Toward Standardized Production

Redesigning the Manufacturing Process for the Production of Superyacht Doors, Platforms, and Hatches

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Preface

This report marks the conclusion of my Master's graduation project for the MSc Integrated Product Design at Delft University of Technology. The project was carried out over a period of 20 weeks in collaboration with Akerboom Yacht Equipment, where I was given the opportunity to work closely with the company's production team and management.

The goal of this project was to redesign Akerboom's manufacturing process for superyacht doors, platforms, and hatches. Through a combination of workflow analysis, design development and stakeholder management I aimed to create a standardized approach that improves efficiency, ergonomics, and safety while maintaining the exceptional quality expected in superyachts.

This project reminded me that true progress lies in finding the balance between efficiency and craftsmanship. In yachtbuilding, where perfection is both tradition and ambition, design must evolve without losing sight of the people and expertise that make it possible.

To everyone who shared their knowledge, time, and trust—thank you.

Jip Brouwer
Leiden, August 2025

Figure 1: Stern and beach platforms on Pure, a concept yacht from Feadship.

Contents

Glossary

This section provides definitions of key terms, concepts, and abbreviations used throughout the report. It serves as a reference to ensure clarity and consistency, particularly for technical or project-specific language.

Closure plate
An aluminum sheet which 'closes' an item as it is the last plate to be welded on. NL: sluitplaat.

Hull plate
An aluminum sheet (sometimes made up of multiple sheets) that is on the outside (hull side) of items. NL: huidplaat.

Girders
The plates that make up the inner structure of the items. NL: schotten.

Item
A collective noun for all platforms, doors, hatches, constructed by Akerboom.

PS & SB
Abbreviations for Portside and Starboard. A large part of the items are made for PS and SB, which is indicated by PS & SB. NL: bakboord & stuurboord.

Stelcon slab
A concrete slab (usually 2x2 meter) with steel bars integrated in it for structural integrity. NL: stelconplaat.

Structure
A framework which consists of girders that makes up the inner structure of items. NL: frame.

Template
Aluminum plates which are used to hold and position the hull plate. NL: zichtmal.

Truss floor
A concrete floor which has steel beams integrated into it. These steel beams can be used to weld to. NL: spantenvloer.

All glossary terms in this report are highlighted in **bold and blue**.

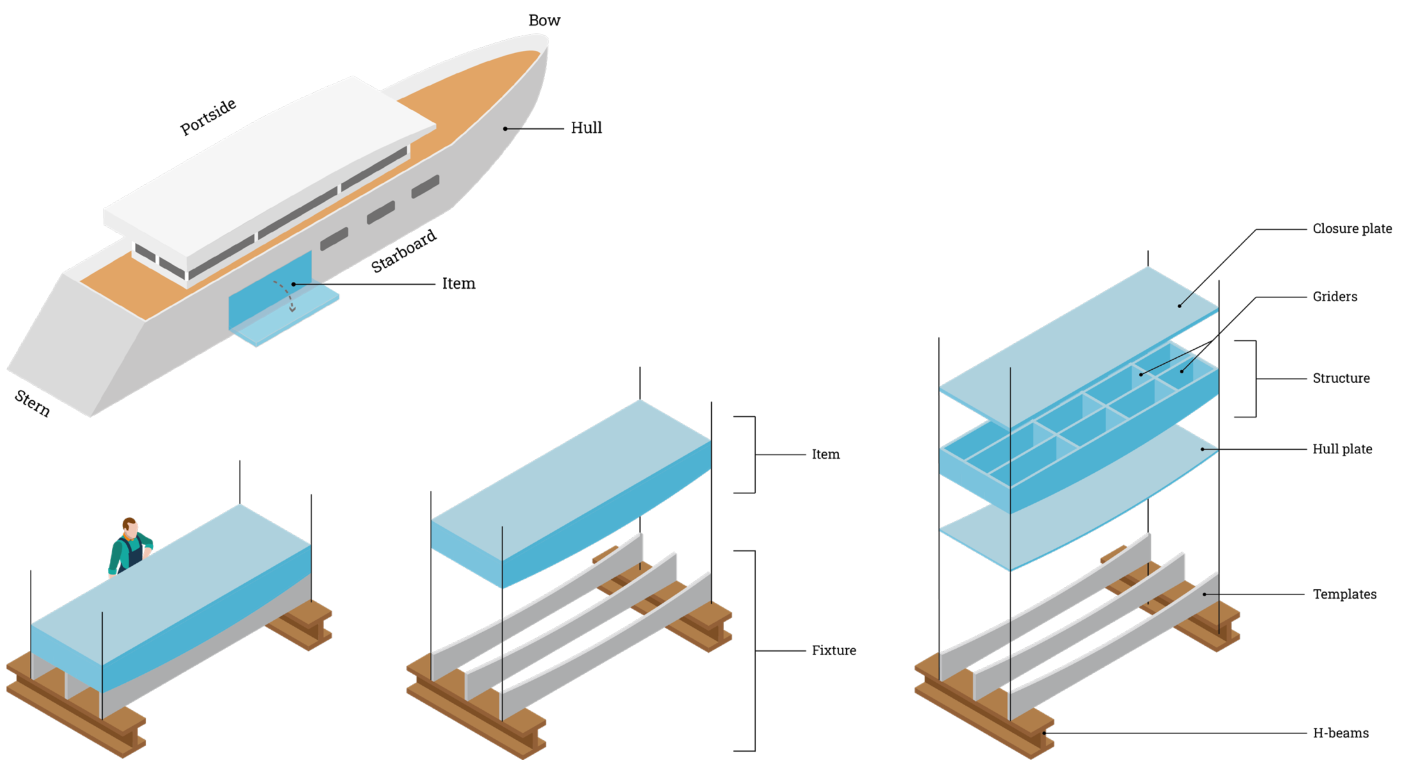

Figure 2: *Simplified illustrations to depict terminology.*

Executive summary

This project aimed to redesign the manufacturing process of superyacht doors, platforms, and hatches at Akerboom Yacht Equipment, a subsidiary of Koninklijke De Vries Scheepsbouw. Akerboom's current sequential, fixed-position manufacturing method results in inefficient space use and physically demanding working conditions. The goal was to develop a standardized manufacturing method and corresponding workstations that improve efficiency, reduce labor hours, and enhance ergonomics without compromising quality.

The research phase involved workflow analysis, ergonomic evaluation, Lean Muda identification, and stakeholder consultations, which revealed non-value-adding activities, layout inefficiencies, and ergonomic risks. Based on these findings, a new manufacturing process was developed, splitting core processes and designing standardized workstations for them.

The concept showed a 23% ergonomic improvement compared to the current state, exceeding the initial 15% target. Lead time simulations demonstrated a reduction of approximately 165.5 hours (26.1%). Financial analysis projected a payback period of approximately four years under full implementation. Furthermore, key stakeholders confirmed the concept's feasibility, viability, and desirability.

Overall, the project provides a blueprint for a standardized manufacturing approach that delivers shorter lead times, improves ergonomics, and ensures long-term economic benefits for Akerboom.

Figure 3: *Beach Platform on the 1966 M/Y Galland Lady.*

1

Introduction

This chapter provides an overview of the project context, outlining the background and setting in which the project takes place. It defines the core problems and challenges that form the foundation of the research phase. Furthermore, the approach adopted to address these challenges is explained, including the rationale behind the chosen methodology. Finally, the chapter presents the main research questions that guide the investigation and development throughout the project.

Project context

Feadship, short for the First Export Association of Dutch Shipbuilders, is a renowned Dutch company specializing in the design and construction of high-end luxury yachts (Feadship, 2020). Established in 1949, Feadship is a cooperative venture between two shipyards: Royal Van Lent Shipyard and Koninklijke De Vries Scheepsbouw who were later joined by De Voogt Naval Architects, which handles naval architecture and design. Both shipyards have received the prestigious "Royal" designation from the Dutch monarchy, recognizing their historical significance and contributions to shipbuilding excellence.

With decades of experience, multiple shipyards, and a legacy of building some of the most prestigious yachts in the world, Feadship continues to be at the forefront of innovation in the superyacht industry. Its combination of heritage, craftsmanship, technological advancement and eye for detail secures its position as one of the most respected names in luxury yacht construction.

Feadship consists of a vast network of companies to enable it to create these state-of-the-art yachts where each company is responsible for a different phase of the yacht construction process. For De Vries' department: STI is responsible for the 3D design of piping and mechanical systems, De Klerk Binnenbouw (DKB) handles the interior design and execution (Van Der Loo does so for Van Lent), and Slob is the shipyard where the cascos are built. Another key player in De Vries' network is Akerboom Yacht Equipment. Originally founded in 1860 as Akerboom Bros Shipbuilders, Akerboom specializes in designing and manufacturing high-quality custom yacht equipment, including but not limited to doors, hatches, and platforms (Akerboom Yacht Equipment, n.d.). Akerboom's facilities in Leiden and Katwijk are equipped with the machinery to produce high-quality aluminum equipment which seamlessly integrates into the superyachts.

Akerboom's products are highly tailored and project-specific, which is why the company operates using an Engineer to Order (ETO) model. This operational approach involves the customer throughout the entire design and engineering process (Scallan, 2003). Products are developed from scratch, based entirely on the client's specifications and unique requirements.

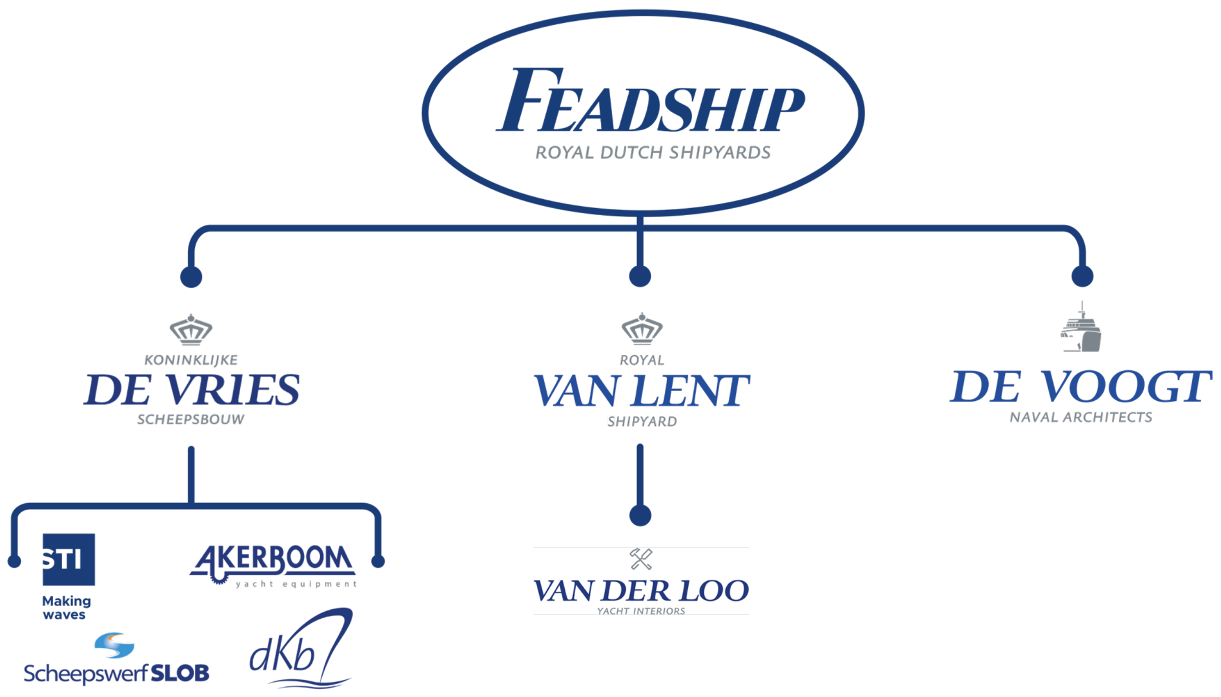

Figure 4: *Organisation chart of Feadship's orginisational structure.*

Welding

Welding is a core activity within Akerboom's manufacturing process. To support the reader's understanding of this report, a brief explanation of relevant welding principles is provided.

Welding involves joining two metal components by melting them and allowing them to fuse as they cool (Phillips, 2016). This is typically achieved through the application of a high-current electrical arc.

Welding can be performed in various positions, each with its own challenges. These positions are typically standardized and are illustrated in Figure 5 (International Organization for Standardization, 2019). The PA and PB positions, often referred to as "welding under the hand," involve welding on a flat or horizontal surface with the weld pool below the torch. These positions offer the most stability and visibility, allowing welders to maintain steady hands and achieve consistent results. As a result, PA and PB welds generally produce fewer defects and require less physical effort (Miller, 2025).

In contrast, more challenging positions, such as PF (vertical up), PG (vertical down), or PD and PE (overhead), demand greater skill and physical endurance. These positions not only reduce control over the weld pool but also increase the risk of defects like lack of fusion, sagging, or incomplete penetration. They also contribute to operator fatigue, which can further compromise quality and safety (Miller, 2025).

Welding introduces a significant amount of heat into the material. When one side of a component is welded, the localized heating causes that side to expand and later shrink when it cools. This expansion and shrinking leads to internal stresses and can ultimately cause the workpiece to warp or distort (Encyclopaedia Britannica, 1998).

To mitigate this effect, it is essential to take thermal deformation into account during both the planning and execution of the welding process. This includes strategically sequencing the welds, applying controlled heat input, and when possible, using clamps and fixtures to hold the workpiece in position during welding (Encyclopaedia Britannica, 1998).

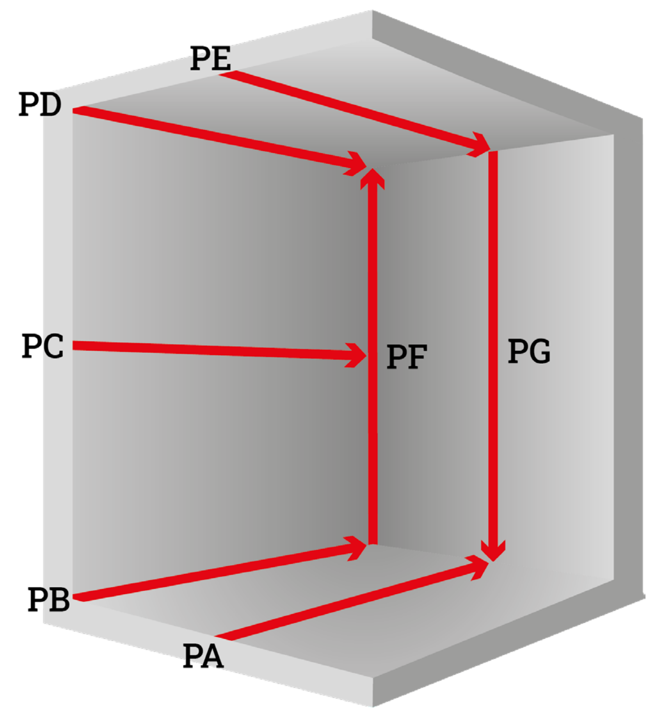

Figure 5: *Welding positions and their denotation.*

Problem definition

This chapter highlights the problems that laid the foundation for this project.

Inefficient space use

Akerboom has two halls where their yacht equipment, commonly referred to as **items**, is manufactured; one in Leiden and one in Katwijk. Akerboom's current manufacturing method is called sequential fixed-position manufacturing (Kiran, 2019). In a fixed-position layout, the product remains in a fixed position, and all tools, equipment, and workers are moved to this location. This layout is typically used for large, heavy, or complex products, such as ships, aircrafts, or construction projects that are too heavy or impractical to move through a facility. Due to this fixed-position, all steps in the manufacturing process need to happen sequentially.

The hall in Leiden consists of a **truss floor** system that allows for the flexible creation of these fixed-position workstations, as employees can directly weld H-beams to the trusses to create a rigid foundation; a so-called fixture. These H-beams also allow for minimal warping of the aluminum material of which the **items** are made. This is especially important as precision is key and tolerances are very tight.

In contrast, the hall in Katwijk only has a small area equipped with a **truss floor**, the largest part of the floor consists of **Stelcon slabs**. These **Stelcon slabs** are unstable and unreliable for manufacturing in the current manufacturing method as they could move independently of each other under the high weights and tensions of the **items** as they are manufactured. Therefore misalignments can occur resulting in defect **items**. Consequently, the floor type in Katwijk restricts the amount of manufacturing and **items** that can be made there. This limitation results in an inefficient use of the available space.

Ergonomics

In addition, the current, self-made, fixture puts a lot of strain on the employees as it is far from ergonomic. The H-beams create, to some degree, a working platform, but they are not designed with worker comfort and safety in mind. Employees often have to adopt awkward postures, bend down frequently, or work at uncomfortable heights, leading to increased physical strain and fatigue over time.

The ergonomics conditions were assessed with an online tool called Ergoscore. This tool was developed by Beroepsvereniging voor Ergonomie (VerV - Beroepsvereniging voor Ergonomie, 2024), the national organization of ergonomics in Belgium. As a professional association, VerV aims to provide a network for everyone involved or interested in ergonomics.

The Ergoscore tool evaluates ergonomic risks in various types of work. It consists of a series of questions focused on specific working conditions (e.g., kneeling or repetitive work). Based on the responses, it generates a risk score that indicates the severity of ergonomic risks. The scoring system is as follows:

- **≤50**: Low risk
- **51–75**: Moderate risk
- **76–100**: High risk
- **>100**: Very high risk

To gain a comprehensive understanding, three assessments were done:

1. **Worst-case scenario** – completed with the foreman, a former welder with extensive experience at Akerboom. The goal of this assessment is to get an understanding of the risks in a worst-case scenario.
2. **Typical daily scenario** – based on direct observations of day-to-day work, providing insight into common daily ergonomic challenges.
3. **Estimated ideal scenario** – a hypothetical situation where all ergonomic improvements have been implemented, allowing a comparison to quantify potential improvements.

The results of these three assessments can be found in the table below. Full test scores can be found in Appendix A.

Table 1: *Ergonomic scores established by the Ergoscore tool.*

	Worst-case	Typical daily	Ideal
Kneeling work	150	175	85
Repetitive work	125	95	85
Standing work	105	85	40
Extreme postures	95	95	75
Lifting	75	75	50
Fatiguing work	47.5	52.5	41.25
Pulling and pushing	25	25	25
Sitting work	25	50	35
Total	**647.5**	**652.5**	**436.25**

As shown in the table, the total ergonomic score for daily activities is higher than the score for the worst-case scenario, which is contradictive as one would assume the worst-case conditions to be more ergonomically demanding.

An explanation for this contradiction is that the worst-case assessment, completed by the foreman, relied on memory and may have overlooked certain situations. Additionally, the foreman has not been directly involved in hands-on manufacturing for some time, which may have contributed to missing details or underestimating risks.

Based on the hypothetical ideal scenario, a potential ergonomic improvement of **33%** is possible. However, since this ideal situation is hypothetical and there is limited time in this project to address all ergonomic challenges, a more realistic target has been set. The goal is to achieve at least a **15%** improvement in ergonomic conditions for the proposed design to be considered successful.

The tasks that have been evaluated pose significant ergonomic risks in the areas of kneeling work, repetitive work, and standing work. These three tasks score the highest on the risk scale, indicating that urgent ergonomic improvements are needed in these areas.

Figure 6: *An employee forced to worked on his knees to reach a welding spot.*

Kneeling work

Evidence from a study show that kneeling work can increase the risk of lower-back pain (Health Council of the Netherlands, 2011). In addition, workers who worked in a kneeling position for more than 15 minutes per day showed a twofold increased risk in lower-back pain. Moreover, kneeling work is strongly associated with knee osteoarthritis. Workers who worked on their knees for more than 30 minutes were almost twice as likely to develop knee osteoarthritis. Finally, working on knees shows an increased risk of bursitis and meniscus injuries due to pressure on the knees. Working on the knees happens primarily when the welders need to weld **hull plates** together.

Figure 7: *An employee cleaning a weld seam (which is an example of repetitive work) while also working on his knees.*

Repetitive work

A conference paper by Nedohe et al. (2022) states that repetitive work is common in welding, with 63% of welders reporting frequent repetition in their tasks. This contributes to a high prevalence of physical discomfort, with 67% experiencing chronic pain during work. The most affected areas are the neck (78%), right shoulder (67%), and upper back (63%). The repetitive motions increase the risk of musculoskeletal disorders such as tendinitis and carpal tunnel syndrome.

Figure 8: *Example of an employee standing in an akward position.*

Figure 9: *An employee working on his knees while welding the hull plate with the buggy.*

Standing work

Standing for more than 30 minutes per hour (i.e. 4h/working day) significantly increases the risk of developing lower-back pain (Health Council of the Netherlands, 2011). Standing for this long shows a 2.1 times increase for lower-back pain. In addition, prolonged standing increases the risk of plantar fasciitis (heel spur) and varicose veins in the legs. Welders at Akerboom frequently remain standing for long periods, exceeding two hours at a time, often continuing this posture throughout the entire workday.

Problem definition

The core issue that lays the foundation for this report is the lack of a standardized system/workstation that can adapt to the manufacturing needs of Akerboom, independent of the existing floor type at both facilities. This gap in the current system reduces overall efficiency, increases the strain on the halls in Leiden, and impacts the smooth operation of the overall manufacturing process. This problem needs to be addressed to improve the working conditions, optimize resource utilization, and enhance the overall productivity and flexibility of both locations.

After multiple iterations, this led to the following definition of the design brief for this project:

"*Design a concept that enables the manufacturing of the eight most frequently produced items, regardless of the floor type, while simultaneously improving ergonomics by 15%, and serving as a foundation for a more efficient working method that integrates seamlessly into the current workflow and enhances it. Additionally, validate the concept and it's integration in the current workflow by means of a test setup.*"

The iterative process of the design brief can be found in Appendix B.

In addition to this design brief, Akerboom has two more initial requirements:

- A labor hour reduction of at least 10%, while maintaining the same quality.
- Reduce the number of (near) accidents.

Summary

Akerboom uses a sequential fixed-position lay-out.

A truss floor is currently required to build on.

Halls in Leiden do not have enough space to manufacture all items.

Hall in Katwijk has lots of space, but is unused due to its Stelcon slab floor.

The current workstation is build with H-beams, which results in unergonomic working conditions

Project approach

To address the challenges of this project in a structured manner, a methodological approach is required. A suitable framework for this is the Double Diamond Model, which consists of four phases. The original definitions of these phases have been slightly adjusted to better align with the project's needs:

- **Discover** – In the Discover-phase the goal was to gather important and relevant information about the project and the design challenge. This has been achieved by observations and interviews with employees and other key stakeholders.
- **Define** – In this phase, the gathered information was synthesized to develop new insights into the design challenge and form a final design brief. And, in addition, set the foundation for the ideation process.
- **Develop** – Here, ideas were generated and refined through iterative development and implementation of feedback. Finally, one idea was selected and developed further into a concept.
- **Deliver** – In the final phase, the concept was improved through additional iterations and expert & stakeholder feedback. Furthermore, users tests were done to validate the proposed concept.

Research questions

To break down the research into easier-to-understand and solvable sections, three key research questions were formed. The goal of these research questions was to guide the research phase and refine its scope.

By structuring the research around these questions, the investigation remains targeted and actionable, ensuring that insights gained directly contribute to the development of a practical and effective solution.

- **RQ1**: *What is the current workflow at Akerboom? What are its bottlenecks, ergonomic- & efficiency challenges, and what are the opportunities?*
- **RQ2**: *What are the specifications of the halls and items? What is the current layout? What are the differences between Leiden and Katwijk?*
- **RQ3**: *What are the current Health & Safety regulations? Which aspects need to be taken into account when designing a new concept?*

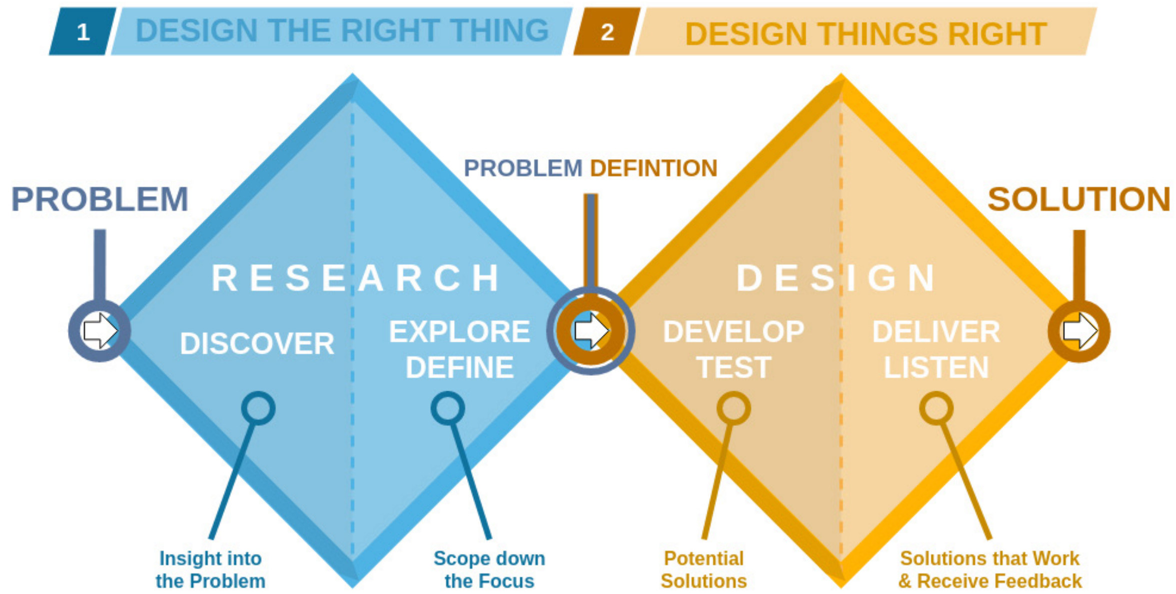

Figure 10: *Double Diamond Approach.*

Figure 11: *A welder welding the internal structure of an item.*

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Research

The research phase was dedicated to developing an understanding of the current manufacturing workflow, identifying key challenges and bottlenecks, and uncovering opportunities for improvement. In addition to mapping out the process, this phase also involved gathering detailed information about the specifications the manufacturing halls and their current lay-out, the specifications of the items being constructed, and the applicable Health & Safety regulations in place at Akerboom.

Research question one

What is the current workflow at Akerboom?

To develop a clear understanding of the current workflow and operational procedures, a Work Breakdown Structure (WBS) and two welding procedure documents (see Appendix C) were reviewed in combination with a series of consultations with the foreman and several members of his team, supplemented by observations in the hall in Leiden. This offered valuable firsthand perspectives on the practical aspects of daily operations, the challenges commonly encountered in the halls, and the established methods used throughout the manufacturing process.

Based on the consultations and observations, a flowchart was created to visualize the typical manufacturing process of Akerboom's **items**. While the real-world workflow involves numerous minor steps, the diagram focuses on the most essential stages to avoid unnecessary complexity. This high-level overview serves to highlight the primary structure of the process and to facilitate the identification of potential bottlenecks, delays, or areas in need of improvement. It acts as a foundational reference for further analysis and development work. A more detailed flowchart can be found in Appendix D.

