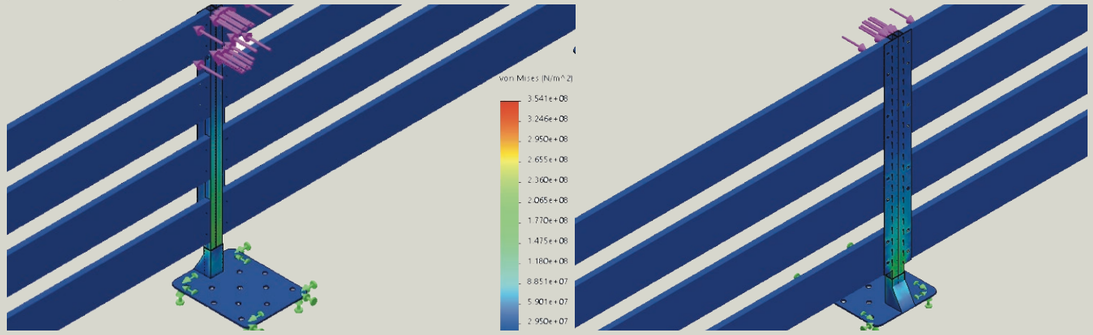


Image 60: Stress distribution in entire contstruction. Source: Author.

With the software it is possible to pinpoint the location of the highest stress and see if these surpass the yield-strength. Image 61 shows that there are no higher stresses then 173MPa present and that these stresses do not surpass the yield-strength of 235 MPa. This means the final design of the support and base will not plastically deform under the prescribed impact. Thus, the requirement is met.

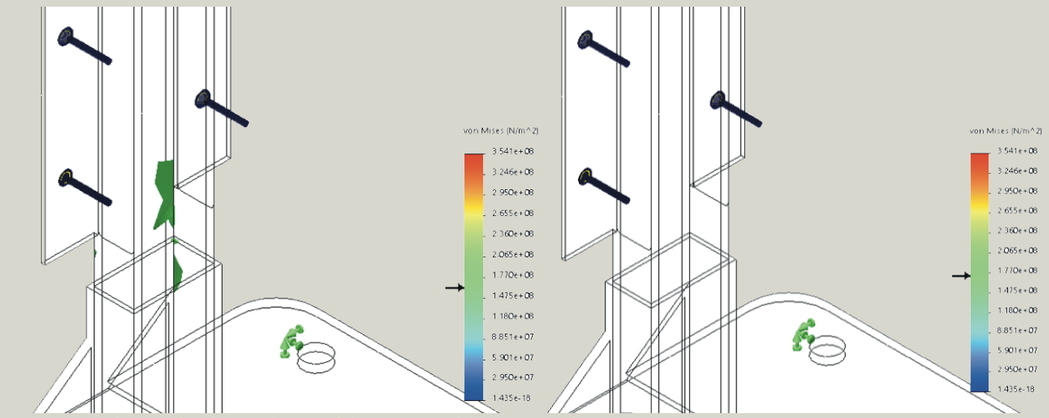


Image 61: Peak stress for the simulation of the entire model. Source: Author.

The parts have also been tested separately. Image 63 shows the simulation of the base and a maximum internal stress of 188 MPa

The support (image 62) shows a maximum internal stress of 196 MPa, which is still below the yield-strenght.

The planks have been simulated with the second scenario (see image 64). The results show the plank is subjected to internal stress of 27 MPa at the hole where the plank is attached to support. This is below the yield-strength of 79 MPa. Furthermore, the plank has a maximum deformation of 1.8 cm, which is acceptable in an extreme scenario.

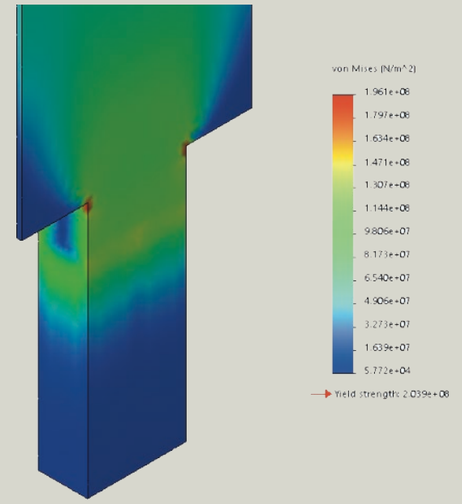


Image 62: Results for the simulation of the support. Source: Author.

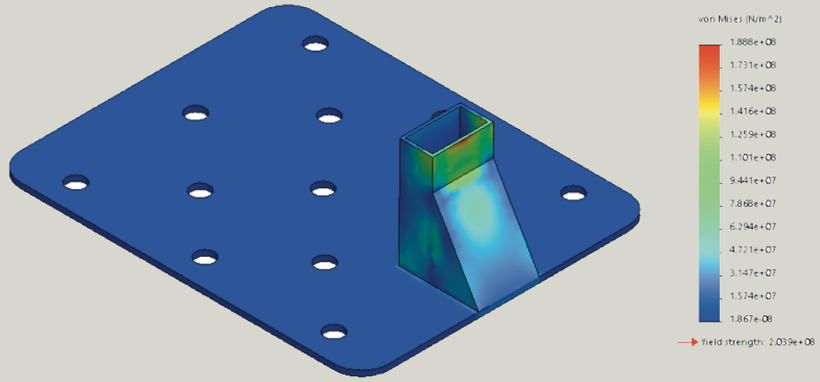


Image 63: Results for the simulation of the base. Source: Author.

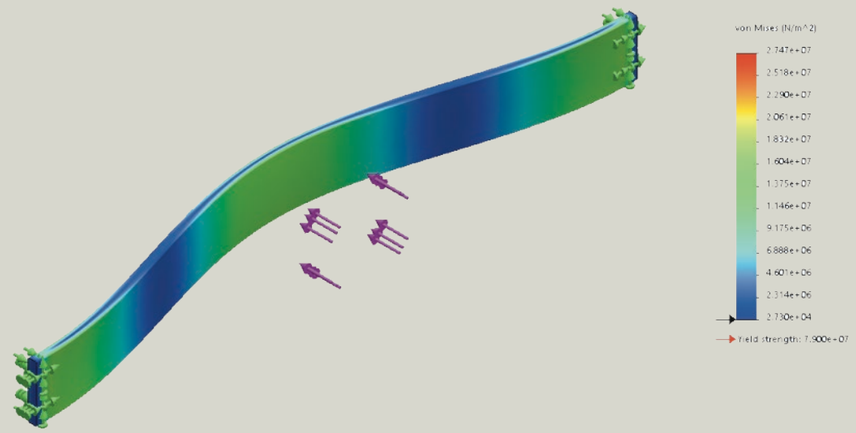


Image 64: Results for the simulation of the plank. Source: Author.

4.3 BUILDING A PROTOTYPE

A full scale prototype was created to validate the assumptions of the concept and to test the construction on strengh and impact (see images).

The prototype is constructed from the materials and parts that were readily available. Minor changes were made in the prototype and material selection in order to deliver a full scale model in a time frame of one week. 2mm steel was used to create the support instead of 3 mm. The test that the prototype would be used for did not require the frame to be the correct thickness, as the main goal was to test the connection between the frame and the wood and the installation speed.

The prototype has been developed according to the following steps:

- First the steel profiles was cut to size and welded together to create the support and base of the boarding. The base had to be cut and put together from flat metal sheets, which made it particulary difficult.

- Next, the holes were drilled in the support for the planks and one hole where the panels would be connected to each other.

- The steel parts were spray painted to protect them against rust and improve appearance.

- PlatoWood planks were sawn to size and assembled to the support. To make sure the holes were drilled in the right place the planks were placed on a flat surface. Then the supports could rest on the planks in the right position.

- Finally, the handrail was placed on top of the panels and the panels could be placed in their respective base. The handrail is the same handrail as the current transparent boarding as it was readily available.