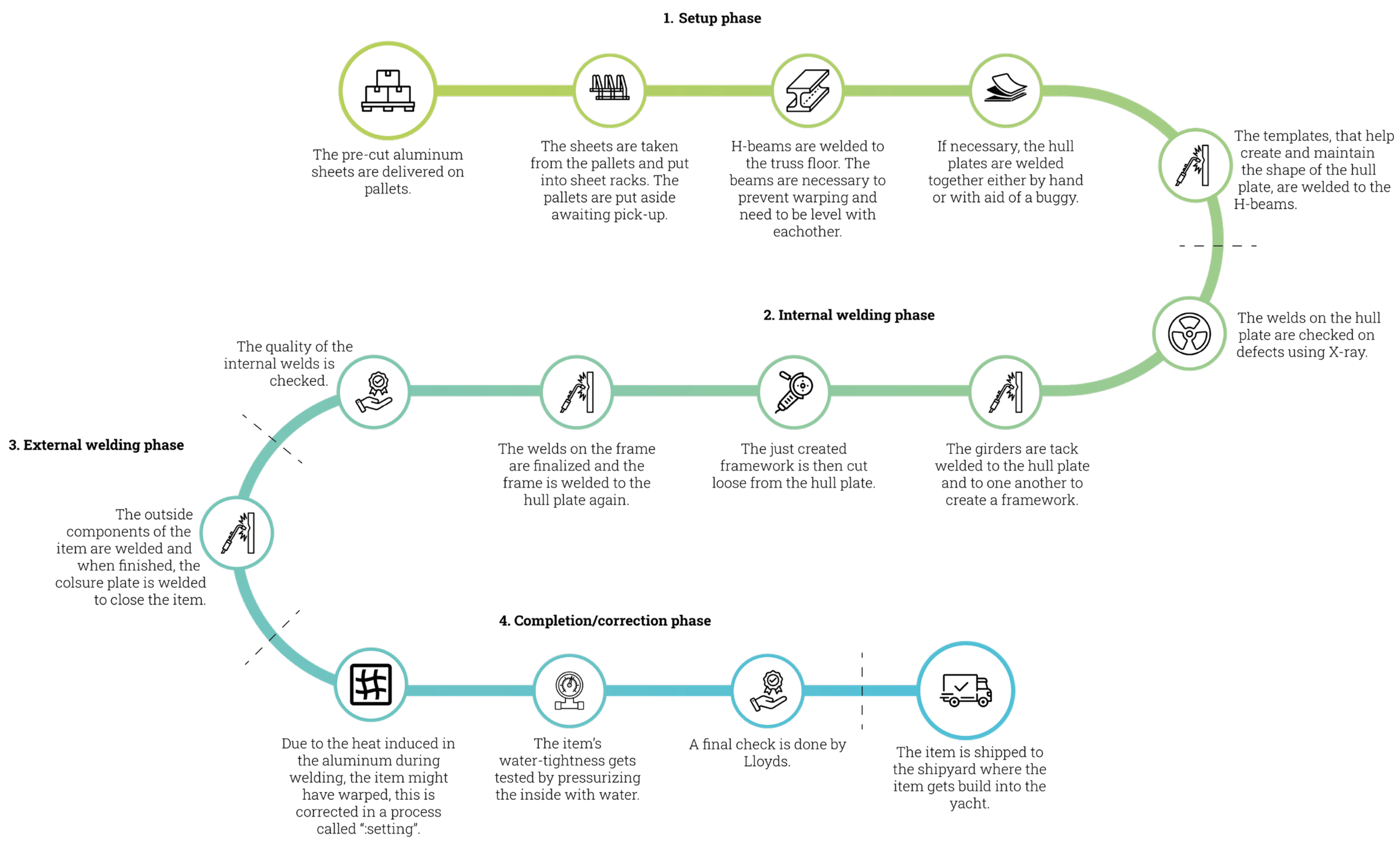


Figure 12: *Flowchart of the workflow at Akerboom.*

1. Plates are sorted and prepared — 2. Hull plates are welded together — 3. H-beams and templates are setup

Setup phase

The setup phase involves a series of precise and carefully coordinated steps to ensure structural integrity and high-quality standards. From the initial delivery of materials to the welding and inspection of the **hull plates**, each phase plays a critical role in preparing the components for further processes. The process unfolds as follows:

The process starts with the delivery of materials on pallets. Upon arrival, the materials are sorted and undergo pre-processing. This may include milling the edges of the plates or welding on additional elements such as strips, or welding the portholes, or scepter pots. Once pre-processed, the plates are placed into designated plate racks for storage and further handling.

Figure 13: *A pallet with material in the hall in Leiden.*

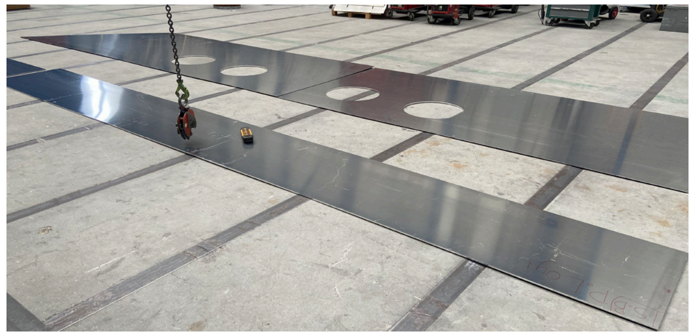


Figure 14: *The hull plates laid out on the ground.*

Following this, the **hull plate** is, when consisting of only one plate, welded directly onto the **templates** or, in cases where the hull is composed of multiple plates, the plates must first be welded together using a welding buggy. This welding buggy is essentially a small selfdriving cart in which certified employees can put their welding torch. First, the plates are laid out on the ground. The buggy then slowly drives past the seam that needs to be welded to create a uniform weld. As the buggy is not self-steering, a welder needs to crawl in front of it, checking the weld, and correcting the buggy's path when it is misaligned. This is a stenuous process for the welder. When one side is welded, the **hull plate** is flipped over and the weld is milled and welded again from this side. This step is needed to ensure proper bonding of the plates in butt welds. These initial welds are inspected with the aid of X-ray to ensure the weld is of proper quality.

Figure 15: *A welder welding the hull plates together with the buggy.*

Meanwhile, the H-beams are aligned and set level with a laser and the **templates** are prepared, after which they are carefully welded to the H-beams. Precision is especially important in this step as misalignment in the **templates** causes the whole **item** to be incorrect.

Figure 16: *The templates aligned and welded to the H-beams.*

After the **templates** are setup, the **hull plate** is welded to them. The **templates** copy the shape of the outside of the yacht. This ensures that the **hull plate** and **item** fit seamlessly into the yacht and follow its contours perfectly. The **templates** are only a temporary support and are tailor-made for each **item**. They serve no other purpose when the **item** is finished so they are disposed after.

Figure 17: *The hull plate welded to the templates.*

Structure welding phase

Following the setup phase, the next stage involves constructing the **girder** framework (or **structure**), a process that adds structural strength to the **item**. While this step may seem straightforward at first glance, it involves a number of challenges that make it both technically demanding and sensitive to disruptions. The details of this phase are outlined below:

Once the **hull plate** is assembled and welded to the **template**, the **structure**, consisting of longitudinal- and transverse **girders**, can be welded. The **structure** is critical for providing strength and dimensional stability. The process begins with material preparation, followed by tack welding the **girders** to ensure correct alignment. Once secured, the **structure** must first be ground loose from the **hull plate** to finalize the welds. This is done to maintain even heat dissipation as ununiform dissipation could result in excessive warping. This is also why proper fixturing is especially important. Once these welds are finalized, the **structure** is reattached to the **hull plate** to complete the internal welding process.

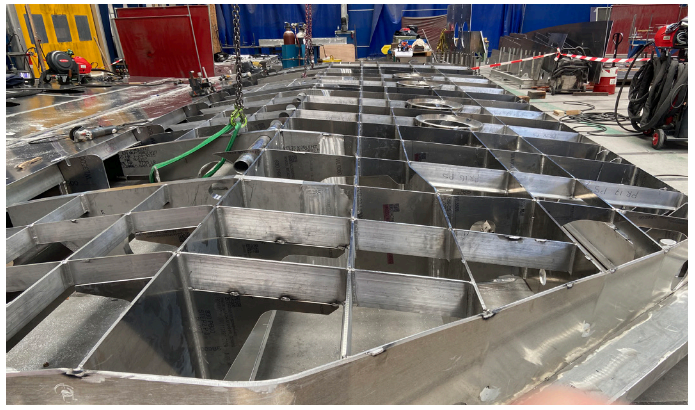


Figure 18: *The internal structure of an item consisting of girders.*

Figure 19: *The structure ground loose and rotated in an upright position, supported by a T-beam, to be welded.*

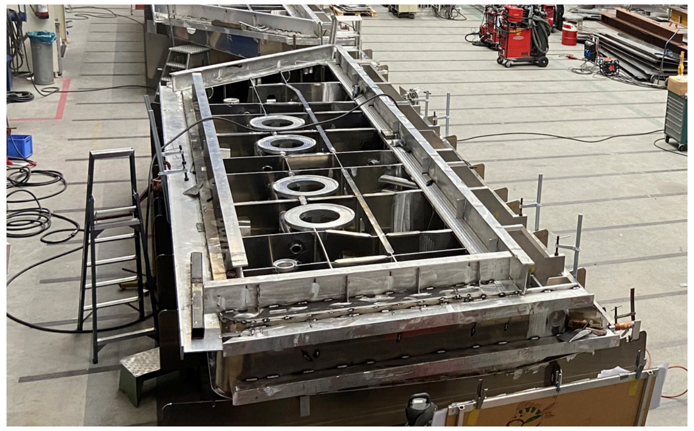


Figure 18: *The structure welded to the hull plate again.*

External welding phase

The final manufacturing steps focus on sealing the **item** and completing the welding process. These steps are crucial in finalizing the structural assembly, ensuring that the **item** is ready for inspection and integration into the yacht.

Once the **structure** is finished, the **closure plates**, which seals the **item** completely, are welded on the **girders**. This is done via slots in the **closure plate** as the plates cannot be welded from the inside. After this, all welds on the outside of the **item** are carefully cleaned and ground flush with the surface. With this final step, the **item** is considered fully welded.

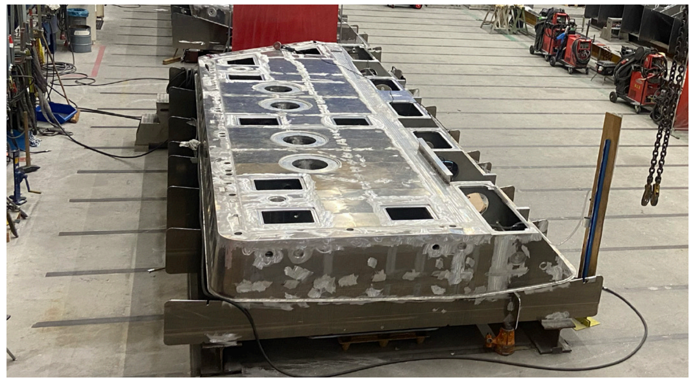


Figure 20: *The closure plate welded to the item.*

Completion phase

As the manufacturing process nears completion, attention shifts toward ensuring the structural integrity and watertightness of the **item**. Despite careful welding, warping and leakages (due to tiny imperfections) can occur and must be addressed through specific corrective and quality assurance steps. The following section outlines the key procedures involved in this final phase.

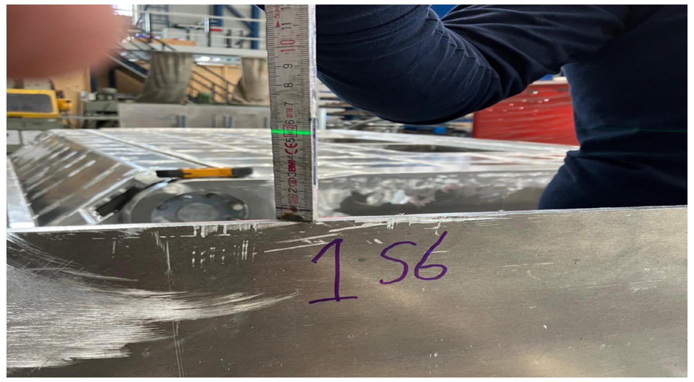


Figure 21: *An item's tolerances checked with a laser.*

Figure 22: *Hydrostatic test on an item to test for leaks.*

Due to heat induced during welding the aluminum **items** can warp. Despite various preventative measures, deformation still occurs in most cases. Warping is acceptable as long as it falls within predefined tolerances. If these limits are exceeded, the **item** must undergo a corrective process known as "setting", in which the component is heated and placed under controlled tension to realign and correct the excessive deviations. The **item** is retested until it passes inspection.

The final step in the manufacturing process involves internally pressurizing the **item** using water. This hydrostatic test is carried out to ensure the **item** is completely watertight, which is essential to prevent potential damage once the yacht is at sea. If any leaks are detected during this test, they are repaired according to the right procedures, and the **item** is retested until it passes inspection.

Quality checks

Three quality checks are carried out during the manufacturing process to ensure each **item** meets the highest standards.

The first inspection occurs after the **hull plate** is welded. Since the butt welds must be strong enough to withstand the stresses of being at sea, they are examined using X-ray imaging to confirm proper penetration and the absence of impurities.

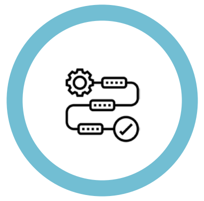
The second check takes place once all internal welds are completed. This is a visual inspection performed by Quality Control (QC). Followed by Lloyd's, a marine classification and insurance company, conducting an additional inspection to verify that the welds meet their standards for certification and insurability.

The final quality check is also conducted by Lloyd's. This inspection is performed after the entire **item** is completed. Once approved, the **item** can be transported to the shipyard and integrated into the yacht.

After installation, Akerboom's role in the initial manufacturing process is complete. However, to ensure the long-term performance and reliability of the **item**, regular quality checks and maintenance are essential. Akerboom supports this through its Global Service Network.

Challenges and bottlenecks

The workflow, while functional, presents several operational challenges and bottlenecks that impact the overall efficiency and productivity of both facilities. The following list mentions the most relevant challenges based on conversations with employees and workplace observations. A detailed list can be found in Appendix E.



Work Process & Manufacturing Method

- Grinding the **structure** loose to weld takes valuable time.
- Aligning H-beams is labor-intensive, but necessary to prevent warping.
- Some engineered procedures are impractical in practice, causing inefficiencies.
- Some **hull plates** are kinked to allow the **item** to rotate within the yacht's hull. The **templates** are used to weld one side of the seam of these kinked plates. However, milling and welding the opposite side is not possible without additional support. Currently, this is solved by first welding part of the **structure** to the **hull plate**, then rotating the **item** to access the other side, a process that is time-consuming and inefficient.

Ergonomics

- Employees are frequently forced into unergonomic positions, kneeling, climbing, or stretching, due to low H-beams, poorly positioned welding tables, and hard-to-reach welding spots.
- While welding the **hull plates** together, the welders need to be on their knees for long periods of time.
- Communication between welders and engineers is indirect and slow, leading to misunderstandings and delays.

Research question two

What are the specifications of the halls & items?

The second research question focused on the specifications of Akerboom's halls and **items**. For the halls, this included documenting their dimensions, as well as analyzing their current layout and estimating potential space savings.

Regarding the **items**, their dimensions and weights were assessed and grouped into three size categories: small, medium, and large. Additionally, manufacturing data from the past seven years was compiled to create an overview of how many **items** of each category are manufactured per year.

Halls in Leiden

The floor map below shows the dimensions and lay-out of halls one (left) and two (right) in Leiden.

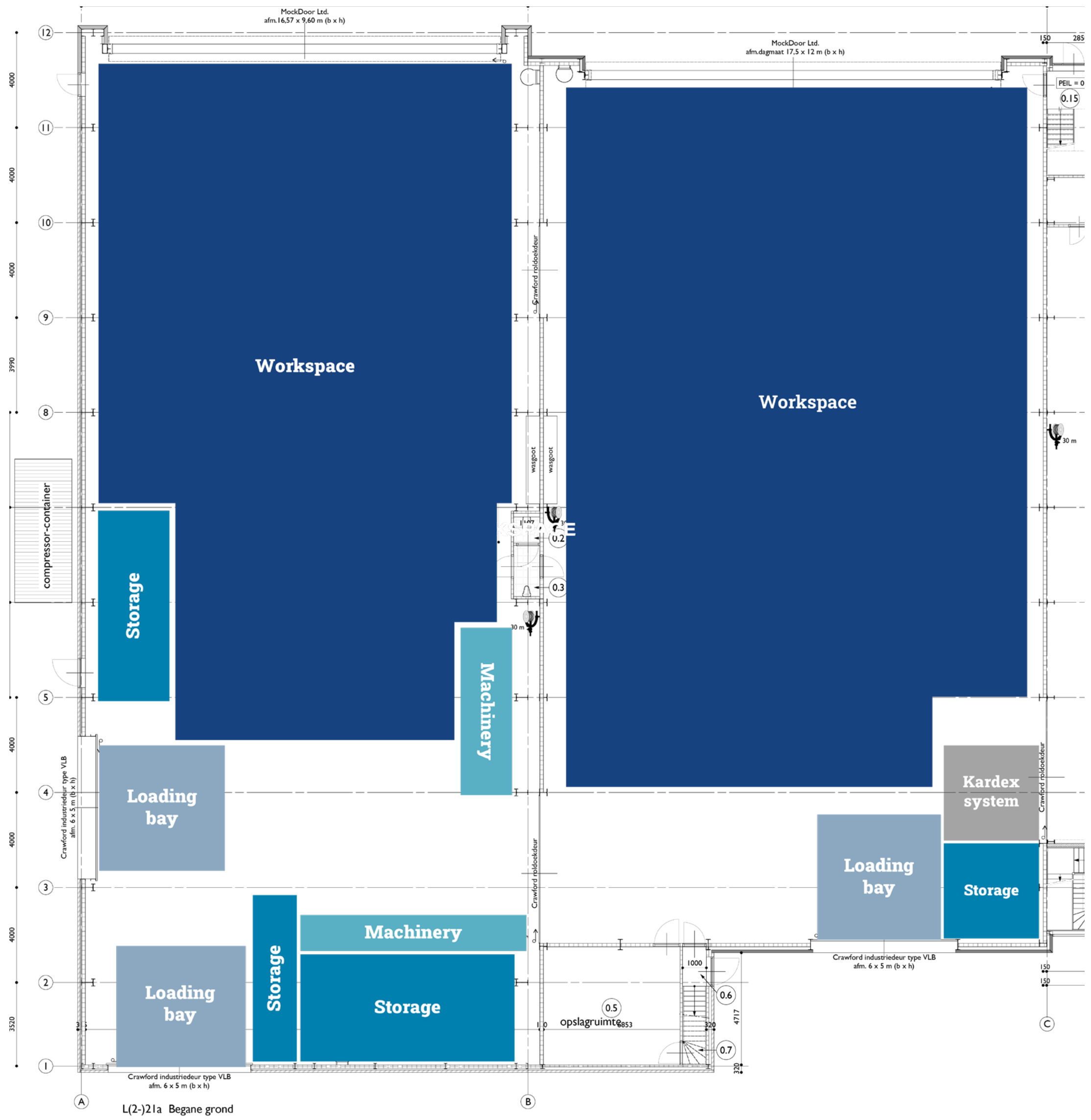


Figure 23: *Floor map of the halls in Leiden with their current lay-out.*

Hall 1 in Leiden has a total surface area of 817 m², while Hall 2 offers slightly more at 837 m². However, due to unusable areas along the sides of the halls, such as structural beams, hand-washing stations, and clearance areas, 5% of the total space is considered unusable. This results in a net usable floor area of approximately 776 m² for Hall 1 and 718 m² for Hall 2.

In its current configuration, only 57.4% of Hall 1 is actively used as workspace. However, when taking the net usable floor area and excluding the loading bay, which is the only fixed, non-negotiable area, there is an opportunity to increase workspace utilization to 627 m², or roughly 84% of the net area. If an additional 5% (approximately 27 m²) is reserved for storage needs, the total potential workspace still remains high, reaching approximately 80.5%. Hall 2, by comparison, already demonstrates relatively efficient use of space. Currently, 76.7% of its floor area is dedicated to active workspace. Through the same adjustments and optimization as Hall 1, this can be increased to a maximum of around 83%, suggesting that Hall 2 is already nearing optimal spatial efficiency.

Both halls are equipped with four overhead cranes, with two cranes allocated to each longitudinal half of the hall. These cranes have a maximum lifting height of 9.5 meter.

Figure 24: *The overhead cranes (yellow) in hall two in Leiden.*

Hall One

Total usable surface area
776m²

Workspace
446m² (57.4%)

Loading bay
52m² (6.7%)

Storage
79m² (10.2%)

Potential workspace
625m² (80.5%)

Hall Two

Total usable surface area
718m²

Workspace
551m² (76.7)

Loading bay
25m² (3.5%)

Storage
16m² (2.2%)

Potential workspace
596m² (83%)

Figure 25: *Overview of the division and potential space in the halls in Leiden.*

Hall in Katwijk

The floor map below shows the dimensions and lay-out of the hall in Katwijk.

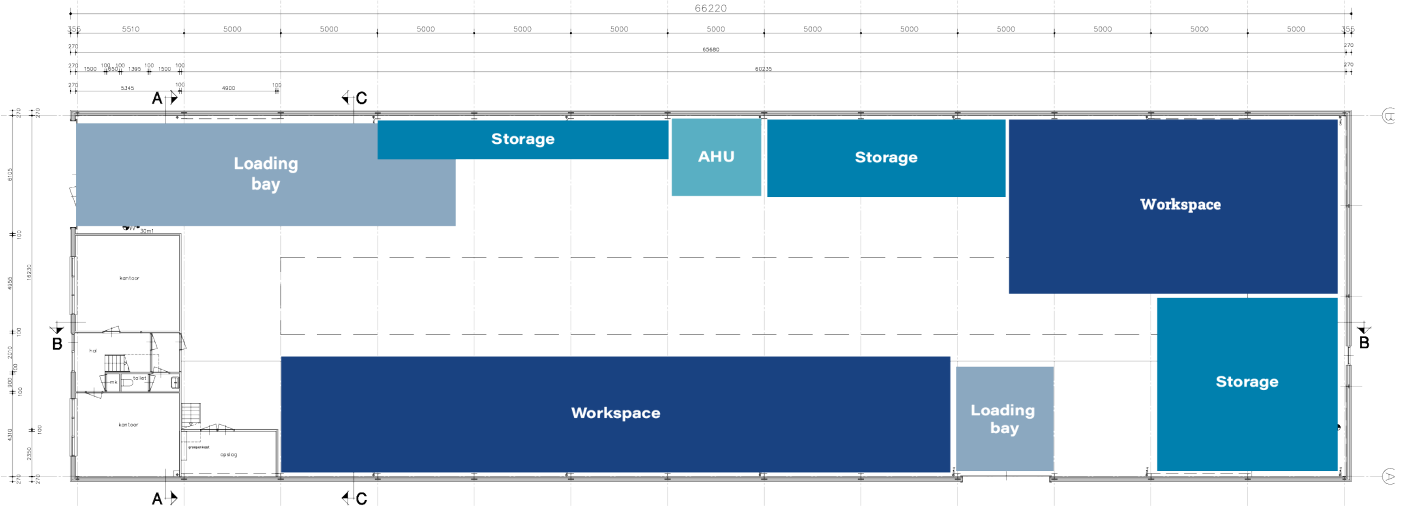


Figure 26: *Floor map of the hall in Katwijk with its current lay-out.*

The hall in Katwijk has a net usable floor area of 1,095 m². Currently, only 363 m², or approximately 33.1%, is utilized as workspace. As aforementioned, this limited usage is primarily due to the absence of a **truss floor**, which is essential for welding the H-beams to, to establish a rigid fixture.

The existing **truss floor** is located in the rectangular blue area at the bottom of Figure 26. The other blue rectangle at the top-right of the Figure labeled "workspace" does not contain a **truss floor**, but is used for the manufacturing of gangways. These **items** are small enough to be welded on a welding table, making a fixed foundation unnecessary.

If, as in hall one and two in Leiden, 5% of the area is allocated for storage, the potential workspace in Katwijk could be increased to 859 m², or 78.5% of the hall's total usable area more than doubling the current workspace. Achieving this, however, requires enabling welding independent of floor type and therefore changing the current manufacturing method as the self-made H-beam fixture requires a **truss floor**.

The hall in Katwijk is equipped with two overhead cranes, which, in contrast to the cranes in Leiden, do offer full-width coverage. These cranes, however, only have a maximum lifting height of 5.75m. This limits the maximum dimensions of the **items** that can be produced in Katwijk.

Hall in Katwijk

Total usable surface area
1095m²

Workspace
363m² (33.1%)

Loading bay
125m² (11.4%)

Storage
159m² (14.5%)

Potential workspace
859m² (78.4%)

Figure 27: *The division and potential space in the hall in Katwijk.*

Specifications of the items

To gain a better understanding of the quantities, dimensions, and weights of the **items** manufactured by Akerboom, an analysis was done. This process involved reviewing 3D models available in OnePush, a software program used by Akerboom as a database for their CAD models, where dimensions and weights are documented and could easily be extracted. A complete overview of the dimensions and weights can be found in Appendix F.

The **items** were divided into three categories based on their dimensions (mm) and weight.

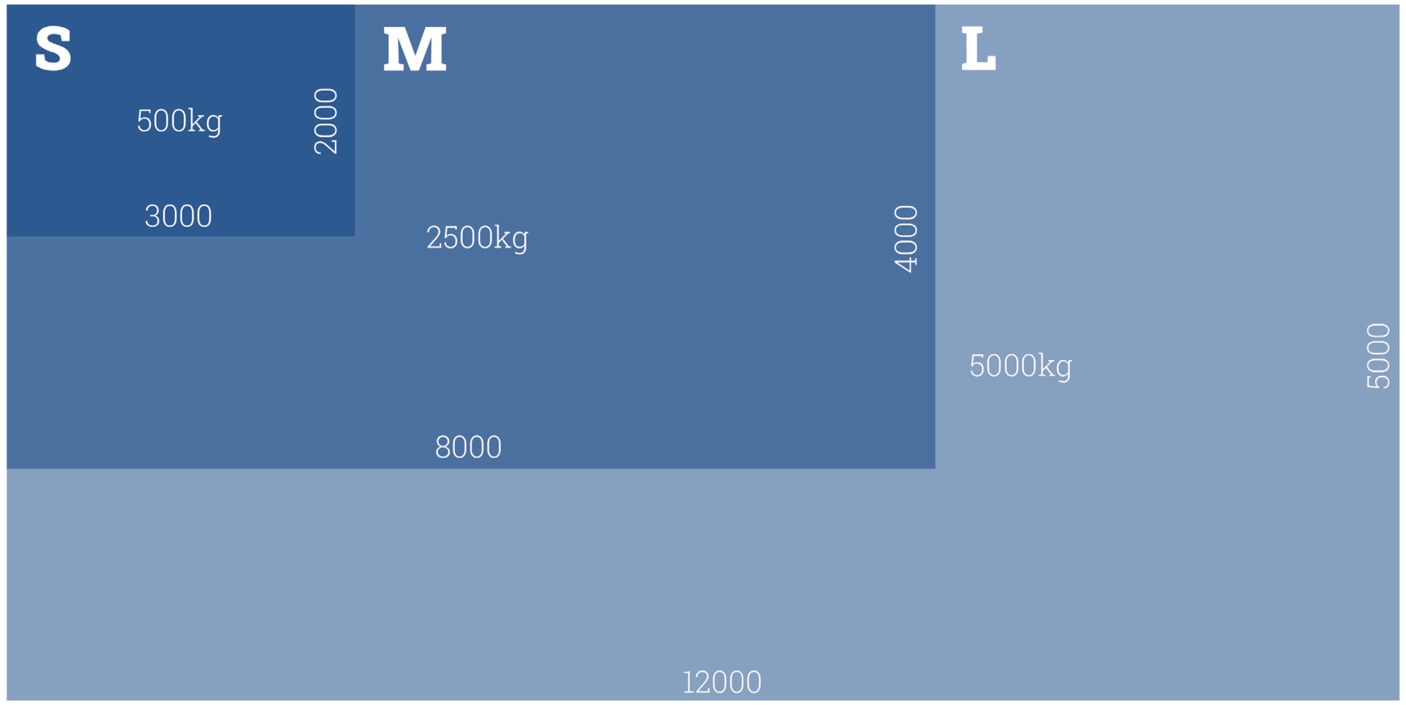
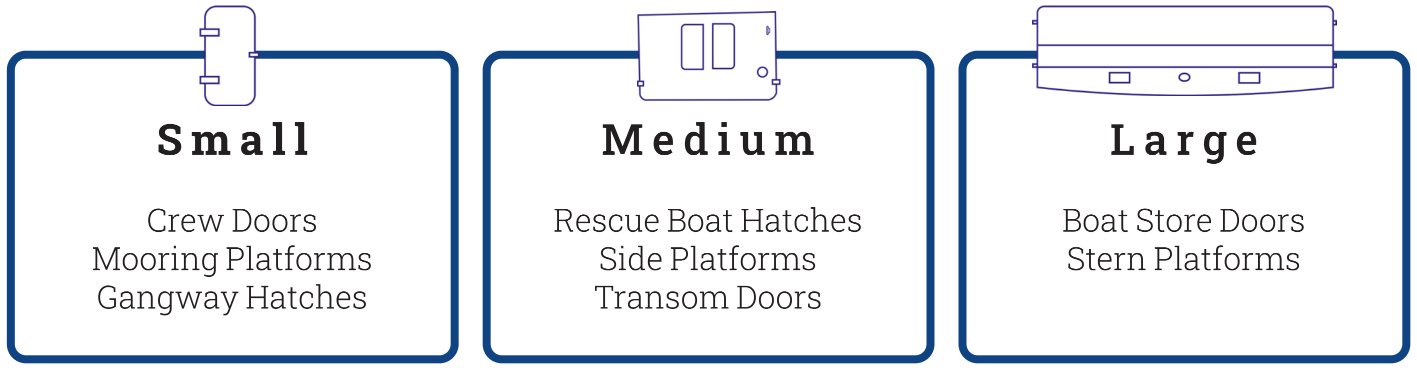


Figure 28: *Dimensions and weights of the three categories of sized of items.*



An overview of the **items** produced in the past seven years was created to gain insight in the quantities of the **items** manufactured at Akerboom (see Appendix G).

In the past seven years, a total of 193 **items** were produced by Akerboom, averaging 28 **items** per year.

To create a clearer and more comprehensive overview, similar **items** have been grouped into **item** categories. First, doors which have a main function of housing boats are now collectively referred to as **Boat Store Doors**. Secondly, platforms which are typically located along the sides of the yacht, are grouped under the category **Side Platforms**. Lastly, **Stern Platforms** now serve as a combined category for Swim Platforms, Stern Platforms, and Transom Platforms, as they all serve a similar function at the rear of the vessel.

Side Platforms are the most frequently manufactued **items**, with a total of 41 units manufactured over the past seven years, an average of approximately 5.9 units per year.

Boat Store Doors follow closely, with 36 units manufactured during the same period, resulting in an average annual manufacturing rate of 5.1 units.

Mooring Platforms, **Gangway Hatches**, **Rescue Boat Hatches**, and **Crew Doors** rank third, fourth, fifth, and sixth in manufacturing volume. Collectively, they have been manufactured 69 times in the past seven years, averaging almost ten units per year.

Together with the **Transom Doors** and **Stern Platforms** these **items** make up a little over 80% (23.4 **items**) of total manufacturing. All these **items** are, in average, produced at least one time per year in the past seven years. All other **items** are manufactured less than once per year and are thus not considered for this project.

Of these 23.4 **items**, 33.3% falls in the small category, 40.6% are medium, and 26.1% are large.

Images of some of the **items** described in this text can be found on the next page.

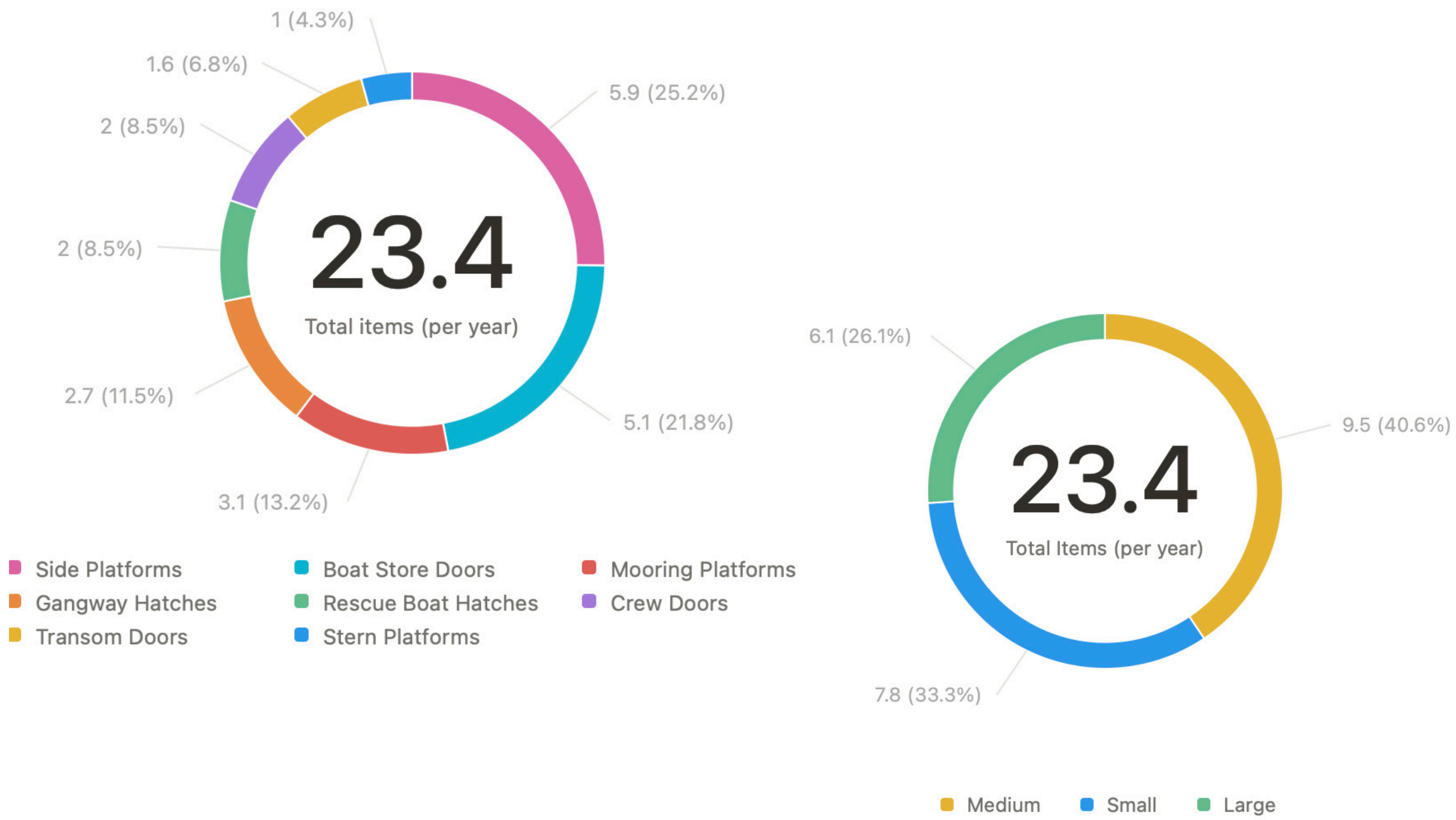


Figure 29: *Amount and type of items manufactured per year.*

It is important to recognize that larger **items** are more complex to handle and manufacture. They require heavy-duty equipment, consist of more components, and often include additional features. In contrast, most **items** produced at Akerboom fall into the small to medium size range, making them more suitable for standardization and ergonomic optimization.

Given the limited time available for this project, the initial design will focus on a workstation tailored to small and small-medium **items**.

In addition, the hall in Katwijk only has a maximum lifting height of 5.75m, preventing the manufacturing of the largest **items**.

To ensure long-term flexibility, modularity will be introduced in a later chapter. This will allow the workstation to be scaled or adapted to support larger or more complex **items** as needed, ensuring the concept remains relevant for future applications.

Figure 30: *An example of a tender store door.*

Tenderstore door
Figure 30 presents an example of a tenderstore door. As the name implies, this door provides access to a storage space housing a tender, a small auxiliary boat. When opened, the tender can be deployed using onboard cranes and lowered into the water.

Beachclub platform
Figure 31 shows an example of a small beach club platform. Positioned along the side of the yacht, this platform folds out to create a compact lounge area where people can relax and enjoy the sun.

Figure 31: *An example of a small beachclub platform on the SB-side of a yacht.*

Figure 32: *An example of a transom door.*

Transom door
Figure 32 shows an example of a transom door. This door provides access to the yacht's stern and, when opened, creates a spacious entry point. When closed, it ensures a watertight seal between the interior and exterior.

Research question three

What are the current Health & Safety guidelines at Akerboom?

The Dutch Working Conditions Act (Arbo) provides a list of key risks within the Metalektro industry, dividing them in six categories: physical strain, machine safety, hazardous chemicals, excessive noise exposure, welding fumes, and fall hazards (5xBeter, n.d.). To help companies assess and improve workplace safety, the Arbo provides a five-step framework for each category. This framework serves as a guideline to identify hazards, evaluating current safety measures, and implementing improvements to aid organizations in complying with the guidelines.

However, the Arbo does not provide universally applicable rules on hall safety that companies must follow. Instead it leaves organizations responsible for developing and enforcing their own internal safety policies and regulations. While compliance with the Arbo's guidelines is mandatory, each company determines the specific measures needed to create a safe working environment.

Akerboom is committed to creating and maintaining a safe and healthy working environment through mandatory online safety training courses and toolbox meetings, which are short periodic work meetings with the goal to create awareness on labor conditions. These initiatives help educate employees about potential hazards, create awareness, and encourage open discussions on best practices for mitigating risks.

Most prevalent risks at Akerboom are: exposure to welding fumes, excessive noise levels, and developing photokeratitis also known as arc eyes.

The risk of developing photokeratitis is particularly high during the welding of **hull plates** using the welding buggy, as this task requires the welder to maintain prolonged visual focus on the weld seam. Even when wearing appropriate protective gear, welders have reported experiencing painful eye irritation, indicating that exposure levels may still exceed safe limits.

When evaluated against the Safety Culture Ladder, which is a tool from NEN to measure safety awareness in organisations, Akerboom currently stands at Step 2: Reactive (NEN, 2024). This ranking indicates that while safety awareness is present, there is still significant room for growth and improvement. Progressing to a higher level requires a deeper integration of safety-conscious behavior into daily operations and a more proactive approach to risk mitigation.

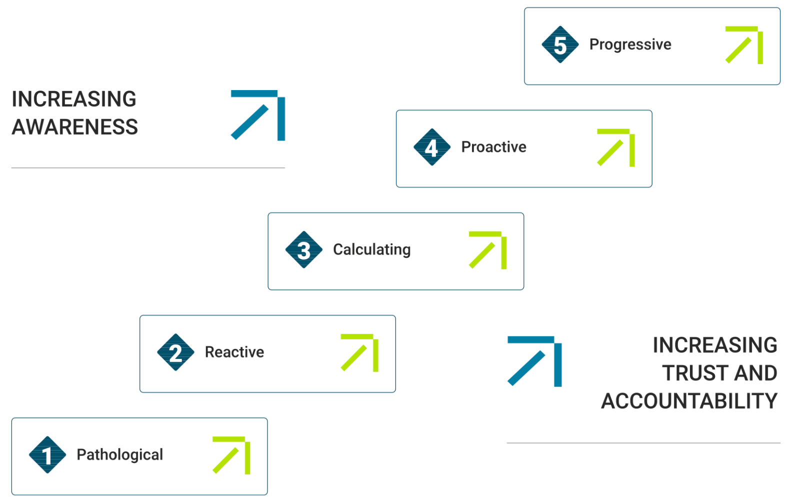


Figure 33: *The Safety Culture Ladder.*

Figure 34: *Relevant risks from the RI&E conducted by QHSSE.*

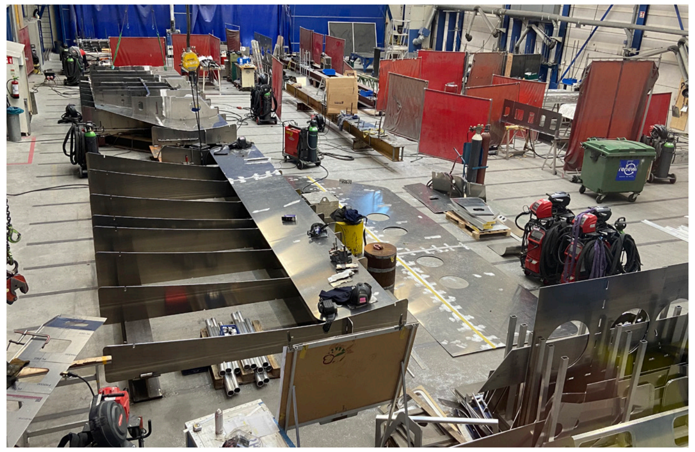


Figure 35: *Current housekeeping in the hall in Leiden.*

Risk Assessment & Evaluation

To set the first step towards safer working conditions and to ensure compliance with safety regulations, Akerboom has partnered with Octant QHSSE Consultants to conduct an RI&E (Risico-Inventarisatie en -Evaluatie). This RI&E describes all risks and ways to mitigate them (Ministerie van Sociale Zaken en Werkgelegenheid, 2024). The project-relevant takeaways of this RI&E are summarized in Figure 34.

To enhance workplace safety and compliance, it is essential to train employees on safe work practices and maintain a clear record of these sessions. Good housekeeping must be prioritized, particularly by organizing cables and clearing unused materials, to reduce tripping hazards (see Figure 35 & 36). Additionally, conducting a more in-depth RI&E focused on physical strain will help prevent long-term health issues. Lastly, all safety equipment, such as fire extinguishers, hose reels, and AEDs, must remain clearly visible, properly mounted, and easily accessible at all times.

As per law, Akerboom maintains a register of all occupational accidents. This record provides insights into the frequency and causes of workplace incidents, helping to identify potential areas for improvement.

At the halls in Leiden, the average number of accidents per year is 4.5 (ranging from a minimum of 0 to a maximum of 11), which is considered relatively low. The majority of these incidents are tool-related. However, one cases is relevant to this project, where restricted movement and poor workspace logistics caused an employee to trip over a pallet resulting in a minor injury.

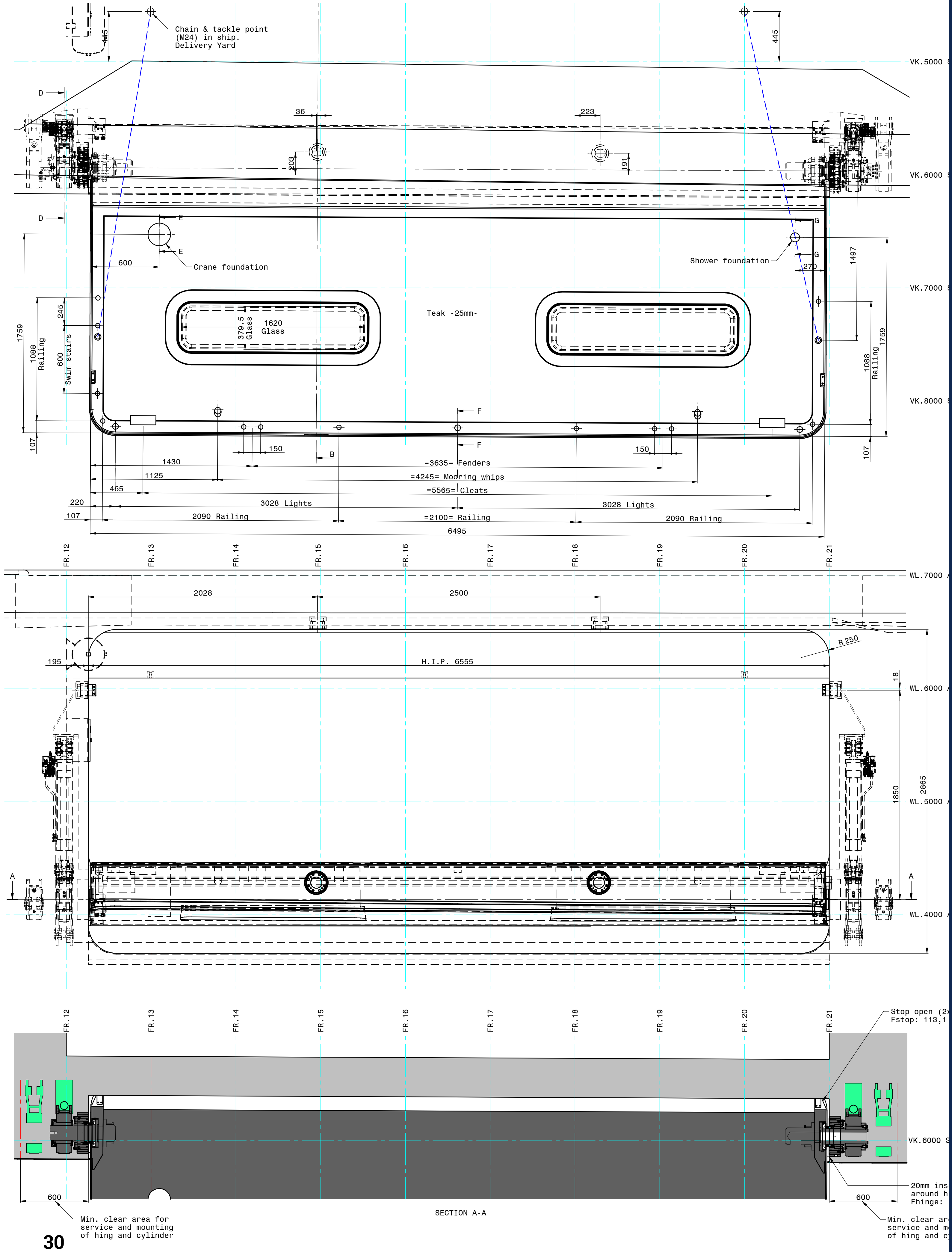
No accidents were registered in the hall in Katwijk, which most likely due to its underutilization.

In summary, Akerboom's housekeeping is a major painpoint and is in dire need of improvement. The workspace needs to be kept tidy and cables and hoses running over the ground should be kept to a minimum. In addition, materials, tools, and equipment need designated locations in the hall, to ensure proper housekeeping and to establish a safe and efficient work environment.

To improve housekeeping, the Lean 5S methodology will be introduced in a later chapter.

Figure 36: *Examples of Akerboom's current housekeeping in the halls in Leiden (top left & right) and Katwijk (bottom left & right).*

Figure 37: *Technical drawings of a beachclub platform.*



3

Ideation

To initiate the ideation phase, desk research was performed and multiple sketches were made. This desk research focused on finding possible lay-out approaches for the halls and kickstart ideation for floor-independent welding.

Sketches of the ideation phase can be found in Appendix H.

Manufacturing optimization

As previously discussed, Akerboom currently has a sequential fixed-position manufacturing system where all manufacturing steps are carried out at a single location within the halls. This demands a highly versatile workstation that can accommodate the diverse requirements of every step in the process. Sequential fixed-position manufacturing is characterized by lots of flexibility, but lacks automation and standardization.

Several alternative manufacturing systems were explored during the initial ideation phase. This resulted in four potential manufacturing concepts aimed at optimizing the manufacturing process at Akerboom. Before presenting these workflows, Akerboom's hall usage preferences are outlined.

Preference of hall

The results of the analysis of the halls concluded that the hall in Katwijk has much potential, but due to its lack **truss floor** it is underutilized. There are several reasons why Akerboom prefers including the hall in Katwijk:

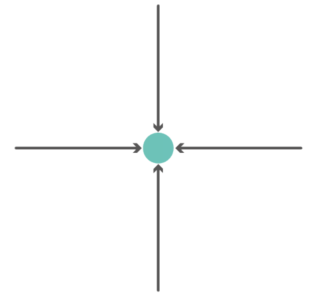
1. The hall has two cranes that cover the entire width if the hall, so transportation through the hall can easily be facilitated.
2. The floor area, although smaller than Leiden's halls combined, is not separated by walls.
3. If most of the work can shifted to Katwijk, one hall in Leiden could be freed up and used for the Assembly department, who prefer the higher manufacturing halls over their lower one as height is needed to test equipment.
4. Additionally, if a large part of work is done in Katwijk, it frees up valuable space in Leiden where more complicated and out-of-standard work, which requires more supervision, can be done. Currently, the available floor space in both Leiden and Katwijk is allocated by first planning upcoming projects in Leiden. When there is not enough space for additional projects, they are moved to Katwijk. This approach can lead to undesirable situations where more complex projects have to be carried out in Katwijk, where there is less supervision and technical support.
5. Unlike the hall in Leiden, which is situated in a residential area, the hall in Katwijk is located on an industrial estate. As a result, it is not subject to the same noise restrictions, allowing work to continue into the evening and night. This enables more productive hours per day.

The hall in Katwijk also has two cons:

1. The hall has a maximum lifting height of 5.75 meter because of its lower ceiling. This restricts the manufacturing of the largest **items** here. Fortunately, the larger **items** are also the most complicated and could therefore be manufactured in Leiden.
2. As Leiden is the main office of Akerboom and Katwijk is not a location that is visited often, there is less supervision there. If the hall in Katwijk is more involved in manufacturing there needs to be more supervision and may even require a more permanent office.

In short this means that, when designing a new workflow, the hall in Katwijk should be taken as a starting point and Leiden's facility will be used to produce more complex and larger **items**.

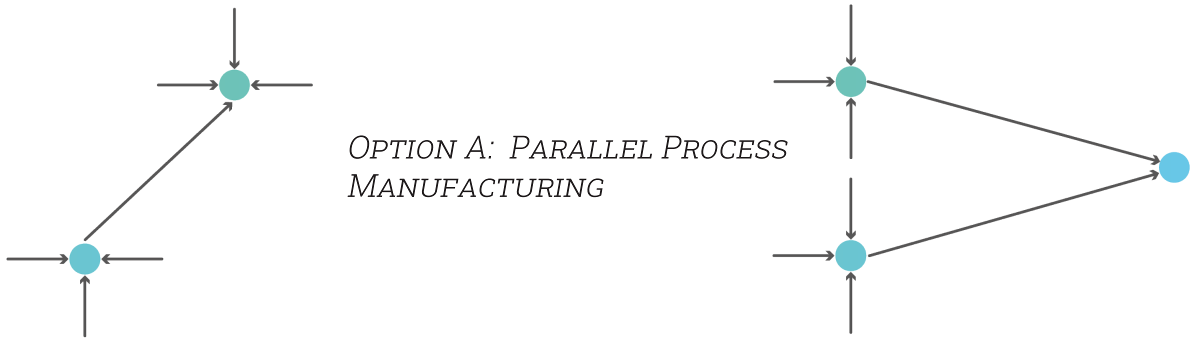
Manufacturing (build) method alternatives



Current: Sequential Fixed-Position Manufacturing

As aforementioned, currently all manufacturing steps occur at the same place in the halls. The advantages of this type of manufacturing are that there is no need to move (sub-) assemblies and thus simpler logistics, there is centralized supervision, and the investment costs are relatively low (Heragu, 2022). The disadvantages are that the workflow is slow and long down-times might occur, material management is very complex, and the process is difficult to standardize and optimize.

As an alternative to creating a new workflow, this current manufacturing method can also be optimized. An advantage of optimizing the current workflow rather than creating a new one, is that there are minimal changes needed and thus integration is less challenging, the investment costs and risks are lower, and it ensures a smooth transition. The current workflow can be optimized by applying LEAN principles.

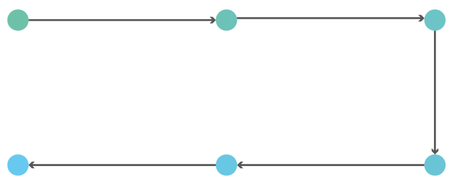


Option A: Parallel Process Manufacturing

As shown, Option A presents a scenario where the manufacuring process is divided into two processes. These processes can run concurrently, thereby shortening the overall lead time. This type of manufacturing is called parallel or cellular manufacturing (Tiwari & Jana, 2021). An additional benefit of this division, is that each workstation can be optimized specifically for its associated process and therefore improve ergonomics, efficiency, and safety.

In this proposed method, the manufacturing process and hall is split in two to create two zones that enable parallel activities. The **structure** is manufactured in the first zone (zone One), while simultaneously, the **templates** and **hull plates** are prepared in the second zone (zone Two). Once both tasks are completed, the **structure** is transported to zone Two, where it is welded onto the **hull plate**. Afterward, the external components and the **closure plate** are welded to finish the **item**. It is essential that the **hull plate** and **structure** fit together without any difficulties, it should be like connecting two Lego pieces. In order to effectuate this, the build methods of these parts may need to be changed. This task can be outsourced to the Engineering department and is out of scope for this project.

There are two versions of this manufacturing method: in the first version, the process is split in two, creating two specialized workstations. At the end, the **item** is finished at one of these two workstations. The other versions starts the same but introduces a third workstation where final assembly/manufacturing takes place. More details on option A can be found in Appendix I.

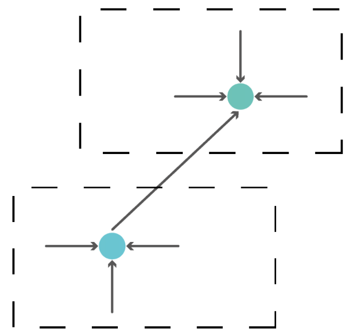


Option B: Product (line) Manufacturing

Option B presents, like the current manufacturing method, a sequential flow. The difference is that in this method, the manufacturing steps do not all happen at a fixed position, but 'flow' through the halls. This is called flow manufacturing (Figueroa et al., 2024). This type of manufacturing could provide a solution for Akerboom's current workflow problems, but implementation of this system can be complex.

An added benefit of this manufacturing method is that automation can be more easily be achieved when **items** are manufactured one after the other and in a line (Cheng et al., 2018). If the **items** were to be put on an automatically moving track, in combination with welding robots, a large part in the process would not require any human interaction. Investment costs for fully automating the manufacturing process are high and require extensive amount of time to be worked out and will thus not be considered for this project.

In the proposed method, the halls are configured in a quadrant-based layout. To support this system, the **items** being manufactured must either be movable or the halls themselves must be equipped with rails to facilitate transportation between quadrants. Each quadrant is dedicated to a specific phase of the manufacturing process and equipped with the tools and setup needed for that stage. This quadrant-based method allows for the simultaneous manufacturing of at least four **items** per hall. More details on option B can be found in Appendix J.



Option C: Divided Parallel Process Manufacturing

The current and previously mentioned methods consider the halls in Leiden and the hall in Katwijk as self-contained locations between which no flow of parts or **items** consist. This demarcation of activities can be beneficial as it creates overview, clear boundaries, and similar processes can happen simultaneously.

However, a third option arises when considering the halls of both facilities as a whole and implementing an organic cooperation.

Combining the halls and letting them cooperate is a form of synergy. Implementing synergy across Akerboom's halls requires strategic consideration of which processes are best suited to for each location. The previously defined division of the manufacturing process (**hull plate** and fixture preparation, **structure** welding, and external component welding) provides a clear **structure** for this allocation.

In this third proposal, **hull plates** are produced in Leiden. The sections are delivered directly to here, eliminating the need for additional sorting. A workstation can be created in the hall specifically designed for pre-processing and welding **hull plates**. This focused workstation will significantly increase efficiency. Meanwhile, the **structure**, which generally has a longer lead time, can be manufactured in Katwijk. More details on option C can be found in Appendix K.

Floor-independent welding

The most prominent challenge in Katwijk is the floor type, which is largely made up of **Stelcon slabs**. These slabs are not secured enough to manufacture on as they can sink into the ground under the high weight of the **items** and H-beams. In addition, being able to place the **item** at different working heights and orientations could improve the ergonomics. So, the proposed designs should not only allow floor-independent welding, but possibly also allow the **items** to be rotated and lifted into different orientations.

Idea One: Tiltable Fixture

This first idea proposes a tiltable welding fixture. This tiltable fixture is similar to a regular welding table which offers multiple clamping possibilities. To this fixture, the **templates** can be clamped.This design can be used in every phase of the manufacturing process as it offers both horizontal and vertical working positions. The four (or more if needed) small legs of the fixture are separately adjustable in height to ensure its level independent of the floor its on. The disadvantages of this design is that the fixture can only be tilted one way. This is similar to the current work method, but requires the welders to use stairs to reach the top. This would be not be necessary when the fixture could tilt both ways. Moreover, this design does not offer height adjustability which is unbeneficial for the ergonomics.