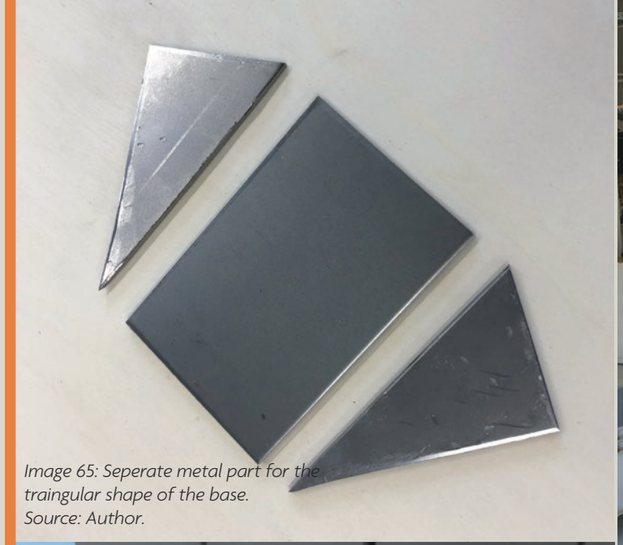


Image 65: Seperate metal part for the traingular shape of the base. Source: Author.

Image 66: Bare metal welded base without the baseplate. Source: Author.

Image 67: Testing fitment of supports with the base shaft. Source: Author.

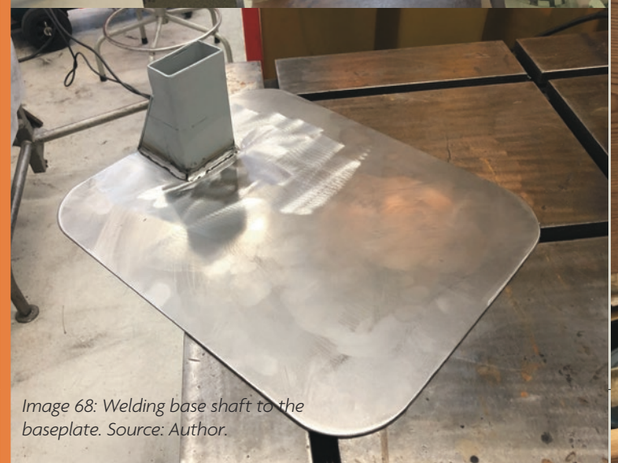


Image 68: Welding base shaft to the baseplate. Source: Author.

Image 69: Rear view of base and support assembly. Source: Author.

Image 70: Total rear view. Source: Author.

Image 71: Detail of bolt connection. Source: Author.

Image 72: Overview of finished supports and bases. Source: Author.

Image 73: Total front view. Source: Author.

Image 74: Detail of the base and panel connection. Source: Author.

4.4 TESTING THE PROTOTYPE

The prototype was used to test features and requirements that were not yet tested in the digital simulation. The installation time and two improper use scenarios have been evaluated - including sitting on top of the boarding and kicking against the planks to see if the screws will hold up.

4.4.1 SITTING ON THE BOARDING

Sitting on the boarding is a realistic improper use scenario (see image 75). It is almost impossible to prevent people from sitting on the boadring and thus this scenario has been evaluated. The scenario calls for 2000N placed vertically onto the top of the boarding. The image shows three adults simulating the load. With the load placed ontop of the boarding the construction had no dificulties coping with the load. After inspection there was no damage or deformation present in the panel.

Image 75:. 3 adults sitting on top of the boarding. Source: Author.

4.4.2 TESTING THE STRENGTH BETWEEN THE WOOD AND THE SCREWS.

During the digital simulation, it was assumed that the planks would provide most of the reaction force when a skater has a direct collision into the stands. This was set at 882N per stand (half of the impact of the skater). The screws that hold the plank in place should be able to withstand this force without damaging the wood. This means that each screw connection must withstand at least 111N, as 8 screws hold that planks in place. The image shows the test that was done to see if the chosen screw a 4,0x25 would be the able to succeed. The result shows that the screw can withstand a lot more then the required force (see image 76).

Image 76: Testing the strength of the screw connection. Source: Author.

4.4.3 THE INSTALLATION TIME

The installation time of the redesign needs to equal (or lower) to the current installation time of the wooden boarding. The old boarding can be installed in roughly 2 minutes per meter. With the new boarding the steps will be placing the base first, then placing a panel into a base on both sides and finally connecting the panel to the previous one through 1 nut and bolt.

After the test the result was:

- 0:14, walking with a base to the location (25m).
- 0:14 for walking with the panel to the location (25m).
- 1:04 for placing the panel in the bases and connecting the panel.

This adds up to 1:32 in total to place a panel. This means that the design meets the requirement.

4.4.4 DESIGN EVALUATION WITH ICE-WORLD, PLATOWOOD AND HILLEGOMSE HOUTGROEP.

During the final stages of the project a meeting with Ice-World, Platowood (manufacturer) and Hillegomse woodgroup (supplier) was set up (see image 77). In this meeting the design and construction of the design was evaluated and financial aspects were discussed. Everyone present at the meeting agreed upon the improved aesthetics of the design, but a possble point of improvement would be the method used to attach the planks to the frame, this will be discussed in the reccommendations.

Platowood: 'I think Platowood is really appropriate for this application and context.' (29-08-2019)

Image 77: Validation meeting. Source: Author.

5. THE REDESIGN

The previous chapters lead to the finilisation of the design. This chapter explains all the details of the final design using the product journey to explain every aspect and every improvement. Besides this chapter a company brochure has been made for the redisign to show customers all the benefits of the new system (see appendix 1).

Image 78:. Connected panels of new system. Source: Author.

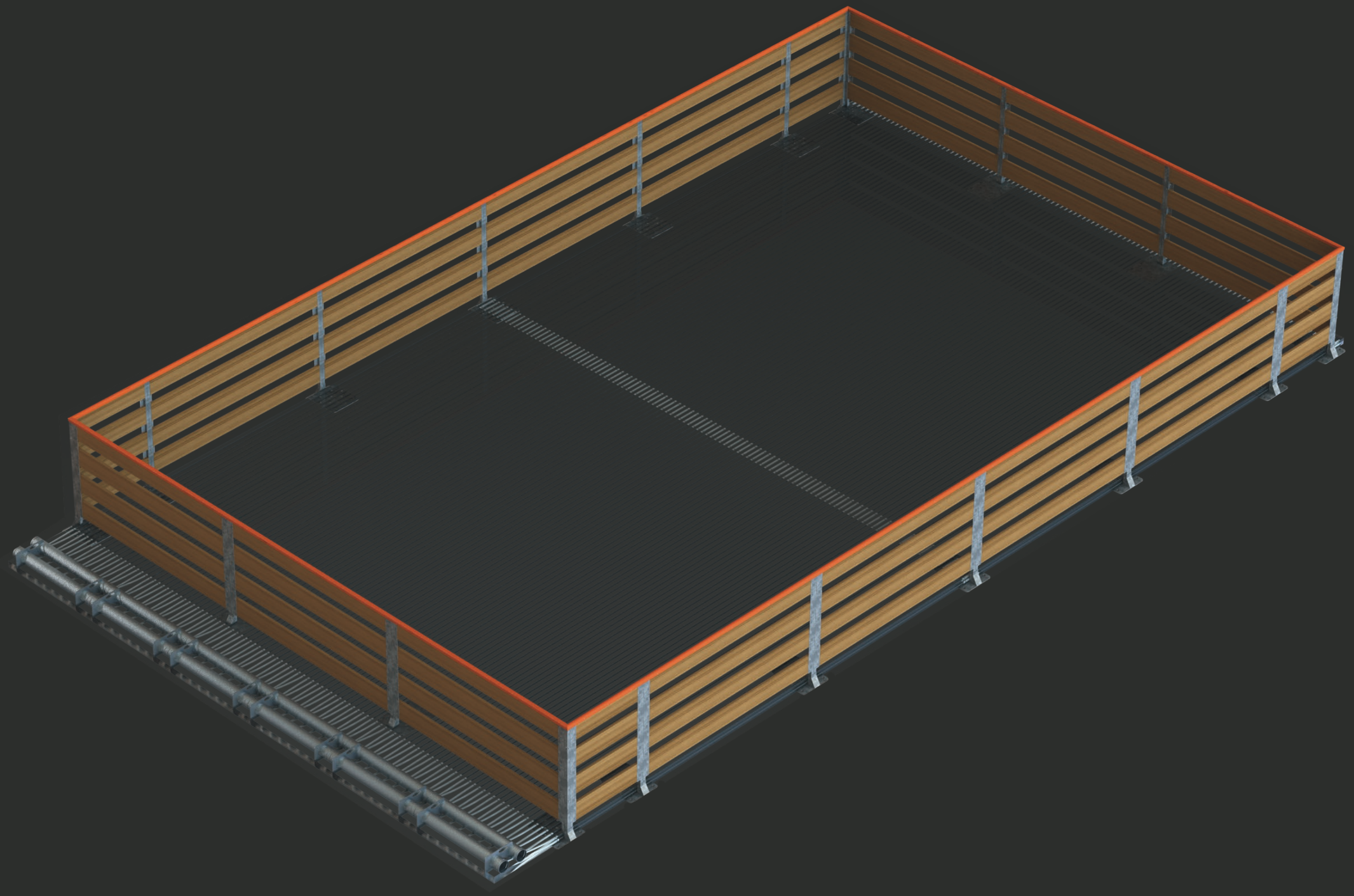


Image 79: Overview new boarding on ice rink. Source: Author.