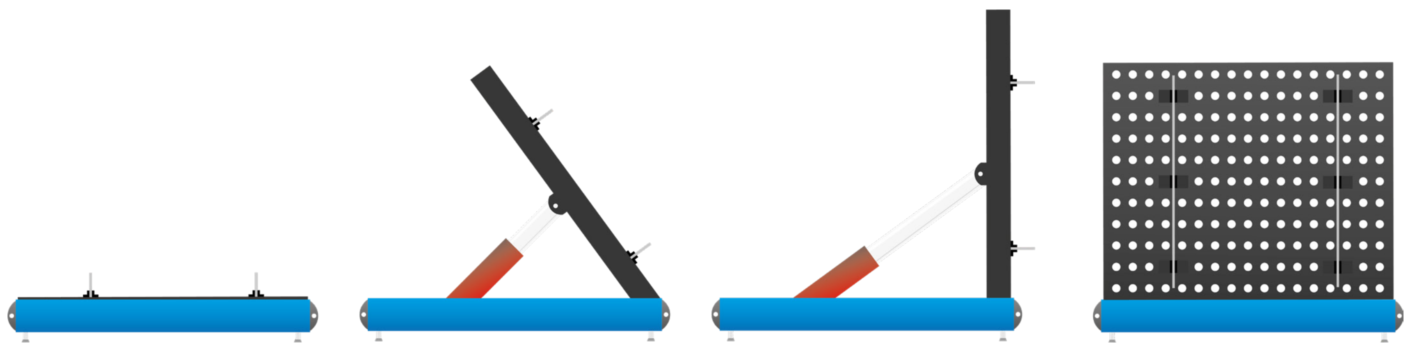


Figure 38: *Schematic overview of the current workflow/lay-out and the three proposed ones.*

Idea Two: Fixed Height-Adjustable and Rotating-Fixture

The disadvantages of the first idea were overcome in the second idea, which proposes a height adjustable, rotating fixture. This idea is based on a car rotisserie which allows the bodywork of a car, or in this case a table, to be clamped between two poles. The fixture can then be raised, lowered, or rotated. With this design all parts of the **item** can be reached without the need for stairs. In addition, the height adjustability offers improved ergonomics for the welders. A shared disadvantage of the first idea and this one, is the lack of scalability. There are fixture add-ons that create an expanded fixture, but placing and removing these add-ons takes valuable time.

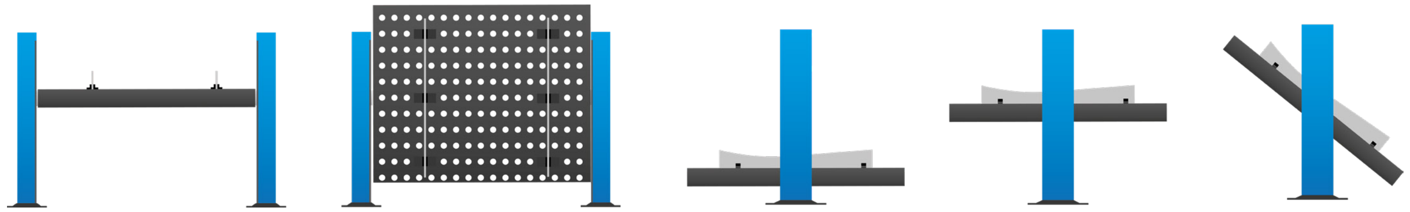


Figure 39: *Schematic overview of the current workflow/lay-out and the three proposed ones.*

This alternative version of idea two overcomes the mentioned disadvantage. The formerly stationary poles are now placed securely on rails so that they can move closer to, and away from each other. By creating a smaller or bigger distance between the poles, the size of the fixture can be varied. This allows the manufacturing of small, medium, and potentially large **items** at the same workstation.

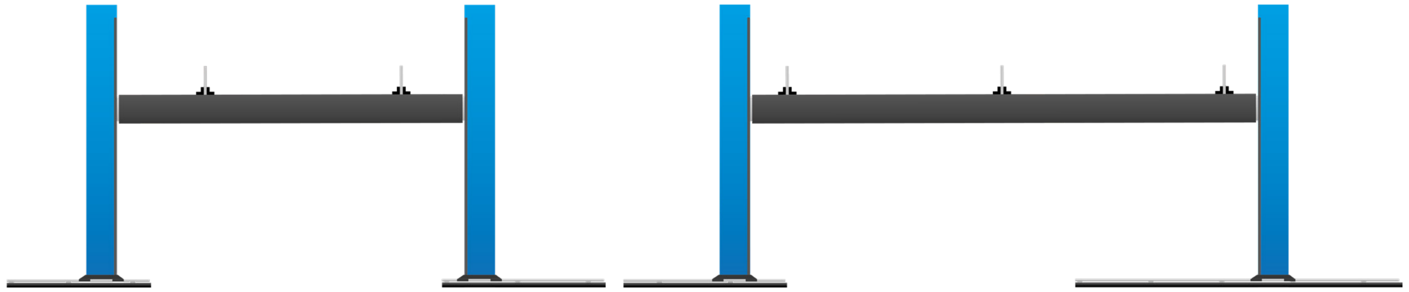


Figure 40: *Schematic overview of the current workflow/lay-out and the three proposed ones.*

Idea Three: Lifting Fixture

The third idea has less features than the other ideas as it can only be adjusted in height. Benefit of this ideas is that the costs are considerably lower than the first ideas. As this fixture is height adjustable it still offers improved ergonomics.

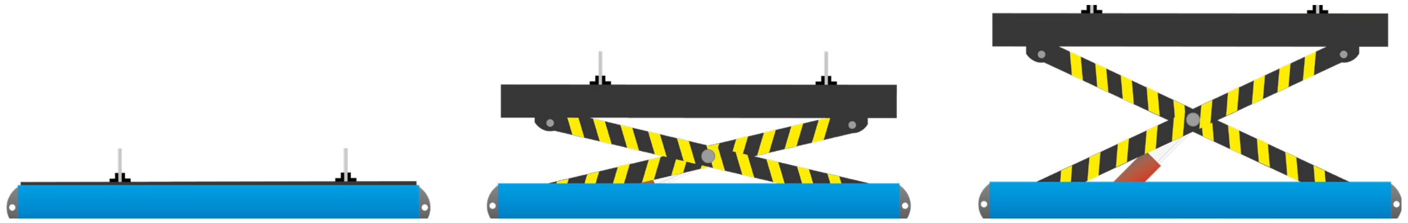


Figure 41: *Schematic overview of the current workflow/lay-out and the three proposed ones.*

Modularity

As outlined in the research phase, the initial concept focuses on small to small-medium sized **items**, which represent the majority of Akerboom's production. Accordingly, the workstation ideas presented so far have been developed with relatively compact dimensions in mind.

However, even within these size categories, **item** dimensions can vary significantly. To accommodate this variation and maintain flexibility, a modular approach is required. Several modularity concepts were explored to address this challenge; these are detailed in Appendix L.

The most promising direction is the semi-modular concept. This approach involves using fixtures designed in fixed sizes, each tailored to a specific size category, that can be expanded or reconfigured as needed. This strategy offers a balance between standardization and adaptability, making it well-suited to the diverse range of **items** handled in production.

More on the integration of modularity can be found in the "Final concept"-chapter.

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Figure 42: *Photo of Pure, a concept yacht designed by De Voogt.*

4

Conceptualization

The conceptual development begins with identifying and optimizing the most suitable workflow. Based on this optimized workflow, a tailored layout for the hall is created. This provides the foundation for further detailing the workstation designs, ultimately leading to the selection and presentation of the most promising fixture concepts for each station.

Manufacturing method choice

To compare the four proposed manufacuring methods, a Pugh Matrix was used. This method evaluates each option against eight specific criteria, listed and described below:

1. **Estimated costs** – The expected financial investment required to implement and maintain the workflow.
2. **Flow efficiency** – How quickly and smoothly the **item** flows through the workflow.
3. **Ease of implementation** – The ease with which the workflow can be implemented.
4. **Lead time** – The estimated total time it takes for an **item** to be finished.
5. **Scalability** – The ease with which the workflow can be scaled up or down.
6. **Manageability** – How easy it is to monitor, control, and coordinate the workflow.
7. **Bottleneck sensitivity** – How vulnerable the workflow is to delays caused by capacity limits or inefficiencies.
8. **Change readiness** – The extent to which employees are willing and prepared to adopt and work within the new workflow. This is based on the amount of differences to the current workflow.

Each criterion was assigned a weight, expressed as a percentage, reflecting its relative importance. The total of all weights equals 100%. Workflows were rated on a scale from 1 (poor) to 10 (excellent), and the weighted scores were used to assess overall performance.

Table 2: *Pugh Matrix.*

Criteria	Weight	Method 1: Improved current	Method 2.1 Parallel Process (2 stations)	Method 2.2 Parallel process (3 stations)	Method 3 Product Line	Method 4 Divided Parallel
Estimated costs	20%	8	7	6	6	6
Flow efficiency increase	20%	6	8	7	8	6
Bottleneck resistance	15%	2	7	8	5	6
Lead time reduction	15%	5	9	9	8	7
Scalability	10%	5	7	7	4	8
Manageability	10%	8	7	6	7	5
Ease of implementation	5%	8	7	6	5	6
Amount of change needed	5%	9	6	6	5	5
Total		6	**7.45**	7.05	6.35	6.2

The results from the Pugh Matrix show that methods one, three, and four scored similarly, while method two stands out with a significantly higher total score of 7.45. This is also inline with subsequent feedback from Akerboom's Production Manager, who deemed method two most promising. Therefore method two, which proposes a parallel process where the **hull plate** and the **structure** are manufactured at different workstations, will be developed into a concept.

The conceptualization process begins with iterating on this Parallel Process Method (PPM) to refine and optimize its **structure**. Following this, Lean principles are applied to the current workflow to identify potential improvements. These insights are then integrated into the PPM to further enhance its effectiveness and efficiency. When finished, a tailored solution for floor-independent welding.

Lead time calculations

To assess how much the Parallel Process Method effectively reduces lead time, a comparison was made between the lead times for two **items**, the PS and SB for the beachclub platform of project 830. The current lead times for these **items** were pre-calculated by the foreman and used as the basis for this comparison (see Appendix N). The manufacturing of an **item** can be divided into four main processes:

1. Welding the **hull plate** and setting up the **templates**
2. Welding the **structure**
3. Finalizing the welds and conducting quality checks
4. Welding all additional components (such as portholes and scepter pots)

The estimated lead times, as derived from the WBS, for these processes are as follows:

- Process 1: **155** hours
- Process 2: **240** hours
- Process 3: **240** hours
- Process 4: **240** hours

The additional components are small components that require minimal space during welding. As a result, Process 4 can be executed in parallel with the other three processes.

Under Akerboom's current sequential, fixed-position manufacturing method, this results in a total lead time of 635 hours per **item**. Therefore, producing both the PS and SB would occupy two workstations for a total of 635 hours (see Figure 44).

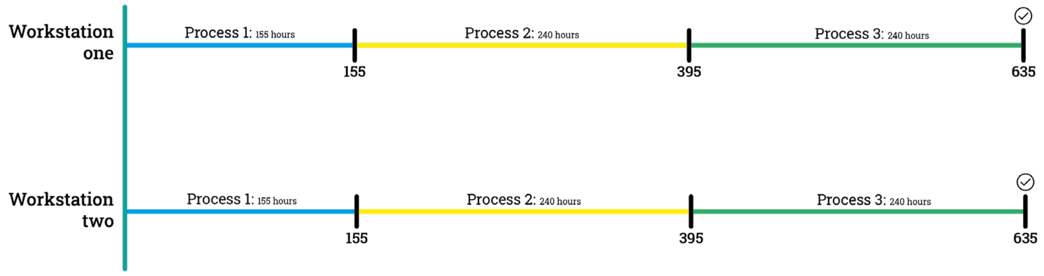


Figure 44: *Overview of the current lead times for two beachclub platforms (PS&SB).*

To calculate the lead time for the Parallel Process Workflow, the same number of hours per process was used as in the previous calculation. A key constraint in this workflow is that Process 3 (finishing and quality checks) can only begin after Process 2 (welding the **structure**) is completed.

Taking this dependency into account, the lead time for a single **item** is reduced to 480 hours, representing a 25% decrease compared to the current method. However, since Workstation One remains occupied by Process 1, the total lead time for producing two **items** increases to 875 hours, which is a 37% increase.

In this setup, Workstation Two becomes available sooner, allowing production of the next **structure** to start earlier. Still, the overall completion time for each **item** remains limited by the availability of Workstation One. As a result, the Parallel Process Workflow does not lead to a shorter total lead time.

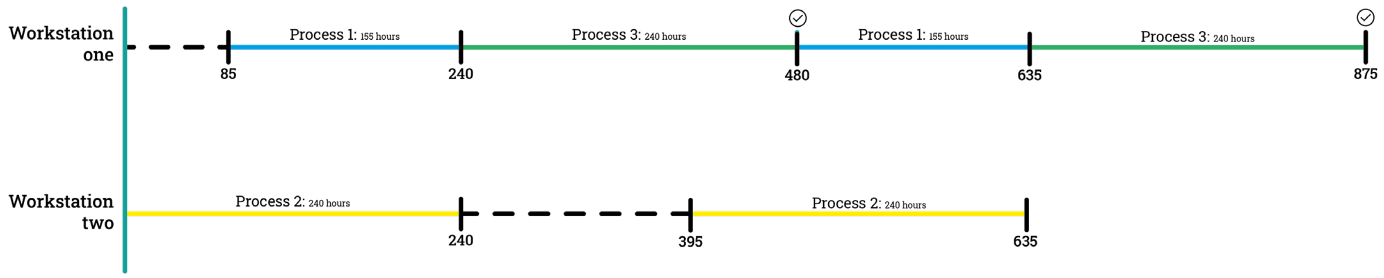


Figure 45: *Overview of the lead times for the Parallel Process Workflow.*

Introducing a third, dedicated workstation for Process 3 (finishing and quality checks) to relieve Workstation One does not result in a shorter total lead time. As in the previous scenario, the lead time per **item** is reduced to 480 hours due to overlapping processes. However, since Process 3 can only begin once Process 2 is completed, the overall lead time still adds up to 720 hours, representing a 13% increase compared to the current workflow.

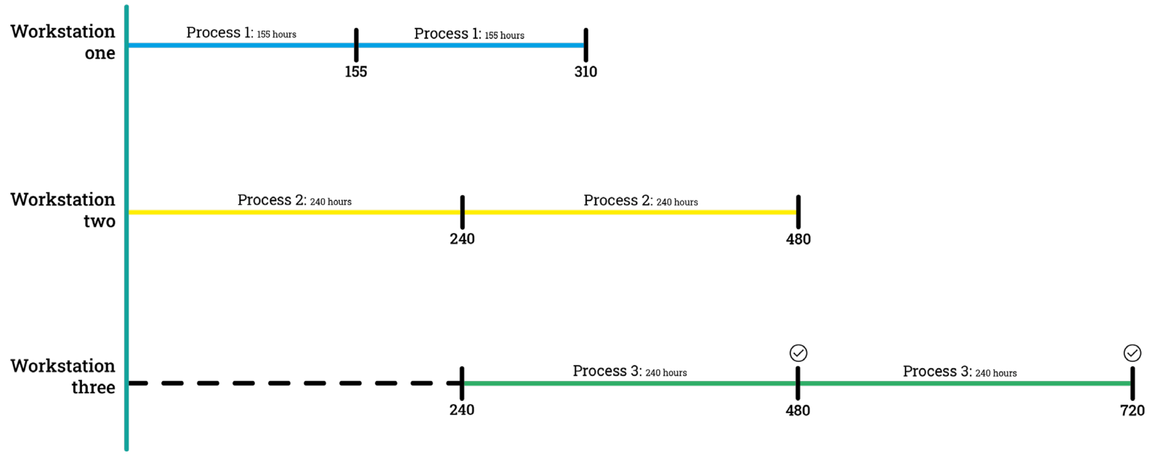


Figure 46: *Overview of the lead times for the alternative version of the Parallel Process Workflow with a third workstation.*

Moreover, this setup requires a third workstation to achieve the same output, whereas under the current sequential method, that same workstation could be used to manufacture an additional **item**. As such, while the distribution of work is improved, the total lead time and resource allocation become less efficient.

To address this issue, the Parallel Process Method must be slightly adjusted. Rather than splitting and then combining two processes, only one step in the process, welding the **hull plates**, is separated and assigned to its own dedicated workstation. At this specialized station, all **hull plates** can be manufactured. The **structure** and remainder of the **items** is then welded at separate workstations, allowing to operate in parallel. This creates three distinct workstations:

1. A workstation where all **hull plates** are welded.
2. A workstation where all additional components are welded and pre-processing of materials is done.
3. A workstation where the **structure** and remainder of the **item** gets welded.

Iterations on method

Iterations on the manufacturing method are carried out using a dry simulation. Additionally, two experts from TU Delft were consulted, with backgrounds in Ship Design, Production and Operations, and Manufacturing Systems to validate the method. Ultimately, Lean principles are applied to improve the proposed workflow.

Dry simulation

To evaluate the proposed method, a dry simulation was conducted to test its feasibility in practice without physical implementation. The simulation involved creating a detailed flowchart of both the current and proposed methods (see Appendix M), which was then reviewed step-by-step with the foreman. In parallel, 3D-printed scale models of the production halls were used to visualize spatial layouts and simulate worker and material movement.

This method allowed for the early identification of operational challenges and bottlenecks that may arise during implementation. The simulation revealed key concerns such as:

- Workflow depends heavily on precise planning and scheduling.
- Flexibility for handling unexpected deviations or rework is limited.
- Specialized workstations may be underutilized between projects.
- Learning curve for workers adapting to the new workflow.

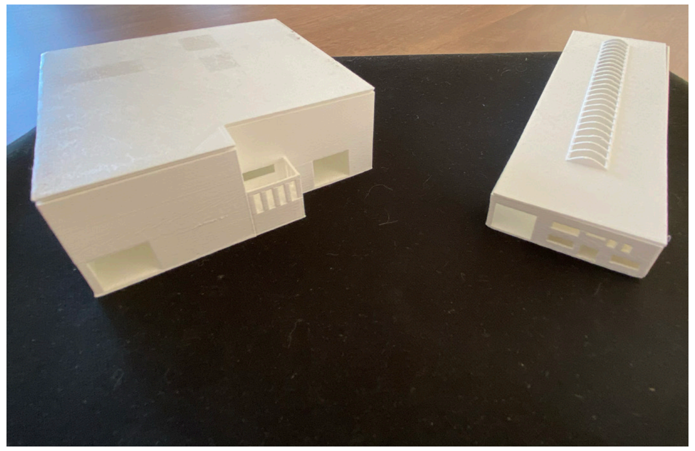


Figure 43: *3D prints of the halls used for the dry simulation.*

Expert consultation

As noted earlier, two professors at the TU Delft have been consulted. One professor has a background in Ship Design, Production and Operations and the other in Manufacturing Systems. These professors were presented the project and the status quo after which a discussion was held. These session both took one hour. The insight from these discussions are summarized below:

- **Modularity within the item** - If the **items** themselves are designed to be modular, the manufacturing process can be standardized. This is a challenge for the Engineering department and out of scope for this project.

- **Pinbeds** - In shipbuilding, pinbeds are used to support the **hull plate**. This pinbed is a collection of pins that can be individually set to height. A pinbed can be used in the process of **hull plate** welding to offer a flexible fixture.

- **Reverse building** - Generally in shipbuilding, the **hull plate** is welded on the **structure** instead of the other way around. This makes **templates** redundant as the **structure** shapes the **hull plate**. This might also be applicable to Akerboom's manufacturing method.

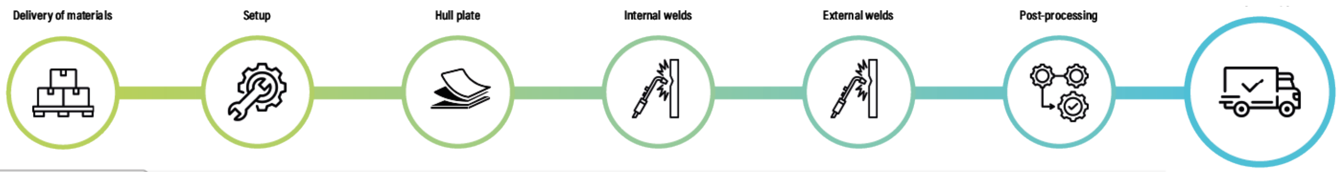
Lean muda identification

A frequently used method to improve processes is LEAN. LEAN originates from Toyota's Production System and aims to identify processes that add value for the customer and eliminate those that do not (De Brouwer & De Brouwer, 2024). In order to do so LEAN uses three M's: Muda, Mura, and Muri. Processes that do not add value and thus are not valuable for the costumer are called Muda or waste. Mura focuses on imbalances and variations in the process causing the lack of a 'flowing' manufacturing stream. An example of Mura is having a very busy process on Monday through Wednesday and almost no work on Friday. Muri refers to the overloading of humans and/or machines. This overload causes extensive wear and tear which is undesirable in the manufacturing process. For this project, only Muda will be considered.

There are two types of Muda: Muda type I and Muda type II (Lean.nl, 2024). Muda type I is also called Necessary but Non Value Added (NNVA) and refers to Muda that cannot be directly identified as a waste, but is necessary for the process, (i.e. adding support to ensure correct alignment). Muda type II (or Non Value Added (NVA) are activities that are deemed unnecessary and should therefore be eliminated. The Muda can be divided into eight categories:

1. **Transport** – Unnecessary movement of products or materials.
2. **Inventory** – Excess stock that doesn't add value.
3. **Motion** – Unnecessary movement of people, like walking or lifting.
4. **Waiting** – Idle time when staff are not productive.
5. **Overproduction** – Producing more than needed, causing other wastes.
6. **Overprocessing** – Steps that don't add value, like extra checks or unnecessary packaging.
7. **Defects** – Products or services not meeting customer specifications.
8. **Skills** – Not using the full potential of employees' knowledge and skills.

Akerboom's manufacturing employees are educated as welders. Considering this, all activities which are not welding can be deemed as Muda as, in that case, they are not using their full knowloedge and skills .
For Akerboom's activities, the categories of inventory and overproduction are not relevant, as they produce unique, on-demand products. As a result, no excess inventory or overproduction occurs. Through observations, the Muda (waste) present at Akerboom was identified and is summarized below. This summary contains both Muda Type I and II.



Transport	• Unstacking/unpacking of pallets • Storage of pallets in the halls	• Sorting the hull plates (SB + PS)	• Rotating the framework to reach all welding spots	• -	• Storing items awaiting pick-up
Motion	• Driving to Katwijk for supervision	• -	• Walking to technical department • Looking for tools	• Walking to technical department • Looking for tools	• -
Waiting	• -	• Waiting for templates to be set-up	• Waiting for additional materials • Getting tools	• -	• -
Overprocessing	• Unpacking the sheets • Sorting the sheets • Welding and leveling the H-beams • Welding and leveling the templates • Reinforcing the templates w/ strips	• Rounding the edges on the plates • Adding strips to hold the plates in place • Preparing the seems of the plates • Setting up welding buggy • Flipping the plate	• Adding additional support minimize errors • Aligning and securing material • Grinding framework loose from hull • Cleaning old welds on the hull w/ grinder • Vacuuming grindings	• Grinding T-profiles loose from frame • Aligning and securing material	• Setting the item due to warping • Grind item loose from templates • Cleaning old welds w/ grinder • Cleaning the hall • Grind H-beams loose from ground • Pressurizing the item to check for welds
Skill					

Figure 47: *Summary of the theoretical Muda per step of the manufacturing process.*

Observations
Careful observations were done to determine the exact amount of Muda in the process and to support the theoretical Muda described on the previous page.

As part of this qualitative observational research, six non-participant observations were conducted during various phases of the manufacturing process. Observations were done from an elevated office overlooking the hall, allowing for unobtrusive monitoring of the welders. Each session lasted approximately one hour and focused on one welder at a time. Of the six observations, two were focussed on welding the **hull plate**, two the **structure**, and two were welding additional components. A clock was used to log the start and end times of activities. Timestamps were registered in an Excel sheet (see Appendix O). The figure below shows the avarage division of time derived from the observations. .

A noteworthy insight is that 63% of the NVA time was spent on conversations between employees, suggesting that communication habits could be a significant area for improvement. However, it is important to recognize that employees are not machines, informal conversations and short breaks play a vital role in maintaining morale and sustaining performance, and therefore even boosting efficiency. Moreover, the observations took place during/shortly after a period of reduced workload for the welders. Several new projects had just started, and welders were in the process of readjusting to the regular work rhythm. This transitional phase may partially explain the relatively high portion of time spent on (informal) conversations.

The remaining 37% (34 min.) of NVA time can be assigned to material handling, checking drawings, looking for tools, or other similar activities. These activities, while seemingly minor, add up to inefficiencies over time. For example, material handling often involved moving materials across the hall due to suboptimal layout or lack of clear storage zones. Employees would walk back and forth to a shared computer to check the digital drawings for measurements, disrupting their workflow. Similarly, tool searching stemmed from a lack of standardized, modular tool storage. Tools were not always returned to their designated spots, and employees often spent several minutes locating them.

Together, these findings indicate a clear opportunity to reduce Muda through better workspace organization, improved communication protocols, and streamlined access to materials and tools. Targeted interventions in these areas, such as implementing Lean 5S, digital workstations, or modular toolkits, could significantly reduce NVA time and increase overall productivity.

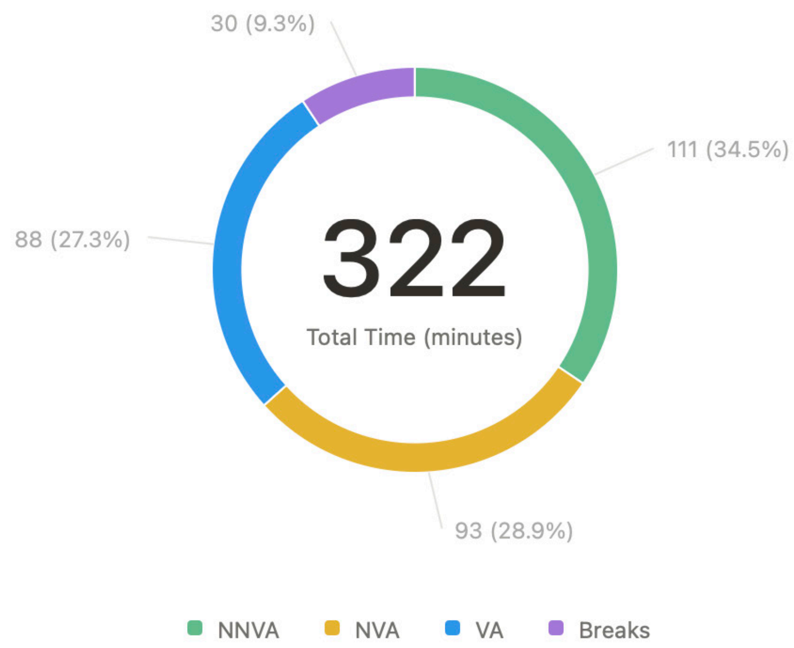


Figure 48: *Circle diagram of the division of time as derived from the observations.*

Improvements
To optimize the current workflow and reduce the observed Muda, several targeted improvements are proposed across the key phases of the manufacturing process. These improvements are based on both observational data and practical opportunities identified during the research.

Setup phase

Pallets and Plates
A significant amount of time is currently lost during the unstacking and unpacking of pallets and the manual sorting of plates. This process can be streamlined by outsourcing sorting and packing to the plate supplier, Snijtechniek Brabant. Since Akerboom's Engineering department has 3D CAD models of all **items** and their assembly sequence, this information can be shared with the supplier to enable delivery of pre-sorted plates directly on vertical plate racks. This eliminates the need for unpacking and re-sorting on-site and reduces unnecessary handling.

H-beams and Templates
The current method of positioning and welding H-beams and **templates** is labor-intensive and time-consuming. This can be improved by introducing a welding table or clamping platform with a perforated top, which allows for flexible and accurate positioning. Quick-clamping systems can reduce setup time and improve precision. Furthermore, eliminating the use of H-beams altogether is possible if the process is restructured so that the **structure** is welded first, followed by directly attaching the **hull plate** to it. This not only saves time but also reduces material usage.

Hull plate welding

A notable source of Muda during this phase are breaks taken due to the physically demanding nature of **hull plate** welding. While short breaks are essential for maintaining worker health and morale, reducing physical strain can decrease their frequency. Improving ergonomics through a better fixture or assisted welding techniques may reduce fatigue and increase effective working time.

Structure and component welding

In both structue and component welding stages, time is often lost due to searching for tools or waiting for them to be issued by the technical department.

To address this, each welder or workstation can be equipped with a personalized, well-organized tool trolley containing the essential tools required for daily operations. These toolkits can be standardized under supervision from the foreman, while high-value or specialized tools remain under the control of the technical department.

To further streamline tool management, RFID (Radio Frequency Identification) technology can be introduced. Tools equipped with RFID tags can carry information about their type, user, certification status, and location. This system allows for easy tracking and reduces time lost to misplaced or unavailable tools, while also improving accountability.

Post-processing

Post-processing involves several steps that contribute to inefficiency, including grinding the **item** free from **templates**, cleaning welds, compensating for warping, leak testing, and workspace cleanup. These tasks can be minimized through earlier process improvements. For example, if the need to weld the **hull plate** to **templates** is removed by changing the manufacturing method, the grinding and re-leveling steps are reduced or eliminated. Additionally, introducing standardized cleanup routines and improving access to cleaning tools and testing equipment can shorten this final phase.

Lean 5S

The Lean 5S methodology is a structured and systematic approach which aims to create a clean, efficient, and safe work enviroment. This methodolgy is the foundation of Lean and aims to eliminate as much waste as possible. When applied to Akerboom's halls it frees up valuable floor space. The 5S method does this in five steps: Sort, Set in order, Shine, Standardize, Sustain (Harkhoe, 2024).

Figure 49: *Circle diagram of the division of time as derived from the observations.*

1. Sort

To sort between essential and non-essential equipment in the production hall, a timelapse was made (see Appendix P). This timelapse involved taking a photo of the hall in Leiden every morning before 07:00 AM, prior to the start of work. This made it possible to track the usage patterns and movement of equipment over time.

From the timelapse it became clear that some equipment took up unnecessary space while certain equipment was consistently in use and remained in roughly the same location throughout the process, other **items** were frequently stationary and unused, unnecessarily occupying space. Most of the equipment was only relocated when they obstructed the workflow or when extra space was needed. This unused equipment contributes to work inefficiency by cluttering the floor and increasing the risk of tripping.

As a result, a distinction was made between:

- **Core equipment**: equipment that is actively and regularly used in each phase of the process and must remain within arm's reach of the workstation.
- **Peripheral equipment**: **items** that are only needed intermittently or in distinct phases and can therefore be relocated to a storage area when not in use.

Based on this analysis and employee input, the following equipment is identified as essential per workstation:

1. **Hull plate workstation**
- *Welding screens:* to delineate the workstation and protect other employees for welder's flash.
- *Weights:* to keep large aluminum **hull plates** in position during alignment and tack welding.
- *Buggy:* to weld the **hull plates** together.

2. **Additional component workstation**
- *Welding screens:* to delineate the workstation and protect other employees for welder's flash.
- *Trestles:* to provide flexible support and temporary fixture options for smaller components or assemblies
- *Machines:* to process materials.

3. **Welding workstation**
- *Welding screens:* to delineate the workstation and protect other employees for welder's flash.
- *Computer:* to view drawings.

All other equipment can be put in storage as it less frequently needed.

Moreover, through conservations with employees the most necessary tools were identified. These tools are used on a daily basis and should therefore be part of the standard equipment. To create a clear overview, the tools are grouped by workstation. The necessary tools summarized in the table below.

Table 3: *Overview of the used tools per workstation.*

Tools	Hull plate	Component	Welding
Welding cart	X	X	X
Grinder	X	X	X
Router	X	X	
Measuring tools	X	X	X
Clamping tools		X	X
Pliers			X
Rubber hammer			X
Iron hammer			X
Steel brush	X	X	X

2. Set in order

Once the essential **items** have been sorted from the non-essential ones, the next step is to organize the workspace to ensure that every tool and piece of equipment has a designated, logical location.This eliminates time wasted searching for **items**, reduces the risk of misplacement, and creates a more professional and controlled work environment. A preliminary lay-out will be proposed in the next section.

For the unnecessary or infrequently used equipment, a dedicated storage zone must be created within the production hall. This storage area should be:

- Clearly labeled, with visual cues such as signage or floor markings.
- Easily accessible, so workers can quickly retrieve or return **items** when needed without disrupting workflow.
- Organized by category or function, for example, separating welding-related tools from general mechanical or lifting equipment.

In addition, commonly used tools at each workstation should be stored in an intuitive layout that reflects their frequency of use. For instance, heavier or larger tools should be placed at waist height to reduce strain, while smaller tools can be grouped in tool shadow boards or mobile carts with outlined positions to promote consistent return and visibility.

3. Shine

In the current situation, cleaning is often left until the end of the week or even project, leading to a gradual buildup of shavings, scrap, and misplaced tools. In the new workflow, cleaning becomes part of the daily workflow. Each station includes access to a vacuum cleaner and cleaning supplies, and a simple end-of-day checklist ensures that surfaces, tools, and walkways are regularly cleaned.

Welding screens help to create a demarcated workzone where tools and equipment should not leave that zone.

4. Standardize

To ensure consistency across all workstations, standardised lay-outs are developed and documented. These include visual guides showing tool positions on the trolleys, cleaning responsibilities, and station-specific setup procedures. For example, all vertical plate racks follow the same organisation logic, sorted by process step and project. Visual management tools such as laminated posters, colour-coded zones, and labels support these standards. This allows welders to easily adapt between stations and ensures quality is not dependent on individual habits.

5. Sustain

Sustaining 5S requires discipline, but also simplicity and ownership. In the new concept, a weekly 5S checklist should be introduced for the foreman to assess workstation compliance. Additionally, welders are involved in defining which tools belong at their station and how to improve the layout over time. RFID technology could be introduced to improve tool tracking and support accountability.

Concept

This chapter presents the final design concept, which brings together the insights gained throughout the research, analysis, and ideation phases of this project. The concept is structured into three components:

1. A preliminary layout for the hall in Katwijk, incorporating space allocation for storage and the flow of goods.
2. Detailed layouts of three workstations, one for each key process, each including the proposed fixture, along with the necessary tools and equipment.
3. A technical description of the fixtures supported by technical drawings and an explanation of their working principles.

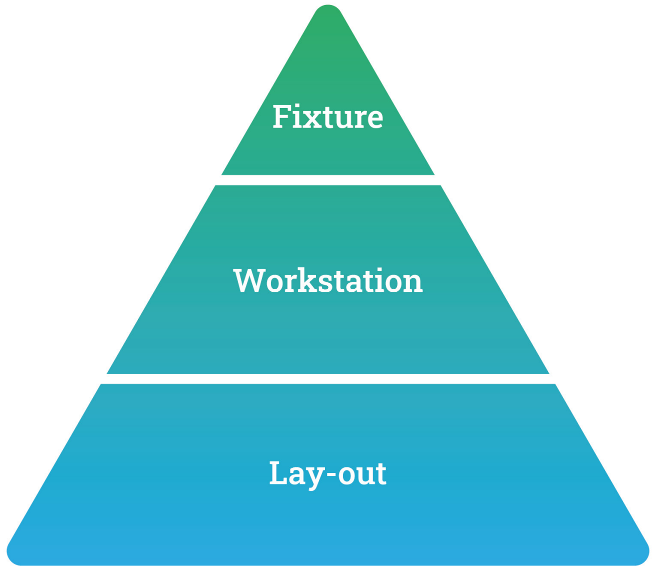


Figure 50. *Pyramid showing the order of integration of the concept.*

Lay-out

After multiple iterations with feedback from Akerboom's stakeholders (see Appendix Q), a final concept for the lay-out of the hall in Katwijk was made (see Figure 51).

The lay-out consists of multiple workstations, each for one step in the manufacturing process:

- One workstation for welding the **hull plate**.
- One workstation for welding the additional components and machinery.
- Four workstations for medium **items**.
- Six workstations for small **items**.

The flow of incoming (green) and outgoing (yellow) goods has been divided into two separate streams: one for medium-sized **items** requiring **hull plate** welding, and one for smaller **items** whose hull consists of a single plate.

For medium **items**, materials enter the hall from the left. As previously described, these materials are pre-sorted by process step and assigned workstation: **girders** are delivered in plate racks and **hull plate** and mouldings on pallets. The pallet with **hull plates** is delivered to the **hull plate** workstation, the pallet with additional components goes to its designated station, and the plate racks are positioned at the welding stations.

Once the **hull plate** is welded, it is either placed in temporary storage until needed (orange), or transferred directly to the next workstation where it can be welded onto the **structure** (blue). This same process applies to additional components.

Figure 52: *Vertical extendable plate storage.*

Figure 53: *Stackable pallet racks.*

Storage

As illustrated in Figure 51, the layout includes two primary types of storage: plate storage and pallet storage. To ensure the concept is complete and practically implementable, proposals are made for both storage types.

For plate storage and the storage of the welded **hull plates**, vertical plate racks are proposed (see Figure 52). Akerboom currently uses smaller, self-fabricated racks of a similar design. However, these racks are not certified, despite certification being legally required. To reduce costs, Akerboom could fabricate the larger plate racks needed for the medium workstations in-house, as they have done previously, provided that the new racks are officially certified before being put into use.

For the storage of pallets, two solutions are proposed. To store big pallets (2x6 meter) cantilever racks can be used. These racks have enough load capacity to carry the big pallets and forklifts can easily take them out.

For smaller pallets, a flexible storage solution is proposed. Figure 53 shows stackable racks offer sufficient capacity to store pallets and other materials, while also allowing for adaptability based on demand. When less storage space is needed, these racks can be easily disassembled or removed, freeing up valuable floor space in the hall and enabling greater layout flexibility.

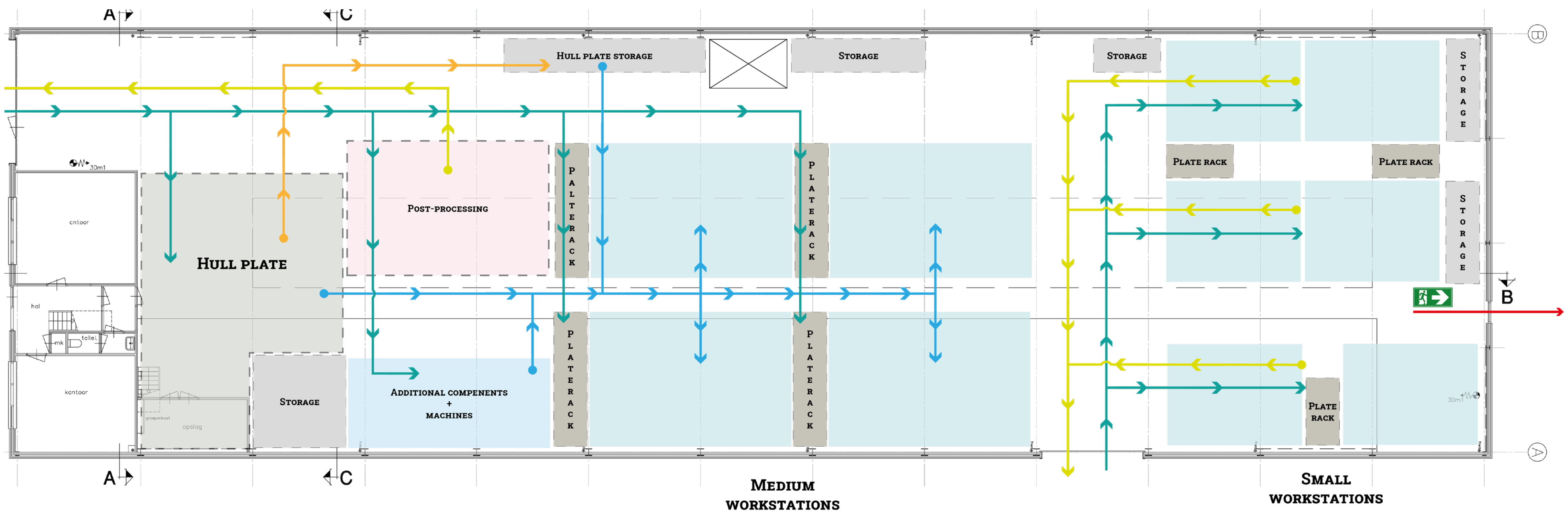
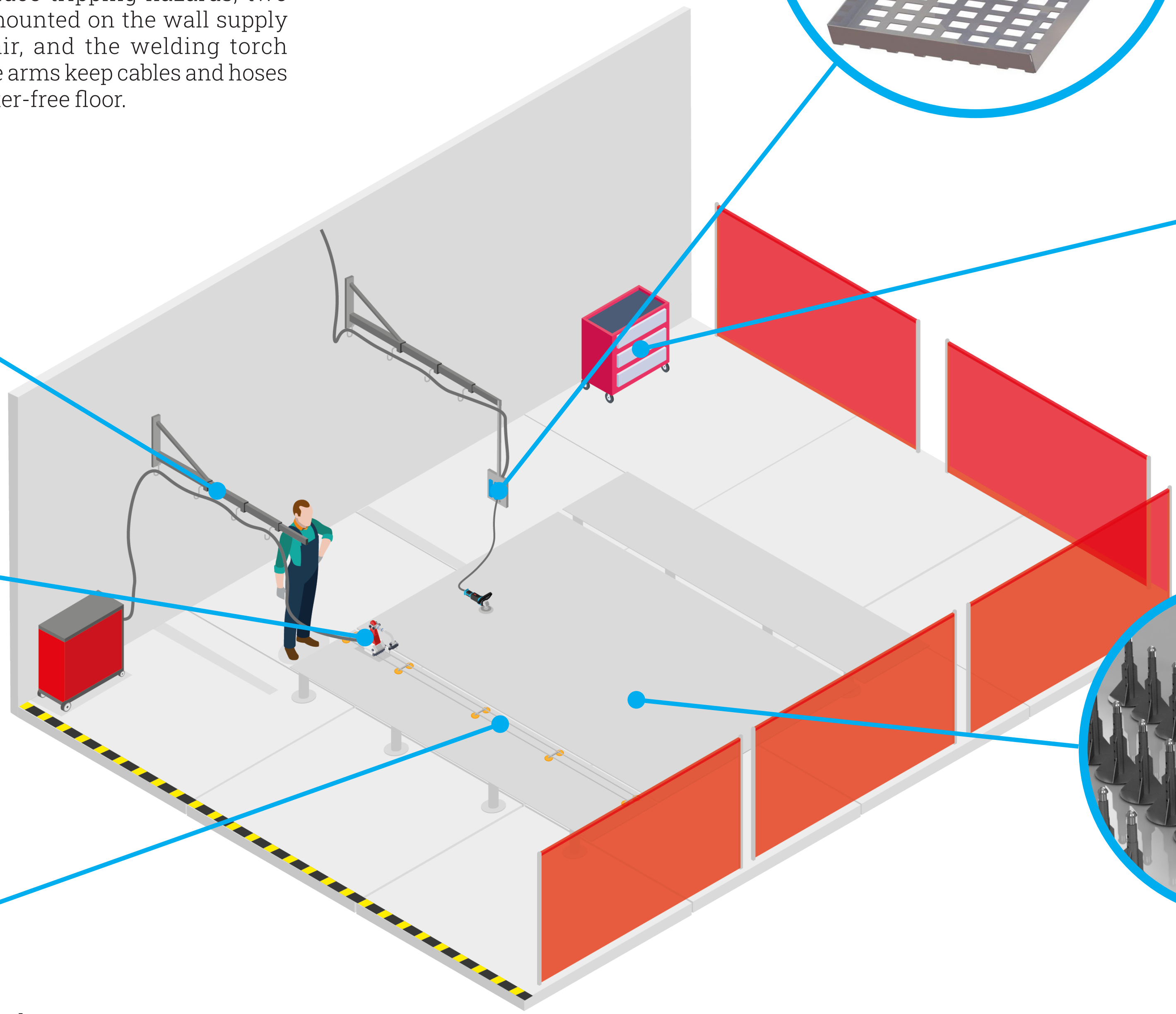


Figure 51: *Proposed layout of the hall in Katwijk.*

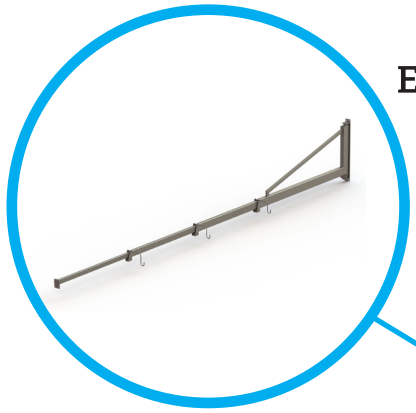
Workstation one: hull plate

The first workstation is designed for the welding of the **hull plate**. The workstation covers an area of 9 x 8 meter (72m²) which is large enough to weld two **hull plates** of medium **items**, simultaneously.



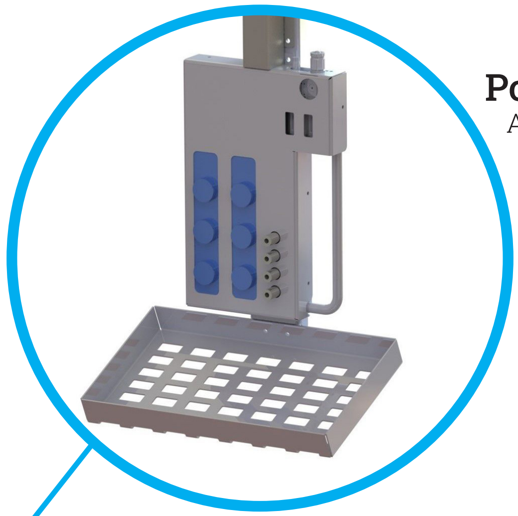
Extendable-folding arm

To improve safety and reduce tripping hazards, two extendable folding arms mounted on the wall supply electricity, compressed air, and the welding torch directly to the fixture. These arms keep cables and hoses suspended, ensuring a clutter-free floor.



Powerbox

At the end of one of the extendable swing arm, a powerbox is mounted, providing convenient access to electricity and compressed air for the welder. Additionally, it includes an integrated tray where tools can be placed for easy access during work.

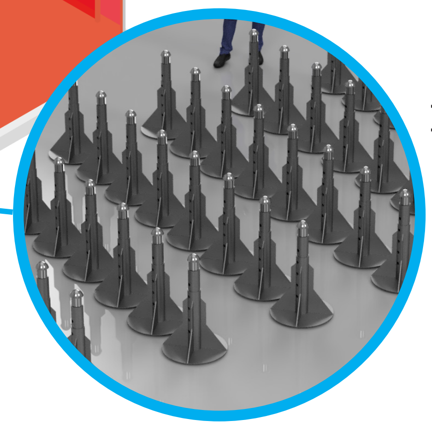


Tool trolley

This tool trolley contains all frequently used tools required for welding and preparing additional components, as identified in the previous chapter. Specialized or less commonly used tools are centrally stored, recorded, and must be checked out through the technical department to ensure proper tracking and minimize the risk of loss or misplacement.

Welding buggy

This welding buggy serves as a modern replacement for the outdated model currently in use. It delivers consistently high-quality welds and, when combined with the vacuum rail system, eliminates the need for manual repositioning, which significantly improves ergonomics.



Pin jig fixture

To support the manufacturing of all types and sizes of hull plates a fixture in the form of pin jigs is proposed. This fixture is highlighted on the next page.

Vacuum rail system

The vacuum rail system is designed to securely clamp onto non-ferrous metals, like the aluminum hull plates. Furthermore, using suction rather than mechanical fasteners, the system ensures firm and uniform attachment without damaging the surface of the material. This method not only speeds up the process but also allows for smooth, precise movement of the welding buggy along the weld seam, improving both efficiency and weld consistency.

Figure 54: *Overview of workstation one.*

Costs

The primary cost driver for this workstation is the welding buggy equipped with a vacuum rail system. However, Akerboom has allocated a separate budget for the welding buggy as they were already planning on renewing the old one. The other big cost for this workstation is the fixture (€6,720, see next page).

In addition, two extendable arms (€895 each) and a powerbox (€950) are required.

The total estimated cost for this workstation is **€9,460**.

Fixture - hull plate

The fixture for the **hull plate** consists of 64 (8x8) individually adjustable jigs. Together, these jigs can support and enable the manufacturing of all types of **hull plates** with a maximum size of 8000x4000mm.

This fixture obviates the current procedure for kinked **hull plates** by offering flexible support and it enables a more ergonomic work environment.

Figure 55: *Overview of the fixture for the hull plates.*

A pin jig is an already existing way to support curved panels and is currently used in very few shipbuilding companies. The design of the proposed fixture is based on images of existing pin jigs as no documentation is available.

This pin jig is height-adjustable, allowing them to accommodate the varying curvatures of different **hull plates**. The main column can be set at fixed intervals between 600 mm and 900 mm, with adjustment holes for locking pins, spaced every 100 mm along the base. This spacing enables fast and repeatable setup for different **hull plate** shapes. These heights were chosen with ideal working heights in mind while also allowing the welder to reach the welding buggy during setup. Additionally, the jig head includes a fine-adjustment thread offering an extra 100 mm of vertical travel, ensuring precise alignment of the plates.

The structural fins and wide base of the jig provide stability during use, ensuring the jigs remain upright even when subjected to moderate side loads or during repositioning.

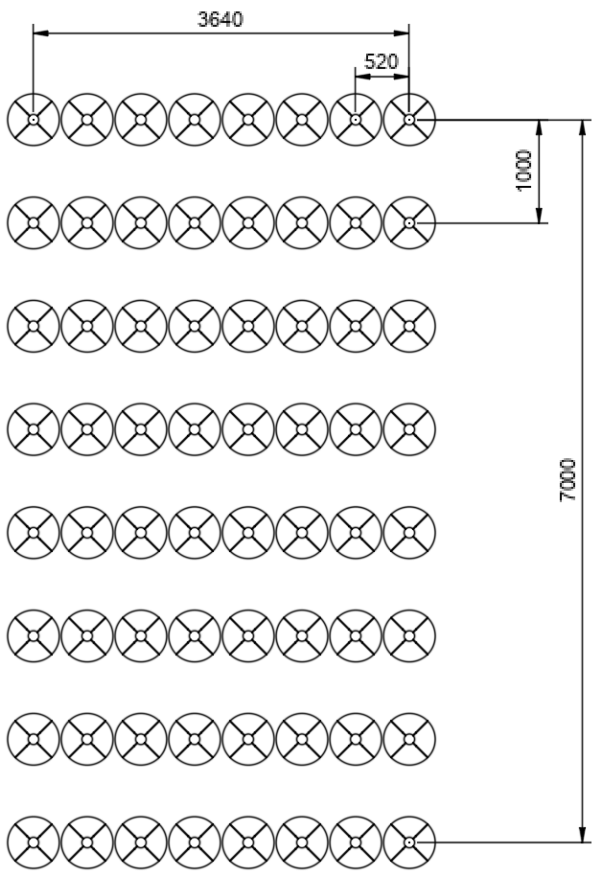


Figure 56: *Top view of the pin jigs.*

The pin jigs are arranged in an 8 by 8 grid configuration, with a spacing of 1,000 mm along the length and 520 mm across its width. This layout ensures full support of the **hull plate** while minimizing the number of jigs required. Since **hull plates** typically only curves along their width rather than their length, closer spacing widthwise is necessary

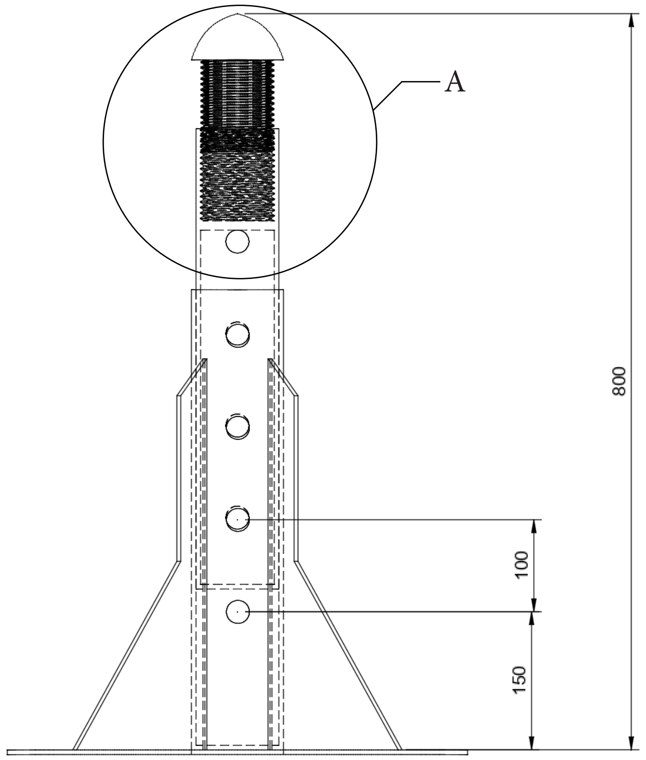


Figure 57: *Technical drawing of the pin jig.*

Detail A - Head of the pin jig

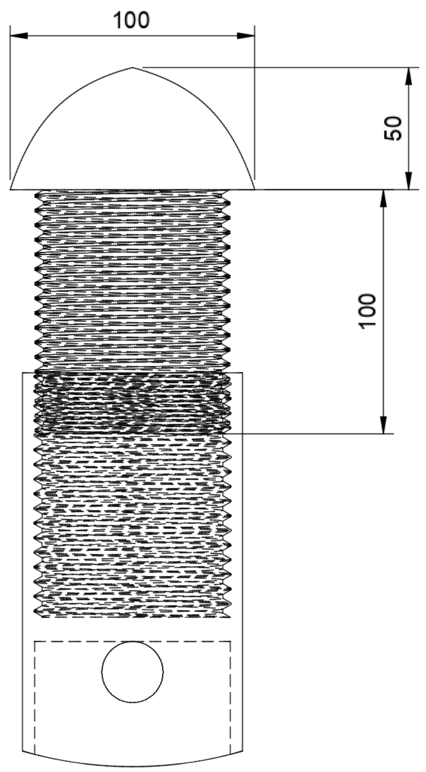


Figure 68: *Technical detail of the head of the pin jig.*

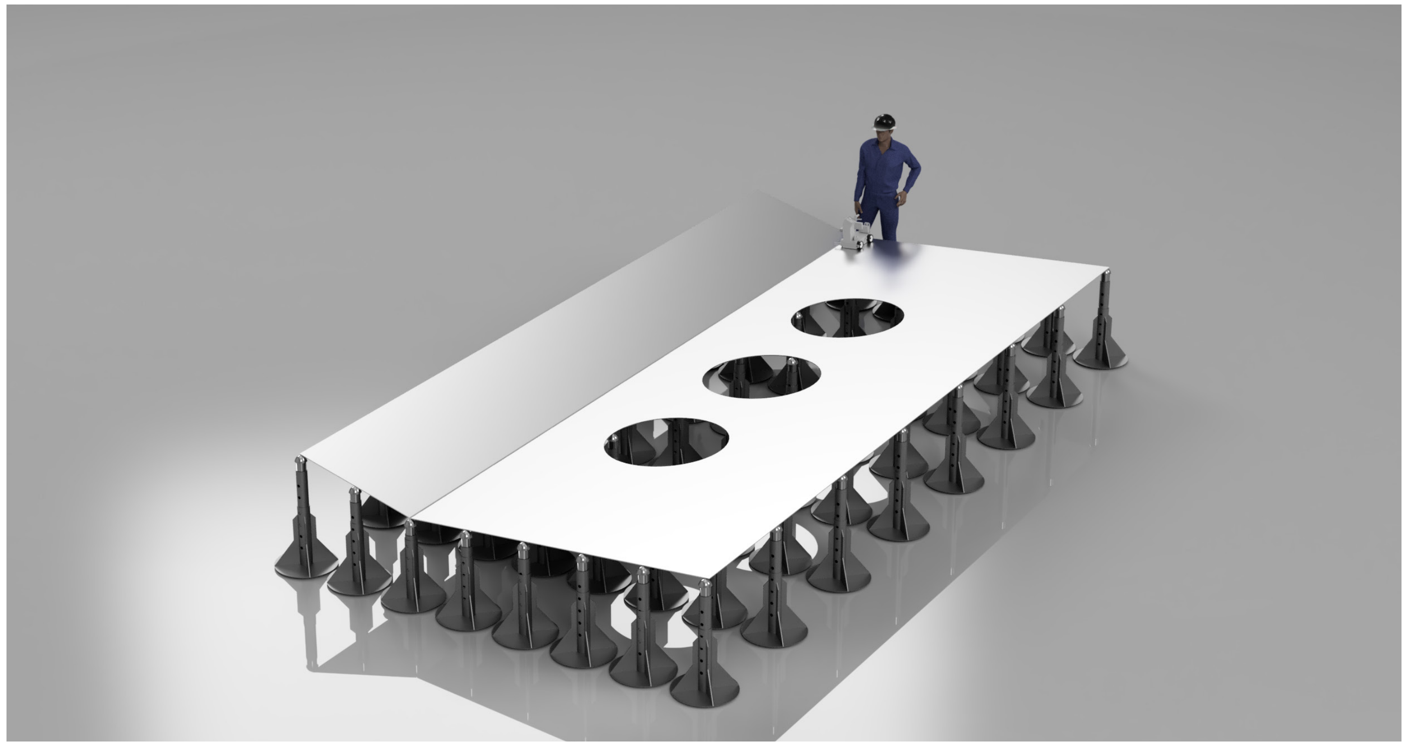


Figure 69: *The pin jig with two hull plates laid on it, ready to be welded by the welding buggy.*

Modularity

The fixture has been designed to support full modularity, enabling it to adapt to a variety of **item** sizes and geometries. This is achieved through the use of independent pin jigs, which can be freely added or removed depending on the required configuration. Since there is no fixed base, the layout of jigs can be scaled or rearranged to match the dimensions of the **hull plate**. This allows the fixture to be reused across different projects without the need for custom tooling or modification. The modular nature of the system also facilitates easier storage, maintenance, and potential future upgrades, making it a flexible and long-term solution.