Image 80: Overview new boarding on ice rink. Source: Author.

5.1 SYSTEM COMPONENTS

The entire system constists of 5 different panels, a base and a corner frame. See image 81, 82 and 83. With these components every regtangular shaped, standard sized ice rink can be realized.

On all ice rinks consiting of even dimensions can be constructed with only '2m' panels. If odd dimensions of the ice rinks are required the '1m' panels can be added. This way all reftangular shaped ice rinks can be constructed. See table XX and table xx for the most occuring ice rink sized and the number required '1m' panel' and '2m' panels.

1. 5 different panels

The exact dimensions of the panels have been calculated. An extensive analysis on the ice rink system dimensions has been conducted to find the most fitting/optimal panel dimensions. After the fitting rink dimensions were found the maximum length was dictated by transport requirements.

The panels are divided into two categories: Header-side panels and non-header-side panels. Non-header side panels are used in the length of the ice rink. Header-side panels are used to install on the width side of the rink.

The non-header and header side panels have different dimensions as they are installed in a different manner. Non-header side panels are installed underneath the ice (thus are 1170 mm in height), while header side panels are installed on top of the ice (only 1135mm in height).

2. Corner support

The corner support is used to connect the header side panels to the non header side panels that meat in the corner of the ice rink.

3. Base

The base is used as the support for the panels. Two panels are placed inside of one base.

NON-HEADER SIDE PANELS

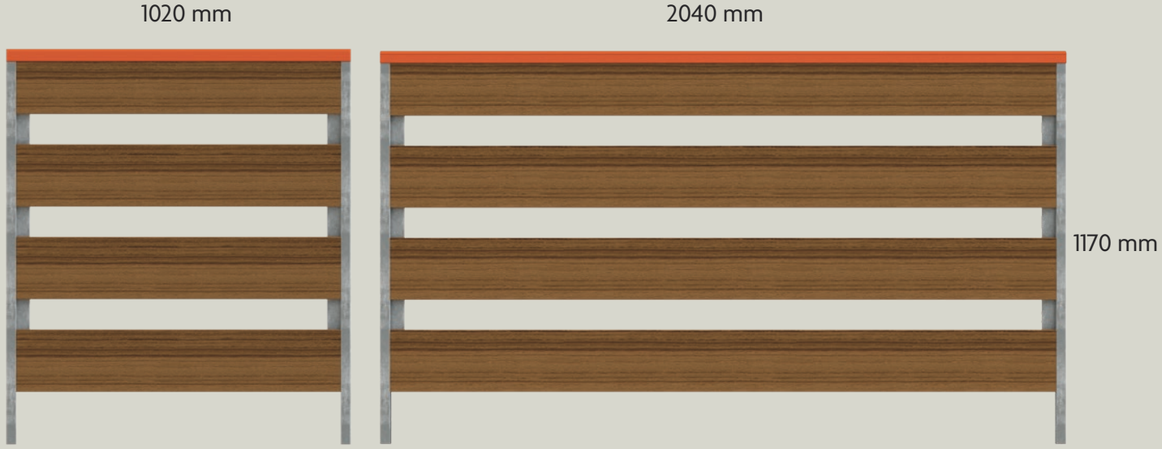


Image 81 Non-header side panels are used on the lenght side of the ice rink and are installed underneath the ice. Source: Author.

HEADER SIDE PANELS

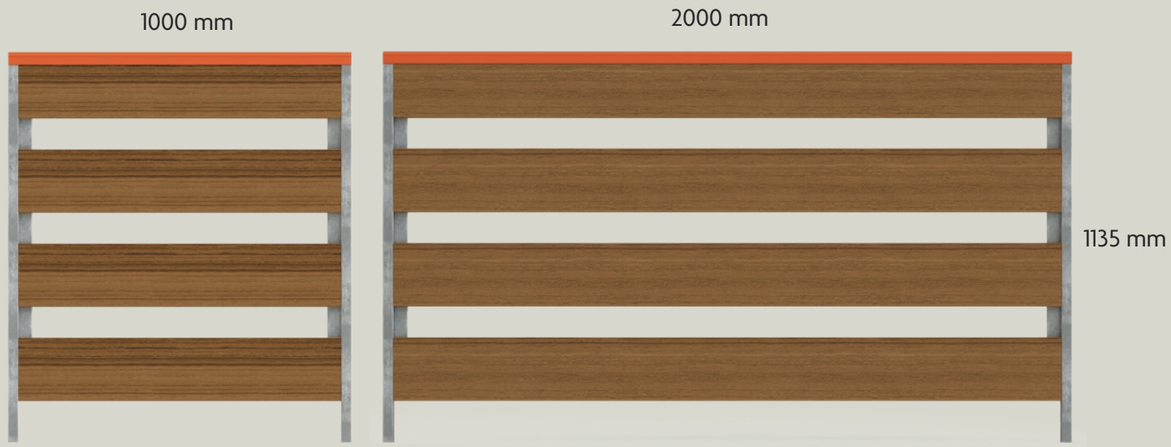


Image 82 Header side panels are used on the width side of the ice rink and are installed on top of the ice. Source: Author.

FILLER PANEL CORNER SUPPORT BASE

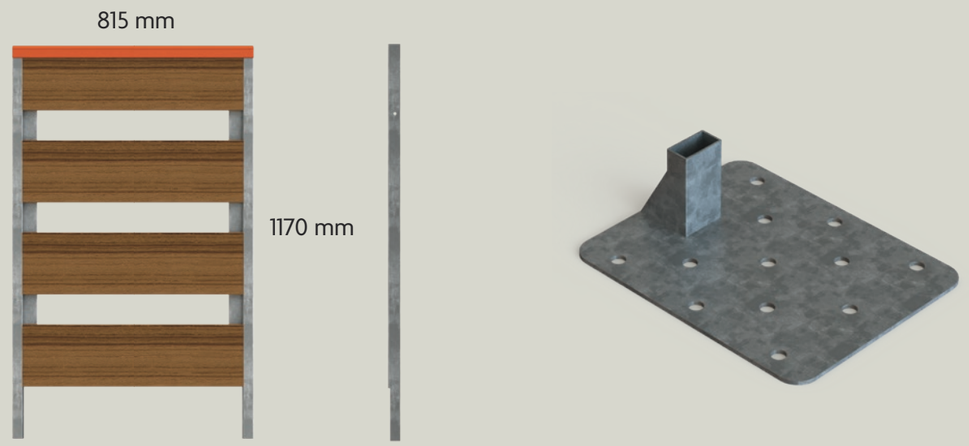


Image 83: Filler panel, corner support and base. Source: Author.

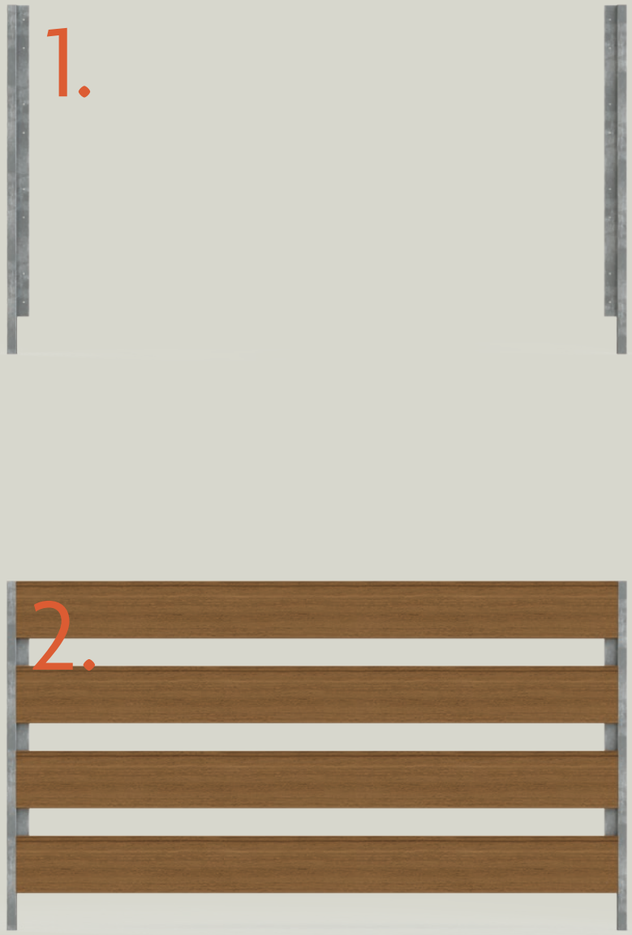


Image 84: Steps of panel assembly. Source: Author.

5.2 MATERIALS

The system components consists of 3 main materials:

The supports are from galvanized steel. This material is widely used for outdoor construction. Galvanised steel is relatively cheap and does not rust.

The planks are created from Platowood. Platowood is an environmental friendly weatherproof wood and has a longer lifespan then the current wood. A material analysis was done to select the optimal material for the planks. See the analysis on the next page.

The handrail is produced from LDPE (Plastic), this is also the material currently used by Ice-World and the most fitting for its purpose, as it is water and impact resistant.

5.3 COMPONENT PRODUCTION

The supports and handrailing will be produced by a known manufacturer Stralco, plans for production can be found in Appendix 23. The wooden planks have a standard dimension supplied by the manufacturer and only needs to be cut to length by a third party wood supplier. Possibilities have already been discussed with Platowood and Hillegomse Woodgroup.

5.4 COMPONENT ASSEMBLY

To create a boarding panel some post assembly is required (see image 84). The assembly process takes place at Ice-World. The base and the corner frame are components that do not require post assembly.

Panel assembly:

1. Take a left and right frame.
2. Drill holes in the planks and attach them to the frame at the right height - at 89mm apart.
3. Place the handrail on top of the panel and join to the top plank with screws.

To increase the productivity, a rig will be used to ensure the planks are placed at the right heights, just like the current wooden boarding.

WHY PLATOWOOD WAS HET BEST MATERIAL FOR THE REDESIGN

A design goal for this project was to improve on the recyclability of the boarding, while still retaining material and aesthetical properties and the possibility to place sponsoring onto the boarding. So alternative materials have been researched that would fit within the requirements. These materials range from plastics to wood and in between (see Appendix 17 for material comparison sheet):

- KLP
- Govaplast
- Duofuse
- Platowood
- Nobelwood

As the dimensions of the planks are dictated by the minimum thickness of the the frame and the safety requirement for the distance in between the planks the main differentiator was weight. When weight was taken into account the only real option that was left was wood, as the specific weight of the plastic and wood composites are almost twice the amount of the wooden counterparts.

Then the final choice was made around pricing. the cost of Nobelwood was 7,25/m and Platowood was priced at 6,32/m. Both products claim to have a lifespan of 50 years, which is also an increase to the expected lifespan of impregnated wood of 10 to 15 years (eppinga.nl,2019) The final choice for the replacement of the impregnated wood is Platowood.

Another benefit of platowood is that the product is ready for processing immediately after the manufacturing process, instead of impregnated wood which has a moisture content of 30-40% after manufacturing (eemwood, 2019). This will enables Ice-World to react to unexpected rink requests.

Platowood is produced without any chemicals, making it a class A-wood for recycling. The other materials were already recyclable.

5.5 COST PRICE ESTIMATION

For the implementation of the new boarding system it is important for Ice-World to know what the costs price would be. As an example the estimation for the most expensive panel is shown, for the entire estimation of the system see Appendix 22. The cost price is increased by 90%, but is still still lower then the transparent boarding, Possible cost reductions are discussed in the recommendations.,

Screws	0,84
Wood	51,57
Frames	21,84
Base	16,11
Handrailing	17,85
Labor	1,87
Total (euro)	110,08

5.6 STORAGE

Next the impact of the redesign on storage will be explained.

Securing the panels

The boarding will be strapped down with the same clamping straps as before only the location will be altered to prevent deformation of the panels. The clamping straps will be placed around the frame side of the panel (see image 86).

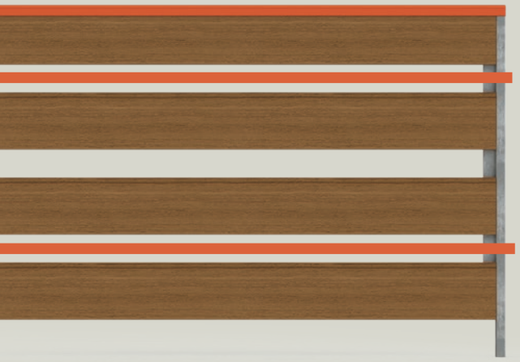


Image 86: Placement of clamping straps. Source: Author.

Storage Volume

One of the most important features of the redesign is the storage volume. One of the biggest problems with the current boarding was that the storage volume was ineffecient.

The panels have been designed with a thickness of only 30mm, this ensures very low storage volume.

The redesign is compared to the current boarding to see the space saved. The current boarding is stored with 40m per pallet (current amount).

The redesign saves up to 75% storage volume.

Storage stability

Placing the panels face down creates stability within the assembly. Having the bases seperate from the panels allows this configuration.

Stacking panels

The redesign is stacked with 33 panels on a single pallet (see image 88). This allows for easy handling during installation and also for the boarding to be stacked twice inside a trailer. The total height of one pallet will be 1,144m (Including the height of a pallet (www.palletcentrale.nl, 2019).

A package of 33, 2,04 m panels weighs 1041kg, this makes it possible for the boarding to be stacked at least 5 times.

Stacking bases

The configuration seen in image 89 measures 900x486x126. The optimal storage configuration still has to be analised, but they would fit within the current storage cases of Ice-World seen in image 87.

Storing wood

When storing a wooden product, it is important that the wood has the opportunity to breath, this means that any extensive moisture can escape and does not cause any change in shape. As seen in image x the panels are stacked in such an orientation that no plank is directly on top of each other, this will allow moisture to escape and ensure preservation of the shape.

Image 87: Storage method of stands for transparent boarding. Source: Author.

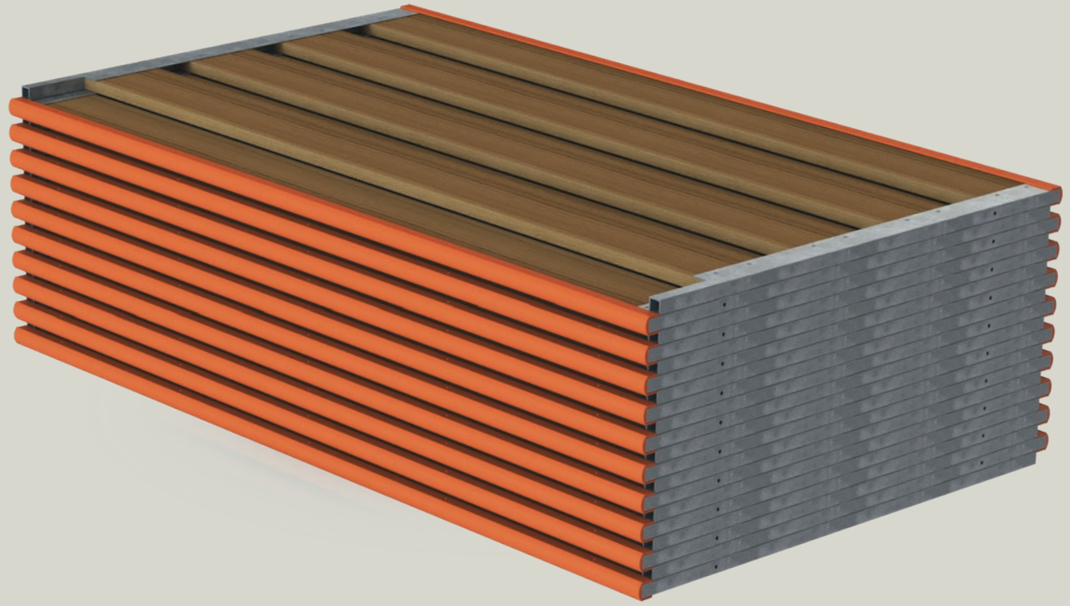


Image 88: 20 panels stacked. Source: Author.