Cost Estimation

As pin jig fixtures are uncommon and little pricing information is available from suppliers, the total cost has been estimated based on material and labour costs.

Material costs

Using Fusion 360, the total weight of a single pin jig was calculated to be approximately 25 kg. Assuming the jig is constructed from steel, and using a steel price of €1.10 per kilogram (based on data from Granta EduPack), the estimated material cost per jig is:

- 25 kg × €1.10/kg = **€27.50**

Labour costs

It is estimated that the fabrication of one jig would take approximately 1.5 hours, at an hourly labour rate of €40. This results in:

- 1.5 hours × €40/hour = **€60.00**

Total cost per jig

Combining material and labour yields a total cost per jig of:

- €27.50 (material) + €60.00 (labour) = **€87.50**

Total cost for complete fixture

For a full configuration consisting of 64 pin jigs, the base cost amounts to:

64 × €87.50 = **€5,600**

To account for possible cost deviations in material, fabrication complexity, or shipping, a 20% contingency is applied:

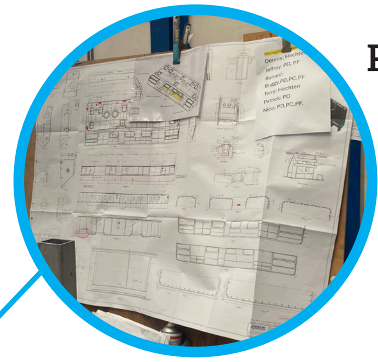
- €5,600 × 1.20 = **€6,720**

Workstation two: pre-processing

The second workstation is dedicated to pre-processing, which consists of welding additional components and preparing other materials.Typical tasks performed at this station include welding parts such as portholes or scepter pots, and cutting plates with overlength to the required length. The setup is designed to support flexible, task-specific work without interfering with the main assembly flow.

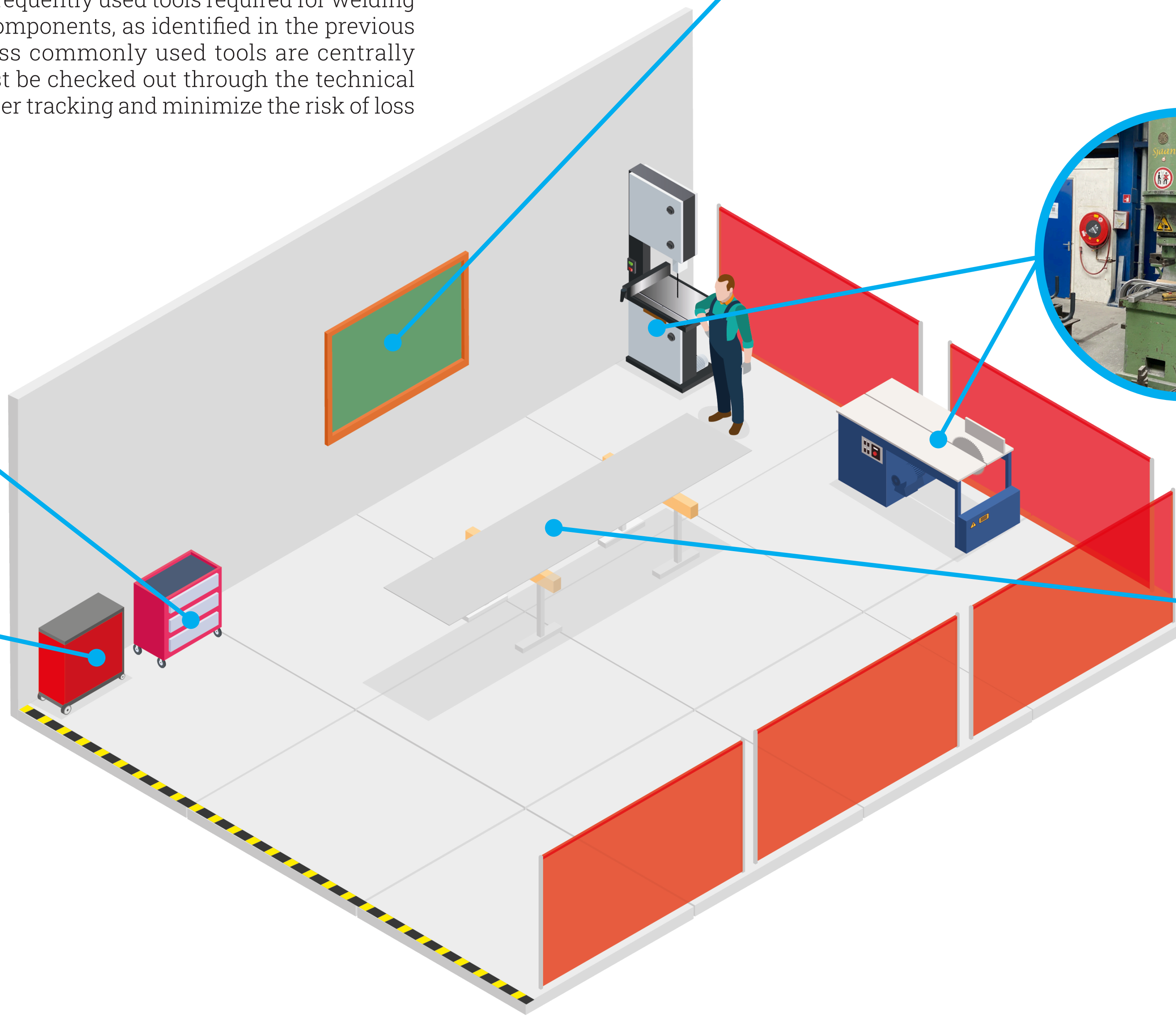
Tool trolley

This tool trolley contains all frequently used tools required for welding and preparing additional components, as identified in the previous chapter. Specialized or less commonly used tools are centrally stored, recorded, and must be checked out through the technical department to ensure proper tracking and minimize the risk of loss or misplacement.



Pin-board

A pin-board mounted on the wall serves as a practical and easily accessible display area for all essential drawings required during this phase of the manufacturing process. This setup allows the welders to quickly reference up-to-date plans.



Machinery

This workstation is equipped with essential machinery, including a bandsaw and a table saw, which are used to cut, trim, and adjust materials to the required dimensions. These tools play a critical role in the early stages of the process, ensuring that components are accurately sized before welding or assembly begins.

Welding cart

The welding cart is a core piece of equipment at the workstation, providing each welder with immediate access to welding tools and supplies. Each workstation is equipped with one welding cart per welder, while additional units are kept in storage and can be deployed as needed to support other tasks or replace damaged equipment. No extendable arm is used in this workstation to allow for more flexibility and scalability when needed.

Trestles

Trestles are used as temporary fixtures to support workpieces during welding and pre-processing. When not in use, they can be easily stored to free up floor space, especially if foldable models are used. Additionally, Akerboom's existing welding tables, which are outdated, can be repurposed as small workbenches for supporting tools, drawings, or lighter assembly tasks. This approach not only saves costs but also promotes efficient use of available resources within the hall.

Figure 59: *Overview of workstation two.*

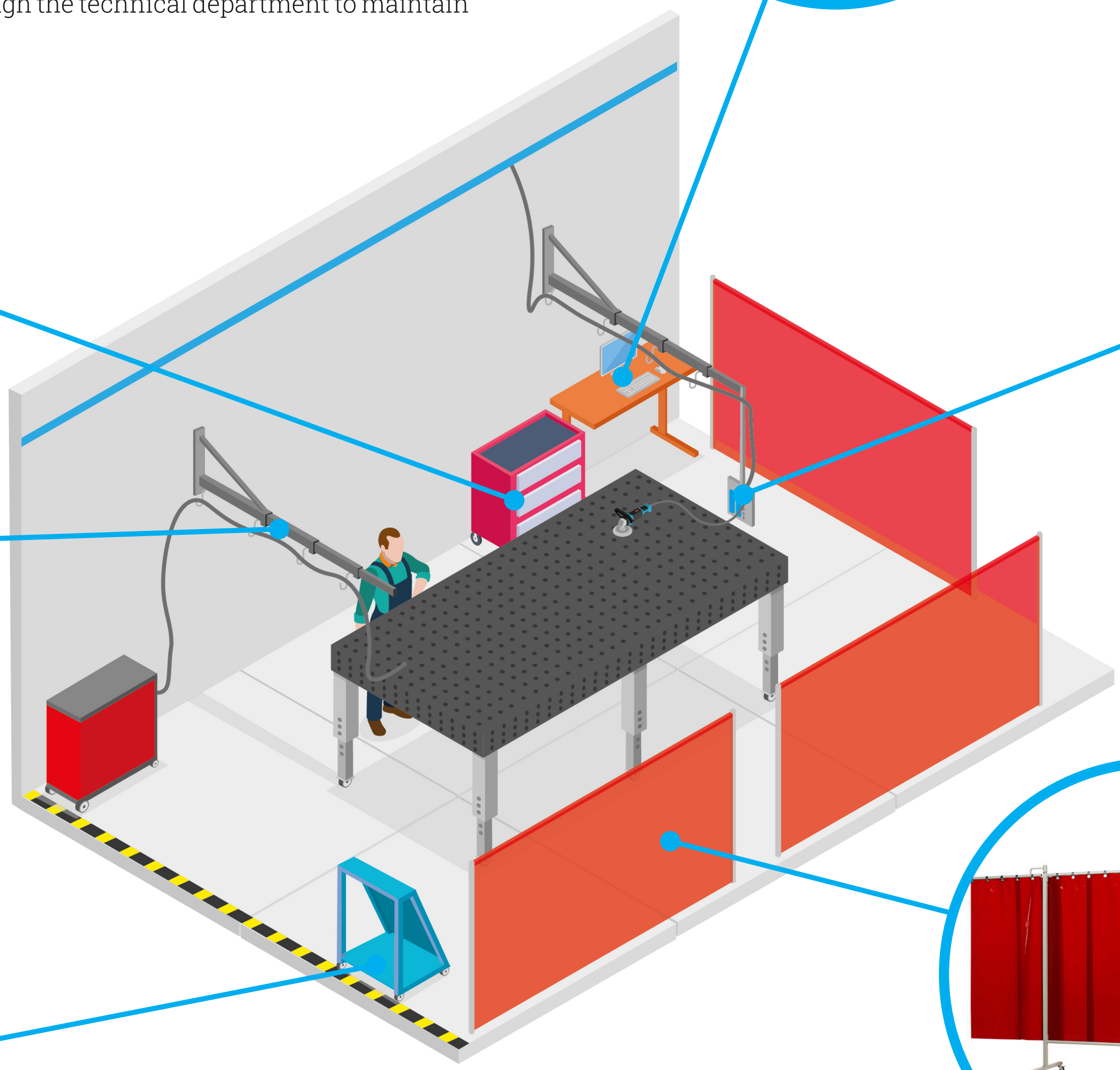
Costs

All equipment and tools required for this workstation are already available at Akerboom, meaning no additional investment is necessary. However, to optimize space usage, Akerboom could consider investing in foldable **trestles**, which can be stored compactly when not in use. These **trestles** are priced at approximately €120 per pair.

As it stands, the total cost for this workstation is **€0**.

Workstation three: structure

The second workstation is designed for the welding the **structure** and welding together the **hull plate**, **structure** and **closure plate**. This figure illustrates the layout of this workstation for a small **item**.



Tool trolley

Each welder is also assigned a personal tool trolley stocked with the most frequently used tools, as identified in the previous chapter. This reduces time spent searching for equipment and supports a standardized way of working. Less commonly used tools are centrally stored, registered, and must be checked out through the technical department to maintain oversight and prevent loss.

Desk & computer

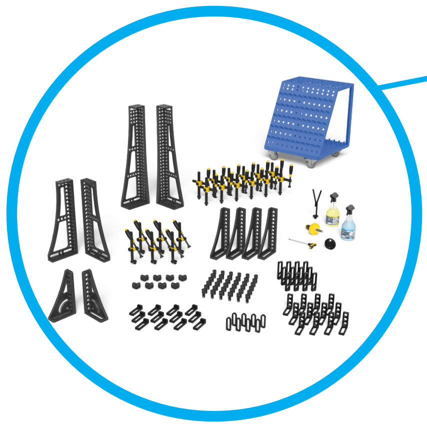
A standing desk equipped with a computer (or thin client) running OnePush is positioned within the station, enabling welders to quickly access technical drawings and verify details during the welding process without leaving the work area, eleminating unnecessary movement through the hall.

Extendable-folding arm

To improve safety and reduce tripping hazards, two extendable folding arms mounted on the wall supply electricity, compressed air, and the welding torch directly to the fixture. These arms keep cables and hoses suspended, ensuring a clutter-free floor.

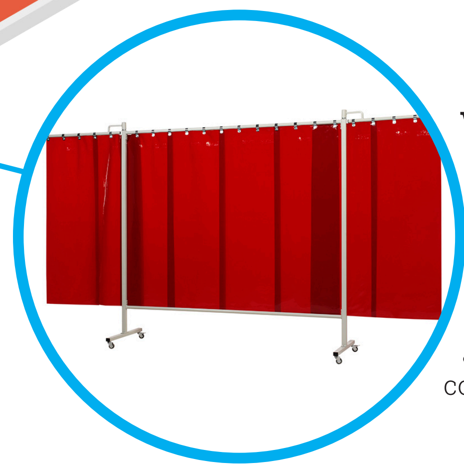
Powerbox

At the end of the extendable swing arm, a powerbox is mounted, providing convenient access to electricity and compressed air for the welder. Additionally, it includes an integrated tray where tools can be placed for easy access during work.



Clamping tools

To clamp the hull plate and templates multiple clamping tools are provided. These tools are stored on a small cart which offers



Welding screens

The workstation is enclosed by welding screens, which define the working area in combination with floor markings. While the screens are movable when needed, they primarily serve as permanent dividers between adjacent workstations, helping to prevent welder's flash due to UV exposure while also minimizing distractions, contributing to better concentration and weld quality during work.

Costs

Most of the required components for this workstation, such as the welding screens, tool trolleys (with tools), thin client, monitor, and welding machines, are already owned by Akerboom. Only a few additional **items** need to be purchased, including clamping tools (€4,293), two extendable arms (€895 each), a powerbox (€950), a desk (€150), and the fixture (€6,254 - see next page).

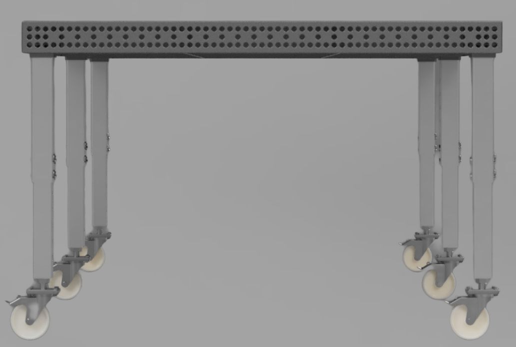
This brings the total cost for a small workstation to **€13,384**.

Figure 60: *Overview of workstation three.*

Fixture - small items

The proposed fixture is a height-adjustable welding table designed for small to small-medium **items**. It features a 3 × 1.5 meter perforated steel top, allowing for flexible clamping of the **girders** and **structure**. The legs are manually adjustable between 700 and 1000 mm working height and are mounted on lockable caster wheels with integrated fine-leveling, ensuring stability on uneven floors. With a load capacity well above the maximum **item** weight, the fixture supports safe, ergonomic, and efficient welding operations.

Justification and alternatives for this fixture can be found in Appendix R.



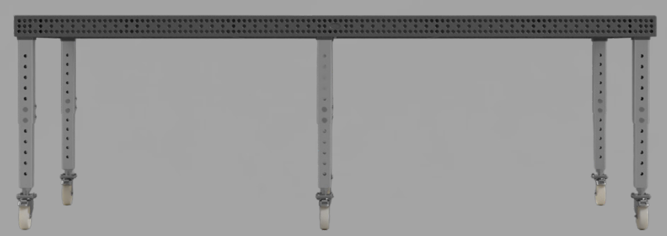


Figure 61: *Overview of the fixture for small workstations.*

The fixture consists of a 3 × 1.5 meter welding top mounted on height-adjustable legs. The tabletop features a standard grid of holes (Ø 16 mm), enabling flexible clamping configurations for the **girders** and **structure**. This adaptability supports repeatability while also accommodating varying **item** sizes and geometries. Moreover, the top is nitrate treated which ensure increased hardness and better protection against weld spatters.

The legs can be manually set at heights ranging from 600 mm to 900 mm in 50 mm increments. With the 100 mm thick tabletop included, the total working height ranges from 700 mm to 1000 mm. Manual adjustment was selected over electronic alternatives due to cost-efficiency and ease of maintenance, without compromising ergonomic functionality for the welders.

Each leg and wheel assembly is rated to carry 500 kg. The welding top itself weighs 716 kg, leaving a safe load margin of 1142 kg under a safety factor of 2. As established in the research phase, the maximum weight of a small **item** is approximately 500 kg, well within the system's load capacity.

For added mobility, the fixture is equipped with caster wheels (Ø 125 mm) with integrated brakes. These allow the table to be repositioned when needed, for example, during reconfiguration or cleaning, while ensuring stability during use. The wheels also feature a fine-leveling mechanism with 20 mm of adjustability, allowing the table to be stabilized on uneven floor surfaces such as **Stelcon slabs**. This improves both safety and operator posture.

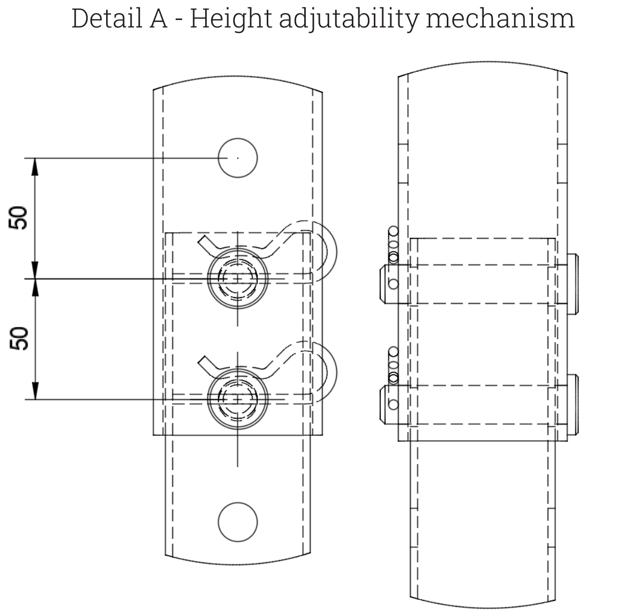


Figure 62: *Detail of manual-height-adjustable legs.*

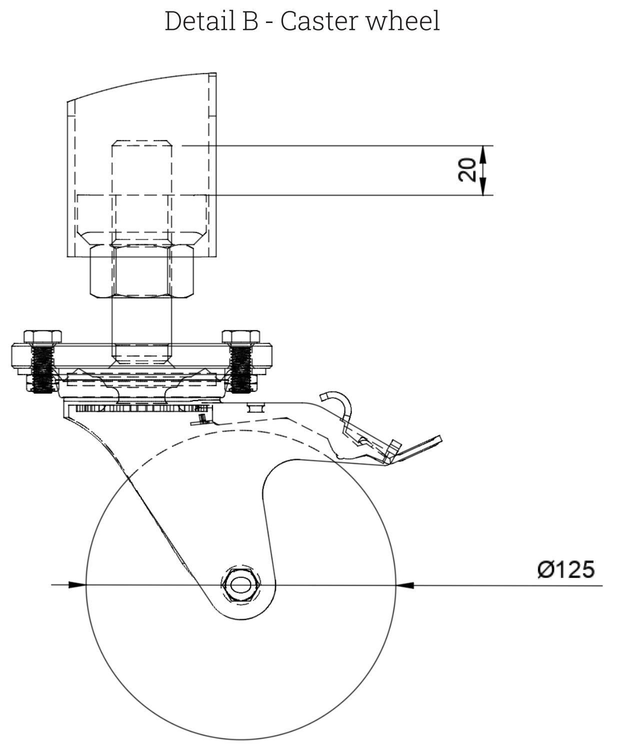


Figure 63: *Detail of the caster wheels.*

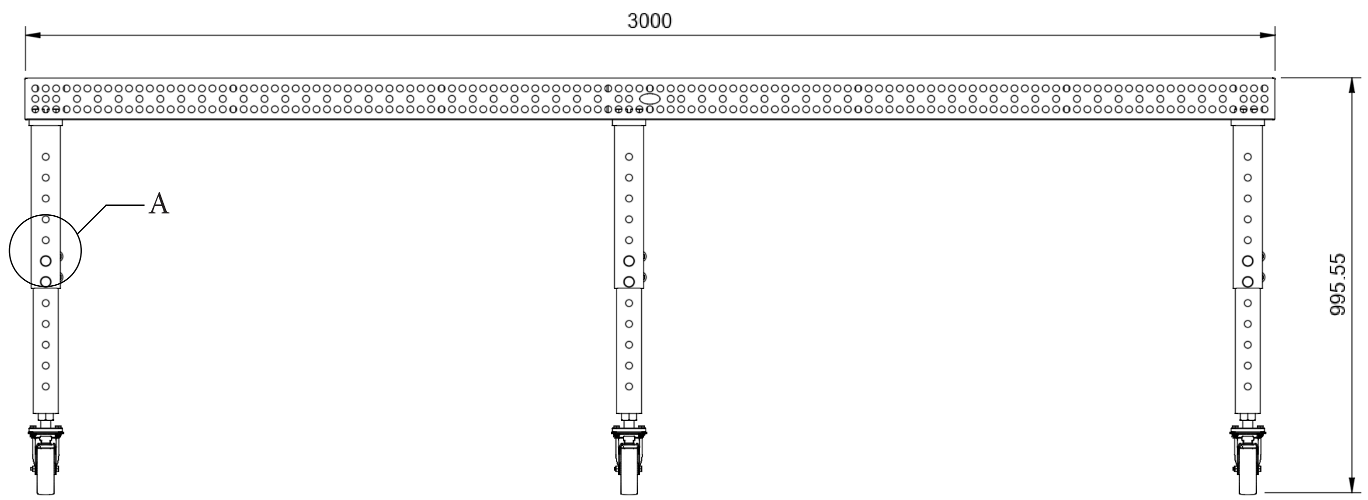


Figure 64: *Technical front-view of the fixture.*

Modularity
To introduce modularity into this fixture, multiple tables can be connected with connection bolts (see Figure 61) to form a larger working surface. This approach aligns with the previously described semi-modular concept, in which a standardized base unit can be extended to accommodate varying sizes and geometries.

Costs
The costs for the proposed fixture can be broken down in the following components:

- Top: €5,324
- Legs + wheels: 6x €155 = €930

Combined, this brings the total cost of the fixture to €6,254.