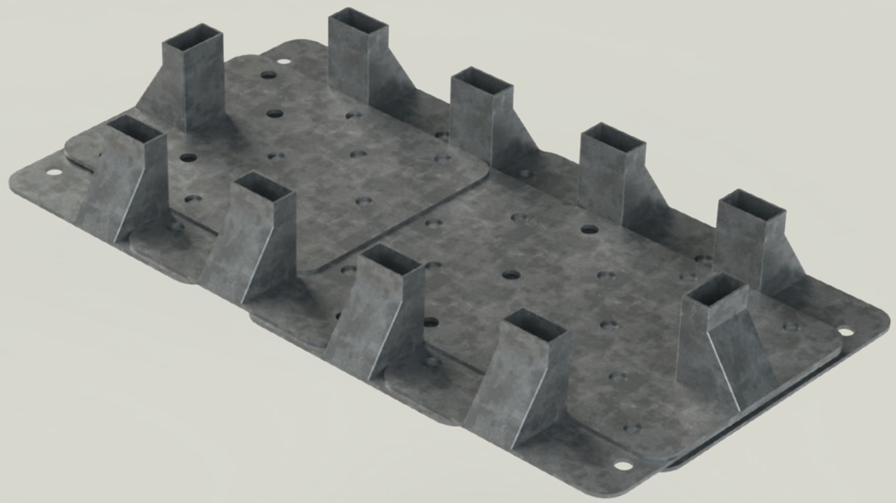


Image 89: 10 bases stacked. Source: Author.

5.7 TRANSPORT

Storage and transport have a close relationship, as the storage method is also used for transport. The trailer dimensions dictated the storage dimensions and maximum lengths of the panels. For effecient transport the maximum dimensions were 2,45 x 1,2 x 2,65.

The largest package of boarding will be 1,2x2,04x1,1

The crate where the bases would be transported in 1,2x0,8x1,2

Both the boarding and bases can be stacked twice on top of each other and oriented inside the trailer in multiple orientations allowing for maximum transport possibilities.

For an average rink 90m boarding is required. The 45 bases needed can be stored in a volume of 1200x800x1200

the 45 boarding panel take up a volume of 2040x1200x1738

In total this will be a transport gain of around 70%

5.8 INSTALLATION

The boarding is installed when the ice rink system is in place. The bases will be distributed around the rink and then the panels can be placed into the bases. When the panels are in place they can be secured to each other and to the floor.

1. Place bases around the rink
2. Place panels into the bases
3. Secure panels to each other
4. Secure bases to the floor

On the non header sides the bases are placed underneath the ice rink systems and on the header sides the bases are placed on top of the system.

Securing plastic foil

In the current situation the plastic foil is finished with a wooden strip that traps the foil in between the wooden strip and the aluminium corner profile (see image 90). With the redesign the base replaces the wooden strip as the base can secure to plastic foil (see image 91). The plastic foil is folded back underneath the system.

Image 90: Finish of plastic sheet with wooden strip.

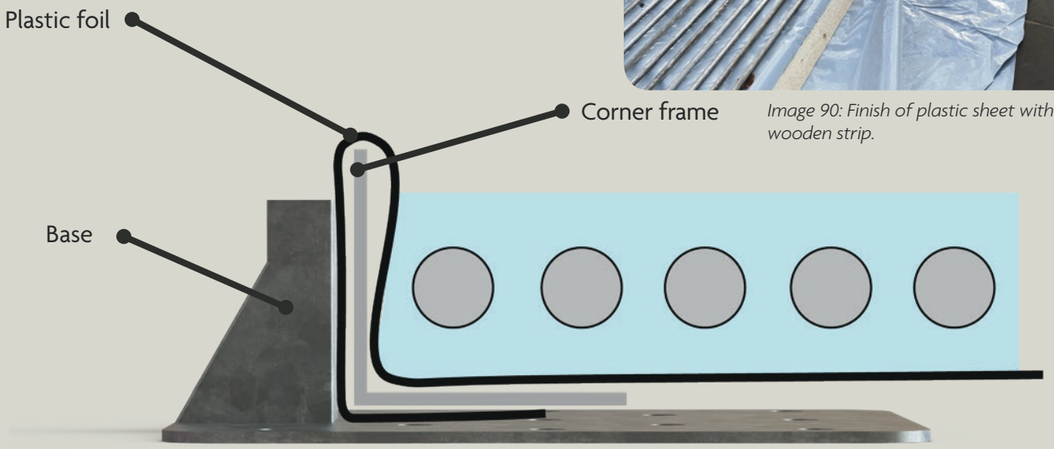


Image 91: Non-header side method of securing plastic sheet with base.

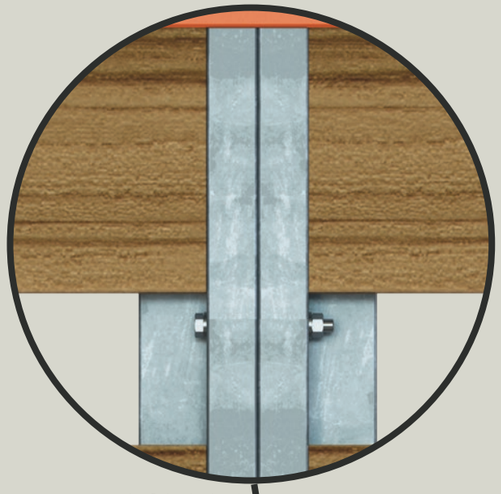


Image 92: Detail of the bolted joint at the top of the panels.

Connection and allignment

The panels are connected with a bolted joint and the base. The base holds to panels together and prevents the panels from seperating. The base also helps alligning the panels. (see image 92 and image 93)

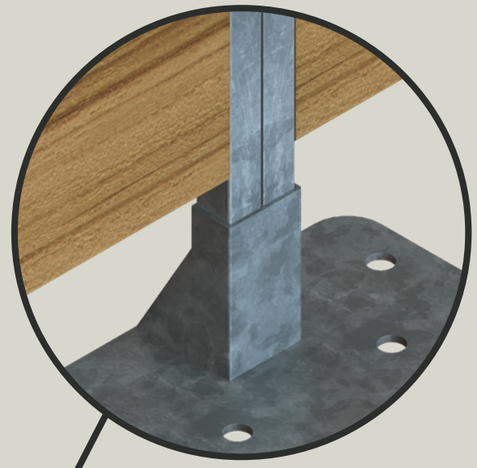


Image 93: Detail of the joinery in the base that prevents the movement of the two panels.

Corner connection
In the corner the two sides are connected to each other via a single frame (see image 97) that alows the two sides to be bolted onto. The frame is finished with a cap on top to create a continious line of the handrailing (see image 96).

The header side have an extra bolt hole, so that every panel can be placed in the corner and be bolted to the corner frame. This also marks these panels to help keep them appart from the non header side as the differences are minimal and the panels could easily be mistaken for one another.

This extra hole is needed for when a particular panel does get placed in the corner, the corner side of the panel floats (see image 98) as it cannot be placed in a base. To secure this side the bottom is bolted to the corner frame (see image 94).

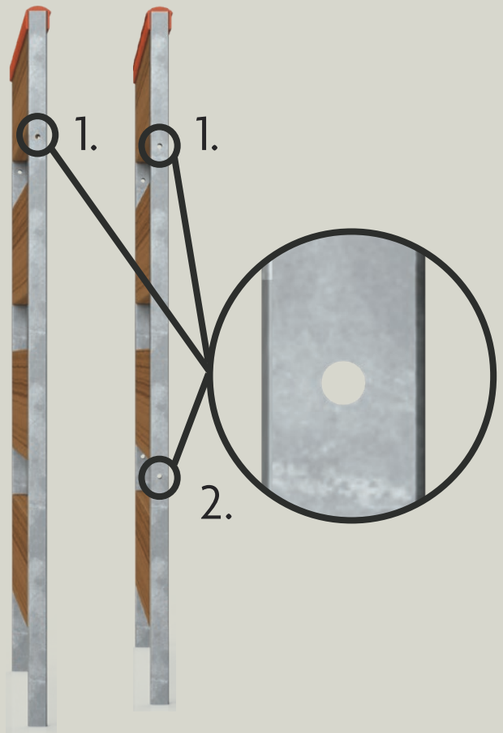


Image 94: Difference in side frame for corner connection. Source: Author.

Securing the boarding
The baseplate has a similar design as the current boarding system. Screws can be placed through the baseplate, into the wooden floor boards. This will secure the baseplate to the floor and preventing the base from moving (See image 98).

These holes also help with the base freezing into the ice and prevent seperation.

Extra Ice
The combination of two sides on top of the ice rink system and two sides underneath the ice rink system was the best compromise between ice surface optimization and simplicity of the entire system.

Custom rinks
Only placing supports of the panels on the sides of the planks allows for any adjustments needed for ice rinks that are not a standard dimension. These adjustments can be done with a simple handsaw without the need of adjusting the metal frame. After the adjustment the support will cover any marks and ensure a look that is the same as a standard panel.

Required Tools
The system can be installed with a 13mm wrench. No other tools are required.

Handling
The larger panels need to be lifted by two persons, but the smaller panels can be lifted by one person.

WEIGHT

• 1,02m	15576 gram
• 2,04m	24986 gram
• 1m	15234 gram
• 2m	23377 gram
• 0,815m	14351 gram

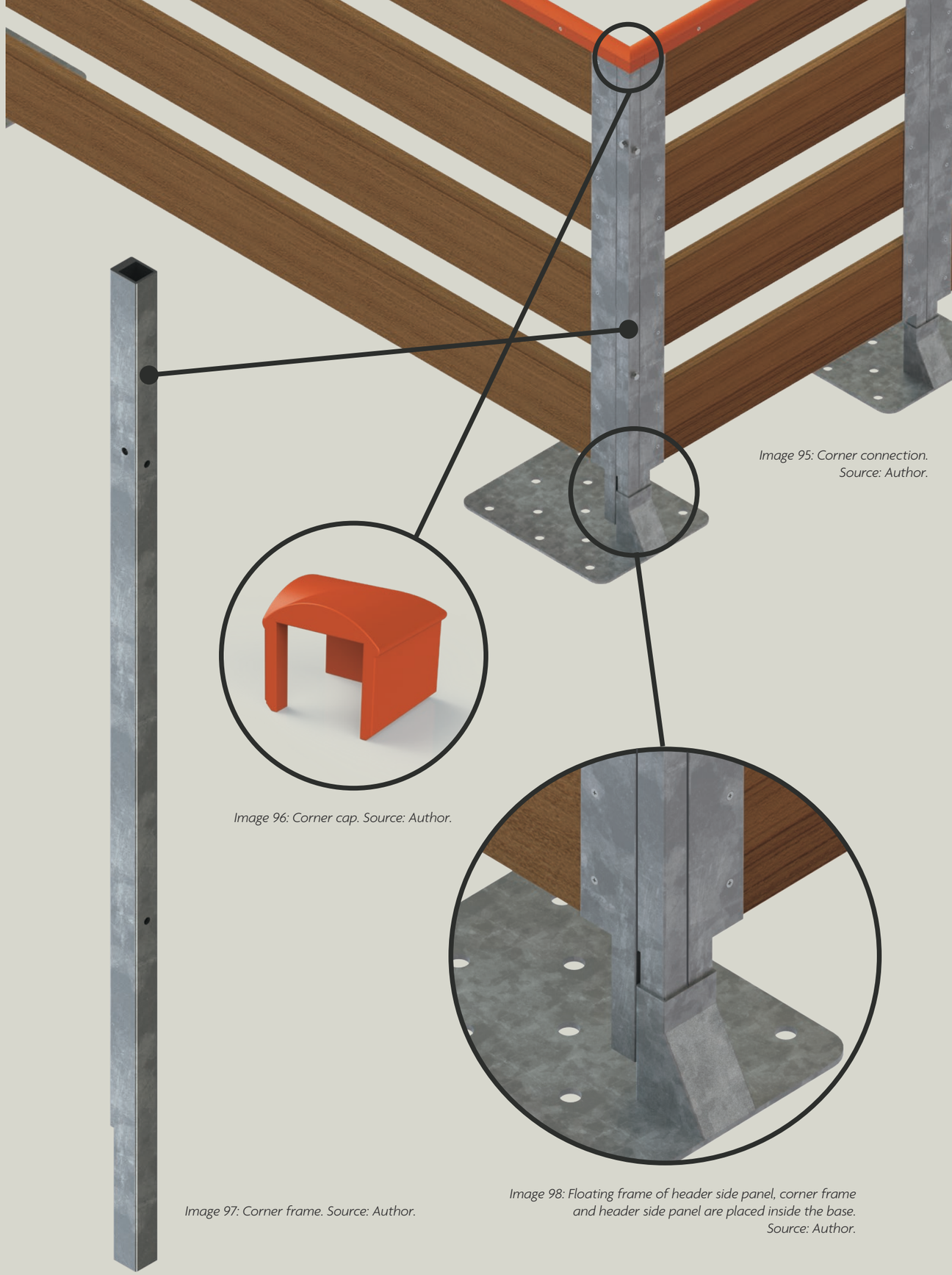


Image 95: Corner connection. Source: Author.

Image 96: Corner cap. Source: Author.

Image 97: Corner frame. Source: Author.

Image 98: Floating frame of header side panel, corner frame and header side panel are placed inside the base. Source: Author.

5.9 USE

Important improvements concerning the use phase are:

System safety
Distance between the panel and the ice is 85mm. This enables drainage for snow and water, but also is safe enough to prevent children from sliding underneath the boarding.

Distance between the boards is set to 89mm to prevent any entrapment of small children.

The height of the boarding is set to 1100mm from the top of the ice to ensure a relative boarding height of 1000mm with skates included.

Sponsoring
The support is placed on the side of the panel, making it possible to place standard sponsoring panels of 2m on both sides. This doubles the amount of sponsoring possible.

Several methods for attaching the sponsoring were explored to enable a more professional look and prevent damage (by screws for example) to the wood. However, the most versitile and cheap method is preferred
Therefore, screws were selected as the most optimal attachment method for the redesign. (See Appendix 21).

Drainage
The redesign leaves gap between the ice and the bottom of the boarding. This keeps the redesign simple, does not require additional drainage parts, minimizing production costs.

Branding
For the new boarding the branding is inspired on the transparent boarding Ice-World uses. Here the handrail is made orange. Using the handrail for branding also has the added benefit of being visible when sponsoring is covering the boarding.

Look & Feel
The use of Platowood makes sure the boarding fits perfecly withing the ice rink atmosphere.

Handrailing
The redesign includes a handrail with a round surface and a small ridge for grip (see image 99), creating a comfortable and secure shape for the ice-skater to hold onto. The shape also prevents spectators to place drinks on top of the boarding and is also less comfortable to sit on top of.

Image 99: Detail handrailing. Source: Author.

5.10 MAINTENANCE & END OF LIFE

Maintenance and end of life are the final steps within the redesign. Important aspects were repairability and lifespan.

Repairs
The construction of the panel allows for individual replacement of the planks. Allowing for easy maintenance and replacement of the planks.

Cleaning
The materials used allow for the boarding to be cleaned without any problems. There are no spots within the construction where any dirt could build up without the accessibility to be cleaned easily.

Longer lifespan
Besides the fact that the frame placement optimizes storage volume, the frame also creates protection to the sides of the planks. This prevents damage to the wood from side impacts during during storage and transport prolonging the lifespan.