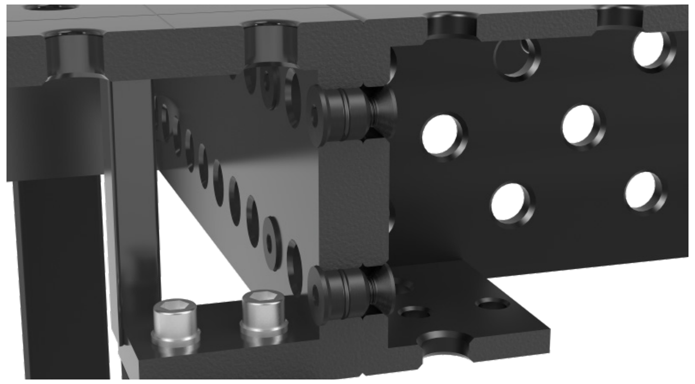


Figure 65: *Example of connections bolts joining two tables together.*

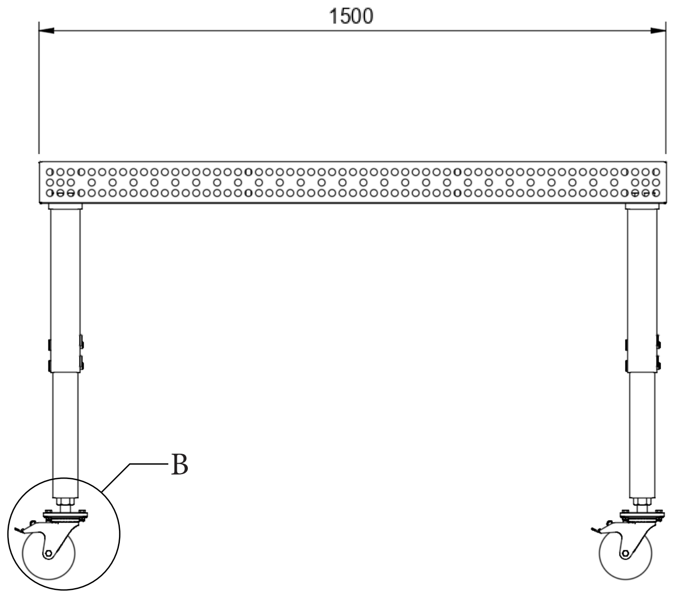


Figure 66: *Technical side-view of the fixture.*

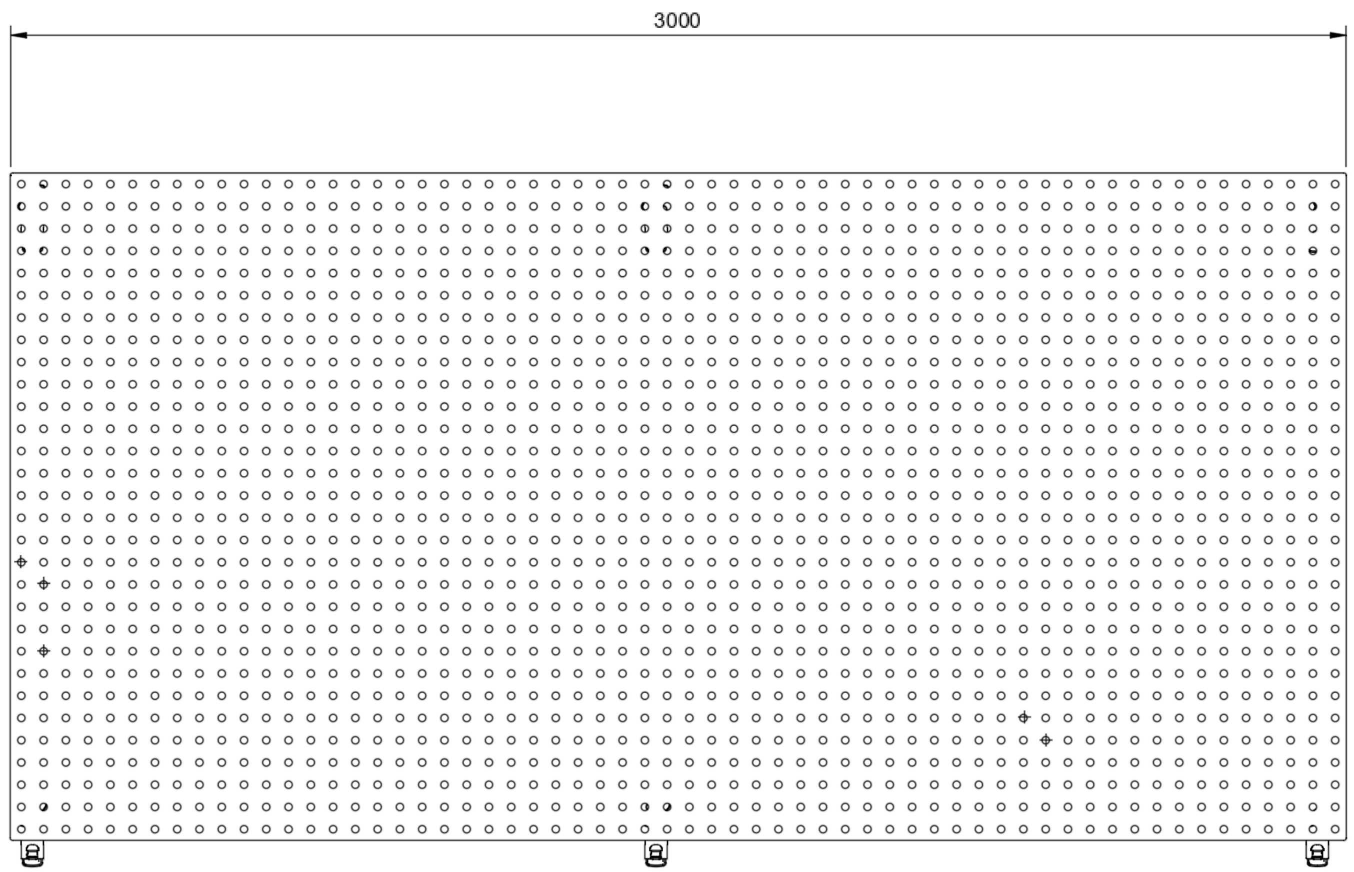


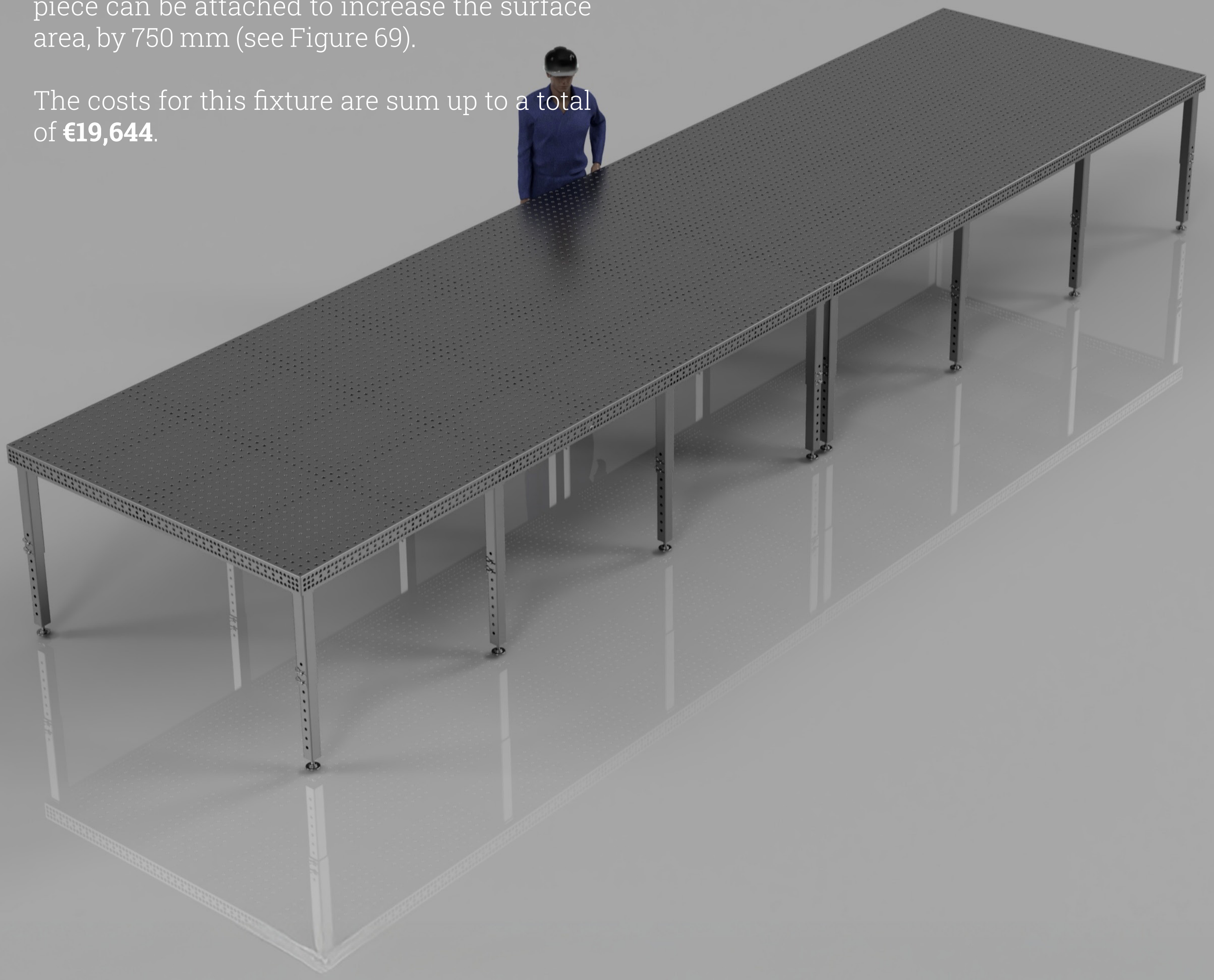
Figure 67: *Technical top-view of the fixture.*

Fixture - medium items

For medium-sized **items**, the fixture follows the same principle as the one designed for small **items**, with key differences in scale and support **structure**. This fixture consists of two 4 × 2 meter welding tables joined together, forming a single continuous work surface measuring 8 × 2 meters. Like the smaller version, the legs are height-adjustable (650 - 1050 mm) to support ergonomic working conditions. However, in this case, the legs do not include wheels, as wheeled supports would not provide sufficient strength to safely carry the heavier loads associated with medium-sized **items**.

Thanks to its modular composition, the fixture allows for multiple configurations depending on the size and geometry of the **item**. If these configurations are not sufficient, an extension piece can be attached to increase the surface area, by 750 mm (see Figure 69).

The costs for this fixture are sum up to a total of **€19,644**.



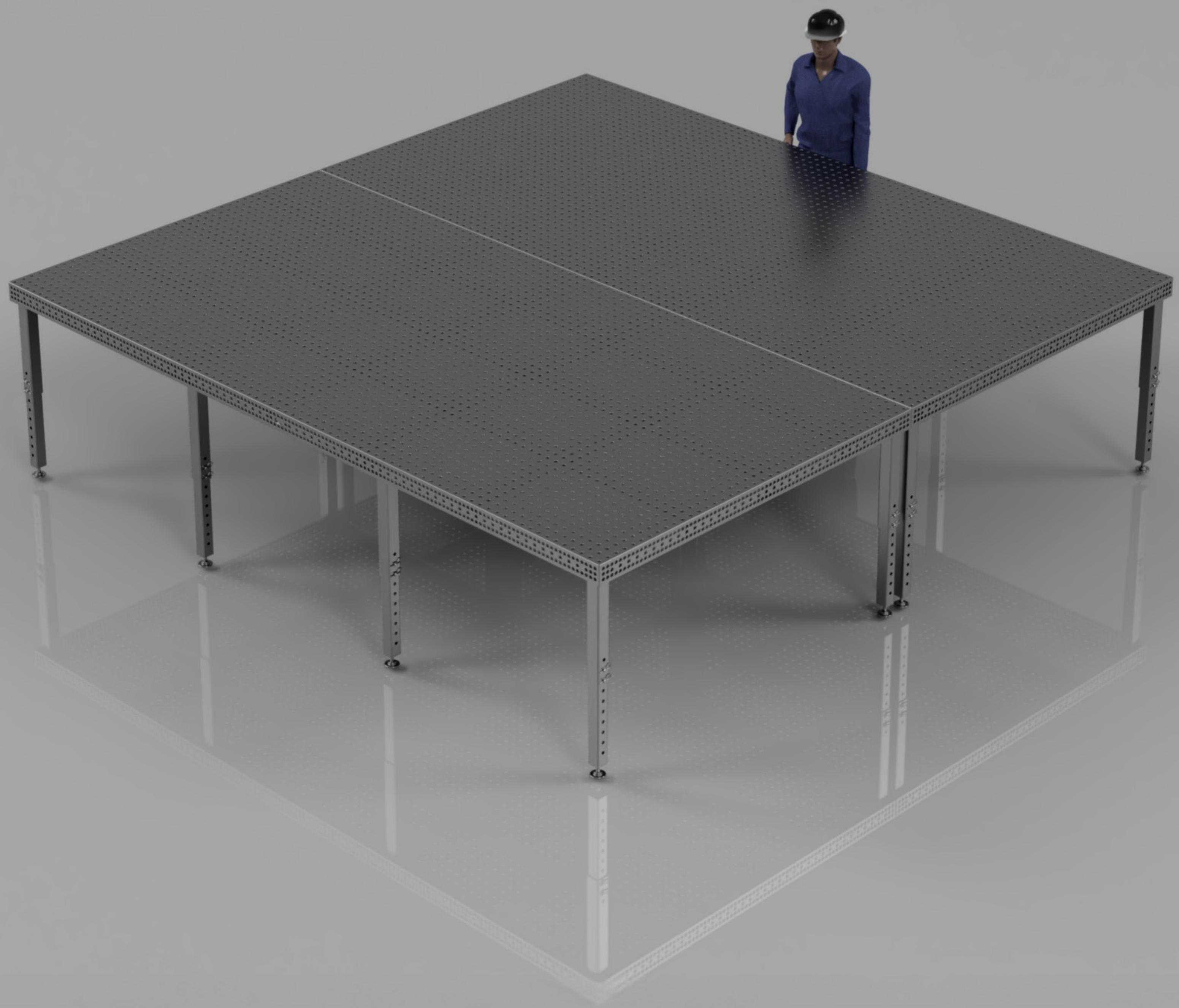


Figure 68: *Overview of the fixture for medium workstations.*

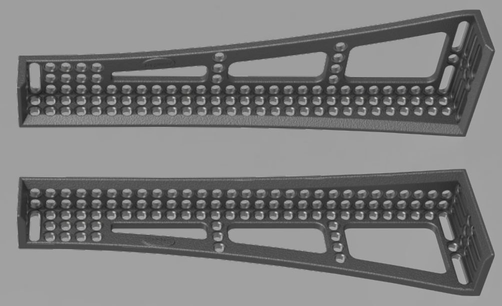


Figure 69: *Example of an extension piece.*

Implementation

To facilitate a seamless transition from the current workflow to the proposed one, the implementation should be carried out in phased stages. It begins with small, manageable changes and improvements, progressively introducing additional modifications until the new workflow is fully adopted and operational.

Phase 1: Configuring

First, as much floor space as possible is cleared by removing obsolete storage, materials, equipment, machines, and other unnecessary **items** from the hall. Next, all tools and equipment are sorted following the Lean 5S results earlier mentioned in this report, and the hall is cleaned. Once the space is cleared and cleaned, work zones and workstations are marked out using floor tape and welding screens. Finally, the appropriate equipment and fixtures are placed in their designated workstations.

Following this initial phase, the layout can be reviewed once more by stakeholders to assess its effectiveness, allowing for any final adjustments to be made. Once the physical layout is finalized and validated, the focus shifts from spatial organization to operational performance.

Phase 2: Test Run

Once any final minor adjustments have been made and implemented, the first test run can begin. It is essential at this stage that the welders, foreman, and all other involved personnel are fully familiar with the new manufacturin method and workflow and clearly understand their roles and responsibilities. To ensure this, a training day can be organized.

The test run begins with a carefully coordinated planning session involving the foreman and planners. For this trial, a small and simple **item** will be manufactured. Ideally, the **item** should be small yet large enough to require welding of the **hull plate**, ensuring that the interaction between different workstations can be effectively tested.

As in the initial phase, this test run is followed by an evaluation. Based on observations and feedback, necessary adjustments are made to the manufacturing mehod before moving on to the next phase.

Phase 3: Further Testing

After the initial test run is completed and adjustments have been made to the workflow, the next phase of testing can begin. This phase involves the gradual introducing more complex and larger **items** to further validate and refine the new layout and processes.

In this stage, a broader range of **items** is manufactured, starting with moderately complex **items** and gradually moving toward larger and more intricate ones. These **items** present increased demands in terms of coordination between workstations, tool usage, material handling, and planning. This allows for a more thorough evaluation of the manufacturing method under realistic production conditions and reveals whether the layout can handle variability in product type and scale.

Throughout this extended testing phase, regular feedback is gathered from welders and the foreman to monitor how well the new manufacturing method supports efficiency, communication, and ergonomics. Any recurring issues, inefficiencies, or safety concerns can then be addressed incrementally before full-scale implementation.

Phase 4: Full Implementation

After completing all testing phases, the new manufacturing method can be fully implemented. Once it is well established and proven effective, it can be replicated in the halls in Leiden to create a standardized approach across all of Akerboom's facilities.

However, implementation is not the final step. Development remains ongoing, with continuous iteration and improvements being made as production continues under the new manufacturing method. This ensures that the process remains adaptable, efficient, and aligned with evolving needs and insights from daily operations.

Figure 70: *One of Akerboom's welders using a grinder on an item.*

5

Evaluation

After the concept has been developed, it must be thoroughly evaluated. This chapter outlines the various steps taken to assess the proposed concept.

Stakeholder evaluation

The first phase of the evaluation focused on gathering qualitative feedback from key stakeholders. The proposed concept was presented using the floor plan, detailed illustrations, and CAD models, after which feedback was collected regarding its feasibility, desirability, and viability. The stakeholders that are consoledated for evaluation are:

- Quality control team
- CEO
- Foremen
- Production manager

Their feedback is summarized in this chapter.

CEO

During a meeting with the CEO, several concerns were raised regarding the concept.

First, initially, a pin jig was proposed to accommodate the kink in certain **hull plates**. However, since the kink follows a relatively simple geometry and support is only needed in that specific area, a full pin jig, designed for a wide variety of plate shapes, may be unnecessarily complex and costly. A simpler and more affordable fixture or dedicated **template** could likely provide sufficient support for this purpose.

A second concern related to the total investment costs of which the fixtures are significant portion. Based on practical experience, the CEO noted that in many cases, approximately 80% of the potential return can still be achieved with only 50% of the original investment. Additionaly, the CEO indicated that, to make the concept more viable, a transition phase is needed were the concept for the new manufacturing method is combined with the current manufacturing method to transition.

Besides the concerns, the CEO indicated the concept to be feasible, viable, and desirable, and the concept is seen as "the blueprint for the future developments of Akerboom".

Quality control team

The quality control team assessed the proposed concept as viable, feasible, and desirable, confirming that the fixture design meets the technical requirements for manufacturing the **items**. They noted that the fixture provides sufficient clamping flexibility to ensure accurate assembly and high-quality welds.

Furthermore, the introduction of multiple dedicated workstations provides sufficient capacity to accommodate Akerboom's fluctuating manufacturing demands, preventing bottlenecks even during peak periods.

> *"This plan is the* ***blueprint of future developments*** *at Akerboom."*

Production manager

The production manager, like the CEO, indicated that a transition phase is needed to make the concept more viable.

Furthermore, the production manager indicated that the concept is desirable. He noted that the proposed concept offers a more standardized and structured manufacturing flow, which not only reduces lead times but also introduces clarity between the different stages of manufacturing. This shift enables the organization to assign welders to dedicated tasks, increasing specialization and process consistency. This is opposite to the current system, where welders frequently switch between tasks, which can lead to inefficiencies and inconsistent quality.

Finally, in terms of feasibility, he confirmed that the concept is grounded in proven technologies and equipment, making implementation realistic and low-risk from a technical standpoint.

Foreman internal

The internal foreman was presented with the current concept and responded positively. He highlighted that the proposed solution would not only make day-to-day activities more efficient, but also improve ergonomics. In his view, the concept introduces a safer way of working by minimizing risks related to cluttered floors and handling of materials. He further noted that the design has the potential to create a more structured workflow, which in turn could reduce delays and interruptions in the process.

The foreman also emphasized that these benefits would likely increase overall job satisfaction among workers, since a safer and more comfortable workspace enables them to focus on quality rather than constantly compensating for poor working conditions.

Foreman external

The external foreman considers the concept both viable and desirable. His main concern lies in its feasibility. Specifically, he questioned whether a clamping table would provide sufficient clamping options and force to maintain the **hull plate** in its intended shape. However, he emphasized that this should be tested and, if it proves effective, he sees it as a promising improvement.

He also noted that the proposed layout is an improvement over the current setup. Utilizing the hall in Katwijk is a key priority, given the limited space available in Leiden.

Additionally, he highlighted that the introduction of new equipment, such as extendalbe arms for cables, is a major upgrade compared to the current situation, where cables are scattered across the floor and a clear **structure** is lacking.

User tests

To evaluate the proposed fixture for the workstations, an investment that must be feasible, viable, and desirable, a user test was conducted. This involved a mock-up of the fixture, on which welders were asked to perform various tasks. Afterwards, interviews were held to gather more in-depth feedback. The complete test setup and interview results are detailed in Appendix S.

A summary of the user test results is presented below.

Ergonomics

A height-adjustable fixture was found to contribute to improved ergonomics to some extent. All five participants used the height-adustability to set the table to their preferred height at the start of the test. However, none of the participants used the height-adjustability feature during the tests. They indicated that a slightly suboptimal posture was preferred over interrupting the workflow to change the height.

By setting the fixture to the preferred height, the participants assumed a more ergonomic posture as compared to a fixed-height fixture. However, as they need to closely monitor the weld pool for precision, the participants still had to stoop slightly to maintain proper visibility. This, was especially true for a taller welder who had to stoop even with the fixture set to its maximum height.

Quality

On visual inspection, the height of the fixture did not directly influence the quality of the welds. However, particpants reported feeling greater control and comfort when the fixture was adjusted to a height that suited their body posture, suggesting that perceived control and confidence improved with better ergonomic alignment. Furthermore, over a full workday/ week, suboptimal ergonomics could possibly lead to a decline of quality.

Figure 71: *Welders performing the user test.*

Desirability

Although the participants indicated that they would not use the height-adjustable fixture in its current mock-up form, they emphasized that a simplified/automated adjustment mechanism would make height-adjustability highly valuable in their daily work.

Several participants shared that prolonged periods of working in unergonomic postures have led to persistent discomfort, including myalgia in the back, neck, and shoulders. This not only affects their physical well-being but can also contribute to fatigue and reduced concentration over time.

Ergonomic evaluation

One of the main objectives of this project was to improve ergonomic conditions. Initial research indicated that a 15% improvement was achievable, and this target was adopted as a project goal. To assess whether this goal was met, the ErgoScore was filled in one final time. These scores were based on observations from the user test as well as informed estimates of the redesigned situation. The full test scores can be found in Appendix T.

The summarized test scores (see Table 4) show that the ergonomic score for the new workflow is **501.2** . When compared to the typical daily situation this means an improvement of **23%**. Which well above the set goal.

The biggest improvement was made for kneeling work, **175** against **75** in the typical daily situation. This is a direct result of the welders not having to work on their knees for long durations while welding the **hull plate**. In addition, repetitive work, like that of welding the **hull plate**, is also reduced, **95** against **70**. Finally, extreme postures and fatiguing work have also been reduced.

In conclusion, the ergonomics have improved significantly with the new proposed design, but there are still a lot of improvements to be made in future optimisations.

Table 4: *ErgoScore scores of the typical daily vs. new concept.*

	Typical daily	New concept
Kneeling work	175	75
Repetitive work	95	70
Standing work	85	85
Extreme postures	95	80
Lifting	75	75
Fatiguing work	52.5	41.25
Pulling and pushing	25	25
Sitting work	50	50
Total	**652.5**	**501.25**

Lead time estimation

Another key objectives established at the beginning of this report was to reduce the total labour hours required for manufacturing by at least 10%, without compromising the quality. To evaluate whether this target has been met, an estimation of the new lead time has been conducted. Additionally, three key stakeholders, the quality control team, the foreman, and the production manager, were consulted to define what “quality” means within the context of Akerboom’s production environment. Although the actual product quality could not be measured within the timeframe of this project due to the long lead times of **items**, these definitions serve as an important foundation for assessing the success after implementation.

Lead Time Estimation
To estimate the reduction in lead time, an example **item** was selected: the beachclub platforms for project 830. As outlined in the earlier lead time estimation (see page 42), the current estimated lead time for this **item** is **635 hours**.

In the proposed concept, several time-consuming steps are fully eliminated, including:

- Adapting the **template**: **40 hours**
- Welding the **hull plate** to the **template**: **60 hours**
- Grinding the structure loose: **15 hours**

This results in an immediate reduction of **115 hours**.

Additionally, the process of welding the **hull plate** is expected to be more efficient due to improved fixtures and better welding ergonomics. The reduced physical strain is anticipated to decrease the number of required breaks, leading to an estimated time saving of 10%, or approximately **5.5 hours**.

Furthermore, the redesigned workflow allows the welding of the **hull plate** and the welding of the structure to take place in parallel. This concurrent processing is expected to eliminate another **45 hours** from the total lead time.

In total, this results in a projected reduction of **165.5 hours**, equivalent to a 26.1% improvement. However, to remain conservative and account for potential inefficiencies during the transition phase, such as unfamiliarity with the new workflow or other inefficiencies, the realistic time savings are estimated to fall between **15% and 20%**.

Based on this estimation, the proposed concept clearly meets, and likely exceeds, the original goal of reducing labour hours by at least 10%.

Reconstruction of planning
To assess the feasibility of the proposed concept in terms of planning, the planning from the past year was reviewed and reconstructed as if the new concept had already been implemented. This planning can be found in Appendix U.

The reconstruction process begins by categorising the **items**: small and medium-sized **items** are assigned to the hall in Katwijk, while large **items** are allocated to the hall in Leiden. Then, for each **item** the lead time per workstation is estimated. Finally, a new planning with these lead times is created.

Figure 72 shows a segment of the production planning specifically for medium-sized **items**. During this period, Akerboom manufactured five **items**, resulting in a combined lead time of 22 weeks.

This planning reflects the sequential and fixed-position approach, where each **item** occupies a workstation for a prolonged period.

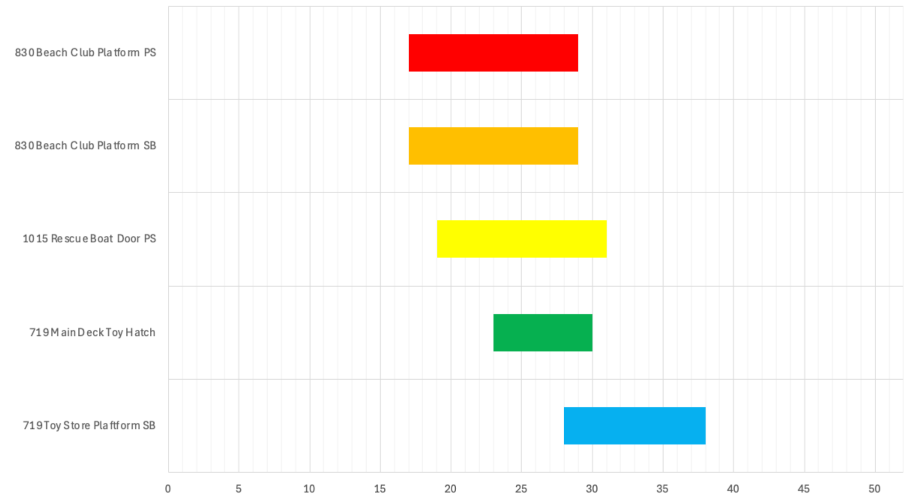


Figure 72: *Overview of the current planning for medium items (from week 16 until week 38).*

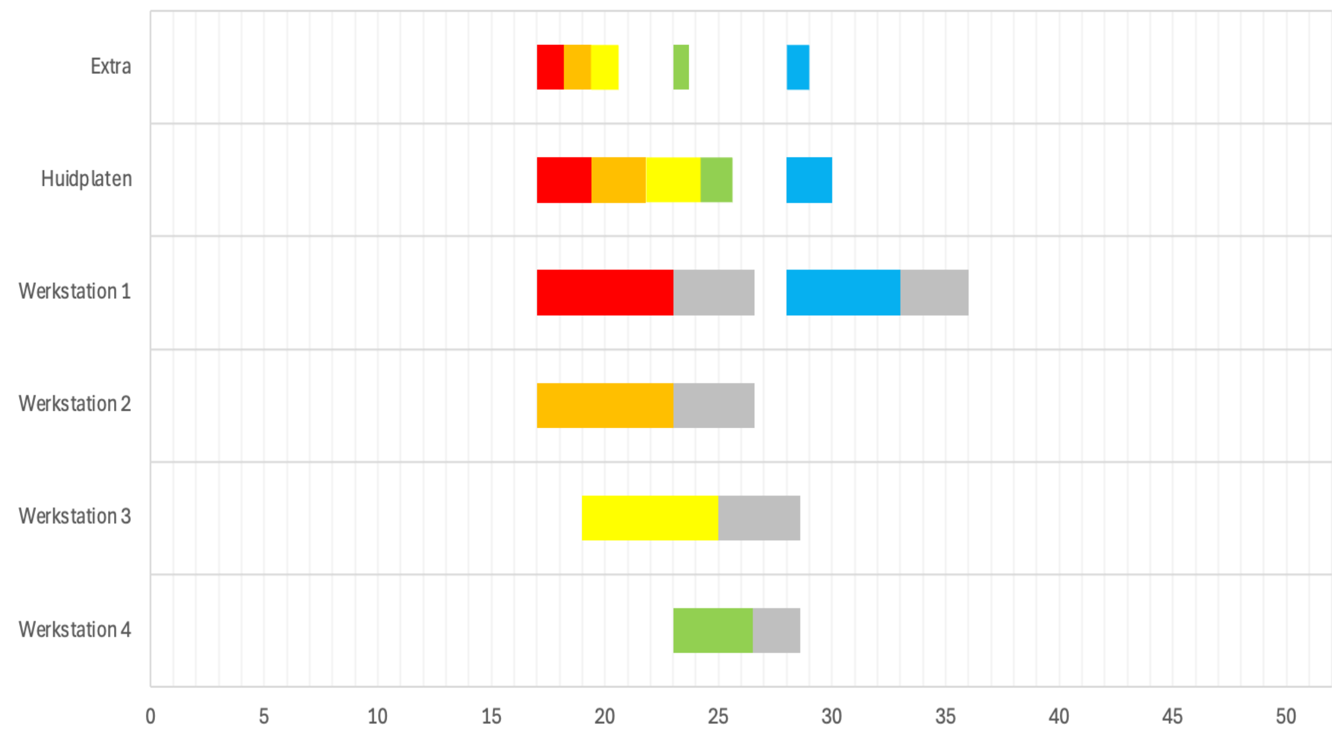


Figure 73: *Overview of the new planning for medium items (from week 16 until week 36).*

Figure 73 presents the reconstructed planning based on the proposed workflow. The schedule is organised across six workstations: one for **hull plate** welding, one for preparing additional components, and four for welding the **structure**. Each **item** is represented by a distinct colour, while grey bars indicate the final completion phase; this phase can only begin once the **hull plate**, extra components, and **structure** have all been completed.