End of Life
All the materials used in the redesign are able to be recycled

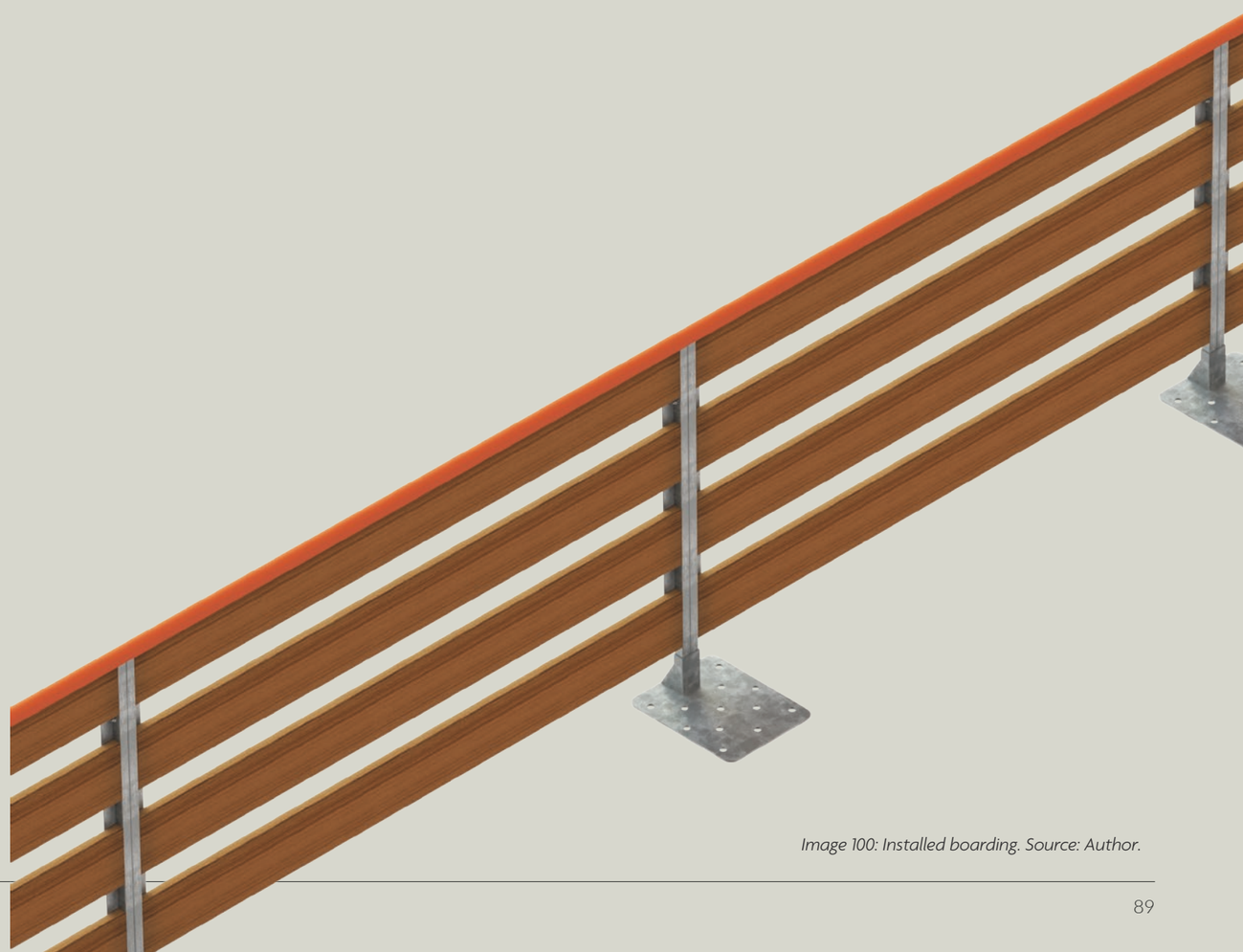


Image 100: Installed boarding. Source: Author.

6. EVALUATION

To get to the final design, the chosen concept needs further development, this chapter discusses the steps and iterations that follow from the development of the concept to final design.

Image 101: Transparent boarding. Source: Ice-World

6.1 CONCLUSION

This graduation project explored the opportunities to optimize the current modular wooden boarding system of Ice-World, so it represents the brand, quality standards and vision. An extensive internal analysis was performed to map all functions, requirements and problems of the boarding system. A condensed external analysis was performed to explore new opportunties and quick wins. The internal and external anslysis resulted into a list of nine design goals.

Design a...

- **a safer boarding.**
- **boarding that fits every commonly used rectangular shaped ice rink with a minimum size of 1x5m**
- **a boarding that is better recyclable**
- **a more efficient storage.**
- **a more efficient transport.**
- **a more efficient installation.**
- **boarding that is easy to maintain and has a long lifespan.**
- **boarding that fits the customers and Ice-Worlds' aesthetic needs.**
- **boarding that optimizes ice surface area.**

These design goals directed the development of the redesign. De redesign is explained below according to the nine design goals.

A safer boarding
On the subject of safety there were two main questions: What is a safe height for the boarding and how will you prevent young children from sliding underneath the boarding. These questions were important to answer as there were no regulations concerning the safety requirements of the boarding. So, to find an answer to these questions research was done within other markets with similar use scenario's such as high-rise railing and playgrounds. Researching these markets led to guidelines for the new design to be able to prevent accidents that were possible before.

Furthermore, the redesign has been tested on strength and stiffness during different scenarios that occur during a skating event. The construction of the boarding system was succesfull in all use scenario's, even the extreme use cases. Thus, the redesign should offer sufficient protection for visitors and ice skaters.

Boarding that always fits
The current boarding systems is not compatible with the dimensions of the ice rink. Observations at various ice rinks showed that it is not uncommen that wooden panels need to be cut to size on site to fit the rinks' dimensions. The root cause of this misalignment was found in the dimensions of the ice rink system. The redesign has been developed to fit with these dimensions, so on site adjustments will be a thing of the past.

More efficient storage
Observations showed that the storage of the current boarding is inefficient and was causing damages, resulting in a shorter lifespan. The redesign enables efficient storage possibilties as the base can be easily disassembled from the frame. This prevents damages and deformations, as the frames are placed on the sides. Having the frames on the sides also protects the ends of the planks.

More effecient transport
The panels of the redesign are reduced to a maximum of 2,04m. This enables more efficient transport - as the panels can be loaded in both the length and width of a the trailer. As the base is separate there are more efficient stacking possibilities. Thus, reducing the overall volume of the boarding on a pallet. This will not only reduce transportation costs, but also reduces emission.

More effecient installation
There were several problems that appeared when researching the installation phase. For example, the connection method not being up to standard and the installation crew having difficulty aligning the boarding. Using the base for alignment and connection reducing the steps and acts needed to connect the boarding will make the installation more efficient and guarantee a higher quality end product.

Easy maintenance
Ice-World wants to guarantee top quality of the ice rink each year. So, it is important that the boarding can be repaired and maintained when it gets damaged. The abuse of the boarding is not divided equally. The bottom plank gets damaged the most from skates constantly hitting the bottom of the boarding during an event. The redesign allows separate replacement of the planks to enable effecient maintenance.

A beter recyclability
In the current society sustainability is a hot topic. Ice-World also knows that sustainability is a very import subject. This is why it was important to try and make the new boarding more sustainable. With the change to Platowood, the entire boarding is able to be recycled.

Longer lifespan
Ice-World requests a lifespan of at least 5 years from their boarding. The current boarding did not always meet this requirement, due to storage and transport. The new construction and storage method should prevent damages done during these phase. Platwood should also have a longer lifespan. So, in theory the lifespan of the boarding has been improved.

A look and feel that fits both Ice-World and the customer needs
Ice-World has a certain brand image and the customer wants to create a certain atmosphere with the event. It was important the both stakeholders were pleased with the new design. This created the use of the orange handrailing and using wood again to fit the customer's needs.

Optimizing ice surface area.
Customers of Ice-World regularly requested the boarding to be placed on the outside of the ice rink system, as the old boarding placement did waste some of the ice available. The redesing is specifically designed to optimize both the simplicity of the system and optimize the ice available for ice skating.

6.2 RECOMMENDATIONS

Developing a product is a never-ending process; this is also the case with the boarding. In this chapter, recommendations will be given to further optimize the redesign. Long term opportunities are also discussed.

Tolerances
The digital model was created with zero tolerance between the stand and the base. The tolerances of the connection will effect the functioning of the system. To find the perfect balance between a tight fit but still being able to install and de-install the boarding without any problems A sample construction is advised to find the right balance between a tight or loose fit.

Possible frame improvents
Tabs could be added to the supports to simplify the assembly process. These tabs will also act as extra support of the plank when a vertical load is placed onto the boarding, minimising the stress on the screws. This would increas the prodcution cost, but could be cost effecient on the long term with a possible increase of the lifespan of the panel and decrease of assembly time.

During an evaluation meeting, the attachment method of the planks on the frame was discussed. Currently the screws allow the panel to be without any parts sticking out, enabling very efficient storage, but there are doubts present on the lifespan of the method. This is why the idea of a nut being welded on the inside of the frame with a bolt on the other side that would be sunk into the plank, has been discussed as possible option. An example of this frame has been created in solidworks. (see image 101.) The extra costs this would create have been requested from the steel manufacturer, but response did not come in time.

Image 102: Frame recommandations. Source: Author.

Base dimension
The base right now is 320x400mm. When comparing the current base with bases of the competition. A decrease in dimensions could be possible. This could reduce the storage and transport volume of the bases. What the exact dimensions would be will need further research.

Pilot test
Platowood claims to have an expected lifespan of 50 years, but this is proven with a different use scenario. The wood should be tested in an ice rink environment to know how the Platowood will perform within Ice-world's operation. Having a pilot test at an ice rink will also allow other features and functions to be tested. This will show if there are any faults in the design that need to be addressed.

Ice rink finishing
For further development, it is important to look at the finishing of the edge of the ice rink. Currently, this is done with aluminium profiles and secured with long strips of wood. These strips of wood are also used to secure and finish the plastic sheet that is laid underneath the ice rink system to keep the water in place. With the new system, the bases on the non-header side secure the angled profile and the plastic sheet. Currently, wooden strips are used around the ice rink to secure the angeled profile and plastic. With the new design, these wooden strips could be used again, but would only play an aesthetical role and would create an extra step in the operation and installation.

Ice rink system
For this project, the objective was to create a new boarding system. Thus, the dimensions of the boarding system were adapted based on the existing size of an ice rink system. The final system ended up being somewhat complicated. It could be interesting to see what the possibilities are when changing the ice rink systems dimensions to be able to simplify the boarding system subsequently.

Lowering costs
Currently, Platowood is used as the primary material of the boarding system. Platowood has several benefits concerning sustainability, aesthetics, production and life span. Looking at the cost price of the system, Platowood has a significant influence. It could be difficult for Ice-World to justify the cost price in relation to the rental price. With the new design, it is possible to use the type of wood of the current system, significantly lowering the cost price. The only aspect that needs to stay the same is the maximum distance between the planks to secure the safety of the system.

Plank configuration
The current configuration of the gaps in between the planks is the minimum to meet safety requirements. Other configurations are possible if the distance between the planks does not increase. For example, 5 planks of 147 mm high. This may have a negative influence on the cost price, but a positive influence on the appearance, because then you can play with the configuration and distances between the boards, like having an icreasing gap towards the top of the panel (see Appendix 20).

Strenghtening the frame
requested a higher safety factor for the direct horizontal impact. The system has been tested with 1667N, corresponding to as person of 80kg. The increase safety factor (of 2021N) showed that adjustments have to be made to the frame. Additional simulations and hand calculations have be performed to finalize the dimensions of the frame that would be capable of handling the higher impact. These simulations and calculations can be found in Appendix 3. The final dimensions needs be 50x30x4.

Handrailing
Currently, the handrailing is fixed to the panel on the backside. This has been done for aesthetic pursposes. When the pilot test shows problems with the handrailing flexing too much or detaching itself from the panel it is advised to place screws on the frontside of the handrailing aswell.

6.2.1 ICE-WORLD BUSINESS OPPORTUNITIES

Investing in cooling machinery (long term)
The major international competitors are experts in cooling machinery and as a side business started to offer ice rinks as well. Ice-World currently has a third party that is responsible for the cooling machinery at the ice rink. Sometimes this creates difficulties with communication, responsibilities or availability of the cooling machinery. When Ice-World decides to integrate the cooling machinery into its business model, it can provide an improved competitive position.

Providing more pieces of the puzzle (long term)
Looking at an average ice rink in the Netherlands, there is much more going on than just the arena itself. Catering, furniture and stage dressing is also essential to complete the event. The Ice-World product is made to fit within the accessories around the ice rink, so why not try to provide the complete package to the customer and tune the separate products to fit each other. This can also make it easier for the customer to organise an event as it just needs 1 supplier instead of several. Products to include might be structures or lighting. This could also lead to service that sets Ice-World aside from its competitors.

Lighting options (short term)
There is a trend going on in the leisure activity sector for ever-growing need for an enriched experience (Oomes, M., 2014). Ice-World fullfils this need with extending their accessories portfolio. It is also interesting to look at the possibilities for the boarding to add to the visitor experience at the ice rink. Opportunities like integrating lighting into the boarding (Appendix 11) or providing lighting solutions for activities like curling, will allow Ice-World to differentiate from their competitors as well.

Sponsoring aid (long term)
Currently, sponsorship is performed in many different ways. As Ice-World wants to improve on the quality and aesthetics of the boarding, it might be interesting for Ice-World to get involved as sponsoring is such a big part of an event. This means Ice-World advises the customer in what material or method to use for the sponsoring. The final design currently provides possibilities for all the different sponsoring used by the customer. The design does not currently improve the quality of fitment or aesthetics of the sponsoring. When Ice-World starts to play a role in providing sponsoring solutions like sponsor panels, it can benefit both parties. As it could enhance the quality of the final product even more.

6.3 PERSONAL REFLECTION

At the start of my graduation, I struggled to find a project that would fit my preferences and interests. I wanted to do a hands-on, practical graduation project for a company that would be able to implement the result in the near future. After my internship at KLM, I was interested to collaborate with a company with a simple hierarchy and ability to make decisions fast. There was one assignment on the TU Delft website that got my attention. The redesign of an ice rink boarding system. When I was younger, I played ice hockey and I still love to skate on ice. I had the feeling that my experience on the ice could be beneficial to the project. I found out that Ice-World was a midsized company with about 30 employees and no complex hierarchy. The assignment itself also appealed to me as it mentioned that prototyping experience was a plus. As a builder of motorcycles, I felt right at home reading the description.

After the project initiation I had to create a project planning. Planning is by nature not my strong suit – I love to explore areas of interest and focus on details. In my graduation project I struggled with keeping the overview, making decision around what to do and (more so) what not to do. Making a realistic planning, and sticking to them, will remain a learning objective for me.

In the first weeks of the project I was really motivated to find innovative solutions like integrated lighting concepts, ddd, ddd. The first results from the research showed however that the current boarding system was in need of solutions concerning the construction, instalment and safety. So, from that conclusion, the project focus shifted to the creation of a safe, long lasting and well-constructed boarding system. This redesign could enable Ice-World in the future to explore more innovative concepts, like integrated lighting. Less exciting (to my personally), but it proved to be a real challenge.

For this project, I stated three personal development goals:

1. I want to improve my prototyping skills. – At the end of this graduation I want to build a working model that can be tested in a real-world setting.
2. I want to improve my communication skills as a designer. - How can I communicate my ideas quickly with other (non)designers? How do I get feedback from people in the organization?
3. I want to improve my ability to translate the analysis of the stakeholders into relevant needs and wishes.

The first goal has been a success, as I was able to build a full-size prototype. The prototype was used to test situation that could occur at the ice rink. During the prototyping phase, I was learned myself how to weld. It was very exciting to learn this new skill and directly apply it.

The second goal proved to be a bit more challenging. I have no problem making conversation with people in the organization but initiating contact at the right moment is a challenge for me. I am very responsive, and I struggled to initiate meetings with my coaches. This will remain a personal development goal for me. In the future, I would like to be more pro-active and open to opinions of others (and not fearful of those opinions).

I have developed a lot concerning the third goal. I was able to perform an extensive analysis of Ice-World operation, and I was able to find the root causes of the problems. I was able to connect with stakeholders and identify their needs and wishes. I believe that I successfully translated the results from research into a functional design - solving several issues. During the development I had a hard time making decisions. As this is one of the few individual projects in my study I was the only one responsible for the decision making. During the project, I learnt that I do not feel comfortable with making decisions on my own. My indecisiveness resulted in a lot a wasted time as I could not move forward. In the future, I really have to seek support when I have difficulty making decision.

Looking back at this project, I would say I have got to meet a group of very helpful people, and I am proud that I was able to finish this project. Thank you all, who helped me through this challenging, but a great learning, experience.

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