When the same **items** are manufactured following the proposed workflow, the overall lead time is reduced by approximately two weeks. Additionally, the production of the 719 Toy Store Platform (shown in blue) can be advanced by nearly 1.5 weeks. Combined, these improvements result in a total lead time reduction of around 3.5 weeks.

It is worth noting that this planning still includes processes such as setting up H-beams and **templates**, and grinding the **structure** loose from the **hull plate**. As these steps are eliminated through the new concept, the actual lead time reduction could be even greater.

It is essential to emphasise that careful and coordinated planning is crucial for the successful implementation of this workflow.

Figure 74 shows, like Figure 72, a segment of the production planning, but this time for large **items**, which wil be manufactured in Leiden.

During this period, Akerboom manufactured six **items**, resulting in a combined lead time of 27 weeks.

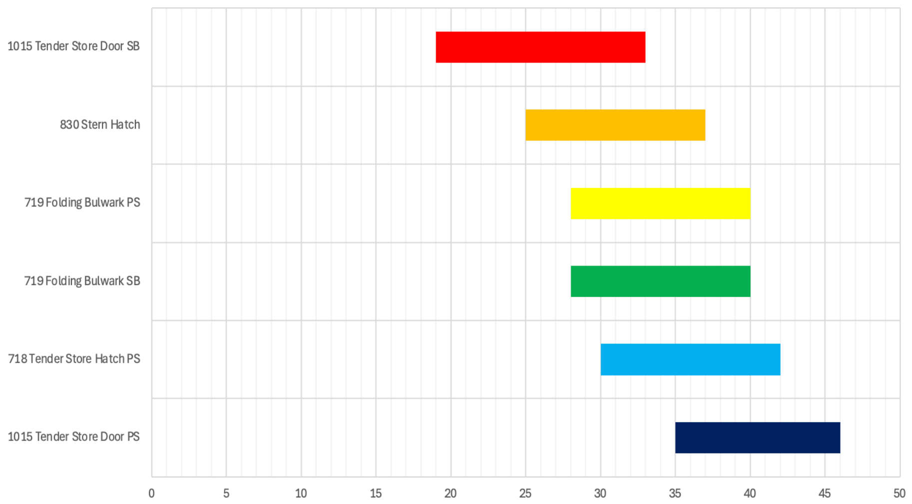


Figure 74: *Overview of the current planning for medium items (from week 19 until week 46).*

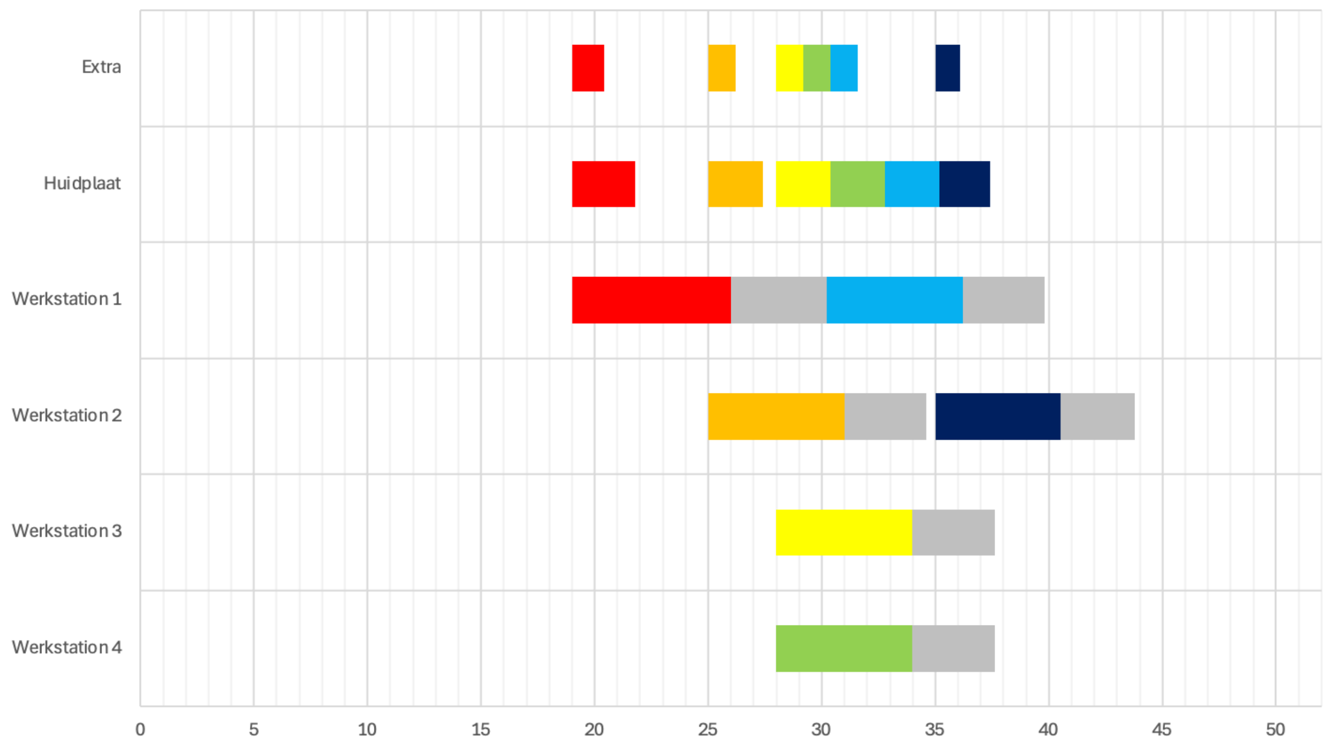


Figure 75: *Overview of the new planning for medium items (from week 16 until week 36).*

Figure 75 presents the reconstructed planning based on the proposed workflow. The schedule is, again, organised across six workstations: one for **hull plate** welding, one for preparing additional components, and four for welding the **structure**.

When the same **items** are manufactured following the proposed workflow, the overall lead time is reduced by approximately two weeks.

Quality Definition

The three stakeholders gave the following definition of quality:

- Quality Control team

The Quality Control team defines a high-quality **item** as one that passes hydrostatic testing with minimal or no leaks. Additionally, the visual and dimensional characteristics of the welds are critical indicators. During quality inspections, attention is given to the presence of welding craters and the height and uniformity of the weld beads. These aspects are measured against the specifications outlined in the welding schedule.

- Production manager

The production manager views quality primarily as adherence to design specifications. An **item** is deemed high quality if it conforms to the technical drawings, even if minor deviations exist. As long as these deviations fall within the acceptable tolerances defined beforehand, the **item** is considered compliant and of good quality.

- Foreman

The foreman described quality as the extent to which an **item** meets both internal and external standards. From his perspective, an **item** can only be considered of high quality if all welds pass inspection by the Quality Control team and if the dimensional accuracy remains within the strict tolerance of less than 2 millimeters, as specified by Lloyd's requirements. He further emphasized that an **item** should not only meet these technical standards but also be completed within the agreed timeframe, since timeliness is a key aspect of maintaining efficiency.

Based on the definitions provided by the three stakeholders, several clear quality criteria emerge. The quality control team emphasises technical performance, such as minimal leakage during hydrostatic testing and weld geometry in accordance with the welding schedule. The production manager defines quality as conformity to the technical drawings, as long as any deviations remain within pre-approved tolerances. The foreman focuses on practical manufacturability, **items** should be produced with minimal rework and must fit seamlessly into the broader assembly process.

Therefore, when evaluating the proposed concept during test runs, the manufactured **items** should:

- Exhibit minimal or no leakage during hydrostatic testing
- Feature welds that match the required height, form, and finish as defined in the welding schedule
- Conform to the technical drawings, with any deviations falling within the acceptable tolerances
- Be manufacturable without excessive rework, enabling a stable and efficient production process

Meeting these criteria will be key in determining whether the concept not only improves efficiency but also maintains, or improves, the current level of quality at Akerboom.

Return of investment

The total estimated expenses for implementing one complete set of workstations are as follows:

- Workstation for **hull plate** welding: €9,460
- Pre-process workstation: €0
- Small **item** workstation: €13,384
- Medium **item** workstation: €26,827

This results in a base total of **€49,671**.

To account for potential unforeseen expenses or cost variations, a 10% contingency is added. This brings the total investment to: **€54,380**

To estimate the return on investment, several assumptions were made:

- Labour hours saved per **item**: 110 hours
- Hourly labour cost: €40
- Number of **items** produced annually: 5

From these figures, the annual labour savings are calculated as:

Revenue = 110 × €40 × 5 = **€22,000 per year**

The estimated return time on investment is then:

Return time = €54,380 ÷ €22,000 = **2.5 years**

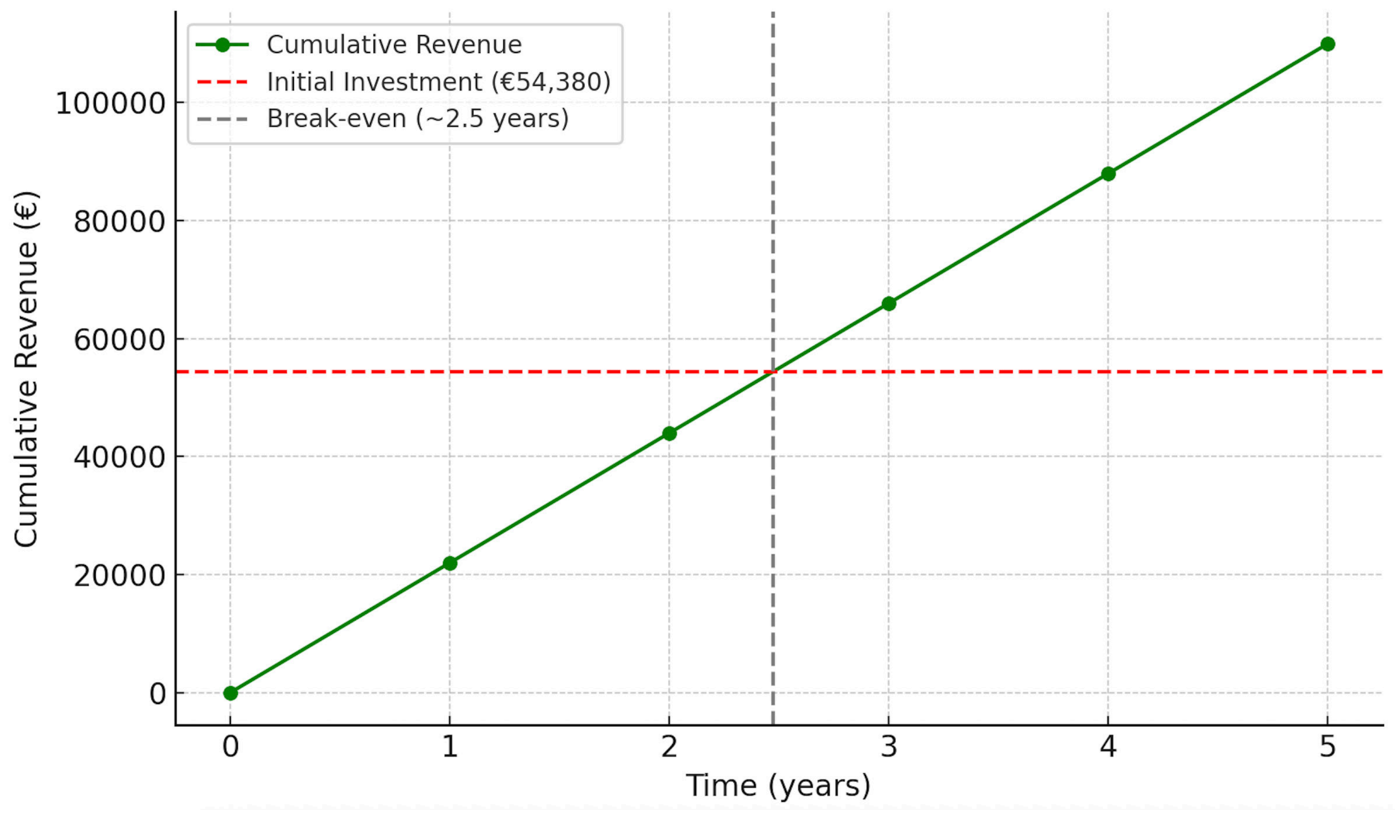


Figure 72: *Graph of the ROI calculations for the trial setup (costs €54,380, revenue €20.000 per year).*

If the proposed concept is implemented on a larger scale, a greater number of **items** can be produced using the new build method, leading to increased labour savings and revenue. However, wider implementation also requires a greater investment, as additional workstations will be needed to support the expanded production.

To estimate the total return on investment under full implementation, a projected quantity of required workstations was determined:

- 2 **hull plate** workstations
- 6 small **item** workstations
- 4 medium **item** workstations
- 4 large **item** workstations

Investment costs for the hull, small, and medium workstations have already been calculated earlier in this report. For the large workstation, an estimation is necessary. Based on the cost progression between small and medium workstations, where costs nearly doubled, it is assumed that the cost of a large workstation will follow the same trend. This results in an estimated investment of €40,000 per large workstation.

Using these figures, the total investment cost for full implementation is calculated as follows:

- Hull: **€18,920**
- Small: **€80,304**
- Medium: **€107,308**
- Large: **€160,000**

This brings the total investment costs to **€366,532**.

Again, o account for potential unforeseen expenses or cost variations, a 10% contingency is added.This brings the total investment to: **€403,185**

When considering the same assumptions of the previous estimation, only now 23 **items** will be produced annualy, the revenue is as follows:

Revenue = 110 × €40 × 23 = **€101,200**

Then the estimated return time on investment is:

Return time = €403,185 ÷ €101,200 = **4 years**

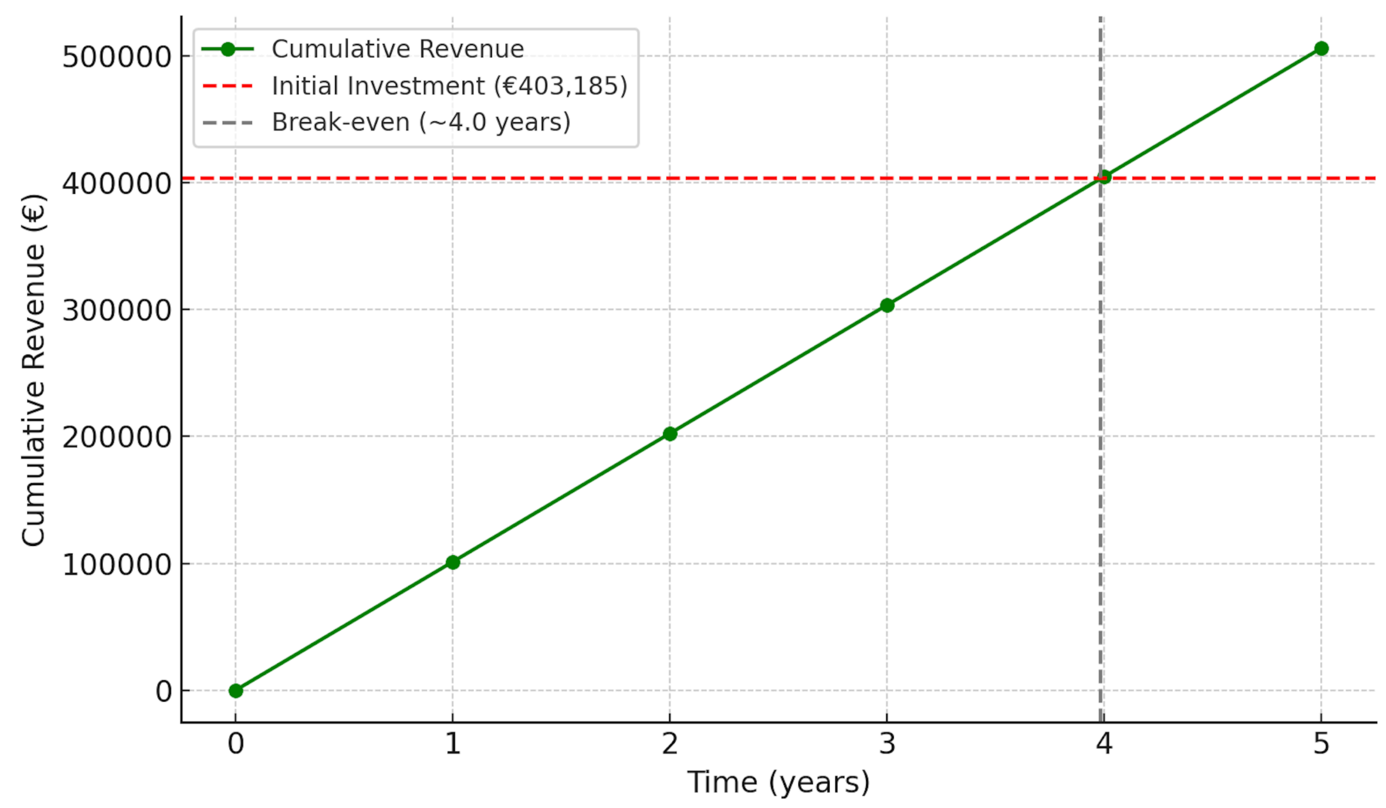


Figure 73: *Graph of the ROI calculations for full implementation (costs €403,185, revenue €101,200).*

Final iterations

Based on the evaluations, final iterations of the concept were made. While efforts were taken to address all stakeholder feedback, not all input could be incorporated within the current scope. Feedback that could not be implemented is documented in the Recommendations chapter, along with additional suggestions for future improvements.

Final lay-out

As outlined in the “Stakeholder evaluation” chapter, both the CEO and Production Manager emphasised the importance of a transition phase from the current manufacturing process to the proposed one. This phased approach would lower initial investment costs and minimise the immediate disruption to existing operations.

Figure 74 presents the final layout in which this transitional stage can be incorporated. In this design, the available section of **truss floor** in Katwijk is allocated to the medium workstations, allowing medium-sized **items** to continue using the current H-beam and **template** fixtures. This enables the new standardised layout and workflow division to be tested without fully abandoning established practices. Meanwhile, the small workstations employ the newly proposed fixtures, making it possible to validate them on a smaller scale. Furthermore, two of the medium workstations are upgraded to medium+ workstations, maintaining the same size of standard medium workstations but offering expandability for larger **items** when required.

Since the medium workstation occupy floor space which was previously allocated to the **hull plate** workstation, the latter is relocated to the other side of the hall. Meanwhile small workstation are relocated to the left-side (top-side in figure) of the hall.

Finally, the workstation for the additional components and pre-processing has been relocated to a centralized location in the hall to ensure minimal movement of materials and subassemblies.

This lay-out now serves as the final lay-out and the foundation of the concept.

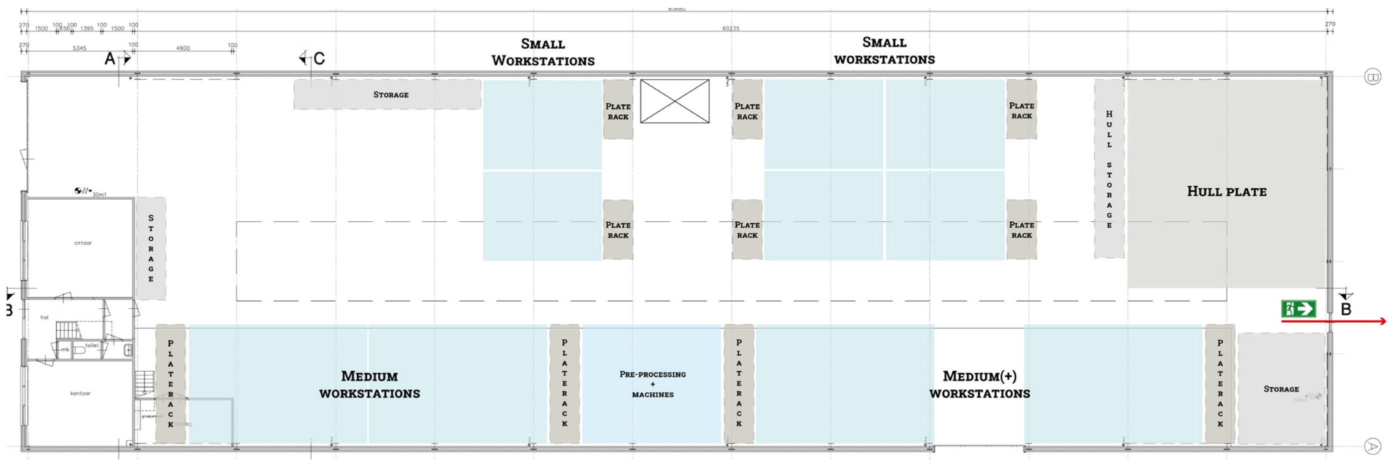


Figure 74: *Floor plan of the lay-out in Katwijk of the transition phase.*

Hull plate fixture

A final design iteration was also carried out on the pin jig used for the **hull plate**. During the evaluation phase, it became evident that the level of flexibility offered by a pin jig exceeds what is required for welding the **hull plates**. Consequently, a simpler solution should suffice.

The redesigned fixture features a frame engineered to support **hull plates** while maintaining the ideal working height for improved ergonomics. This ideal working height is determined as follows:

According to the Centre of Research Expertise for the Prevention of Musculoskeletal Disorders (CRE-MSD)(Centre of Research Expertise for the Prevention of Musculoskeletal Disorders, 2022), the ideal standing working height for light manual tasks, defined as “hand and arm tasks involving moderate force and visual demands”, is approximately 50 to 100 mm below elbow height.

To determine the average elbow height, anthropometric data from DINED was consulted. The analysis focused on Dutch males aged 20 to 60, as the welding staff at Akerboom is currently all male and the profession remains male-dominated in general. According to the most recent DINED dataset, the mean elbow height for this demographic is 1134 mm.

Applying the CRE-MSD guideline, this suggests an ideal working height of 1034 to 1084 mm. For design purposes, the midpoint (1059 mm) serves as the ideal working height.

At one end, an adjustable hinging frame allows for quick positioning at any required angle using a simple locking mechanism, ensuring that all kinked **hull plates** can be accommodated. To facilitate safe and efficient access, integrated stairs enable welders to step onto the fixture and **hull plate** for tasks such as setting up the welding buggy or inspecting welds. This design keeps the necessary flexibility for handling all **hull plates** while significantly reducing setup time.

However, this design has not yet been developed or tested, and should therefore be validated, and possibly redesigned, prior to implementation.

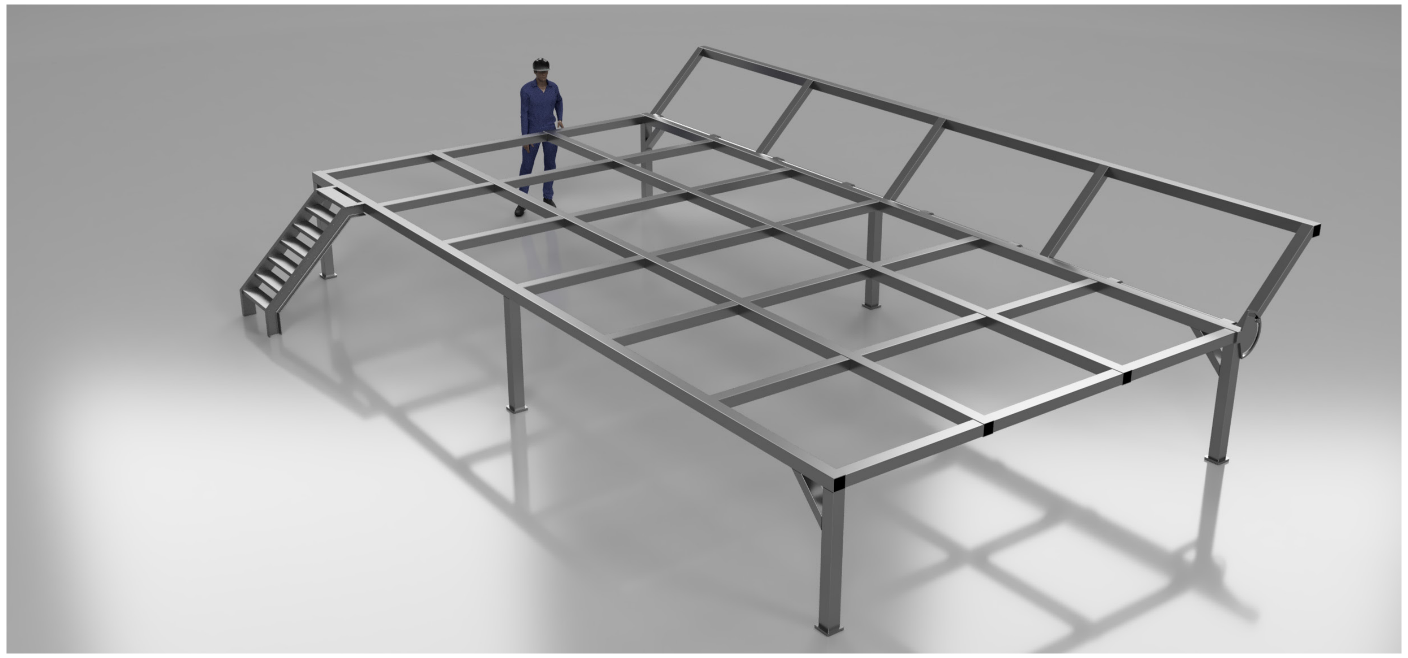


Figure 75: *New proposal for the hull plate fixture.*

Figure 76: *A casco yacht at Slob.*

6

CONCLUSION

This chapter presents the outcomes of the project and summarizes the key insights and results. It revisits the initial goals and assesses to what extent they have been achieved.

Conclusion

This project set out to redesign Akerboom Yacht Equipment's manufacturing process for superyacht doors, platforms, and hatches, addressing the long lead times, inefficient space use, and challenging working conditions of the current sequential fixed-position approach. Through workflow analysis, ergonomic assessments, stakeholder consultations, and iterative design development, a standardized manufacturing method has been created that balances efficiency, safety, and quality.

The proposed concept introduces a clear division of manufacturing activities across standardized workstations. This restructuring shortens lead times, improves flow efficiency, and allows better use of hall space, particularly by unlocking underutilized space in Katwijk. Ergonomic evaluation using the ErgoScore tool demonstrated a 23% improvement, surpassing the 15% target, with significant reductions in kneeling, repetitive, and fatiguing work. Lead time simulations predict labor hour reductions of 15–20% in practice, aligning with the goal of at least 10% savings.

Financially, the concept is expected to deliver a payback period of approximately four years under full implementation, supported by reduced labor costs.

Furthermore, the modular design of the workstations provides flexibility to handle Akerboom's fluctuating manufacturing demands while maintaining quality and safety standards.

Stakeholder evaluations confirmed the concept's feasibility, using proven technologies and equipment, viability, delivering economic and operational benefits, and desirability, meeting the needs of both management and welders. However, successful implementation depends on careful change management.

Ultimately, this project offers Akerboom a blueprint for evolving toward a standardized, ergonomic, and economically sustainable manufacturing process. It provides a foundation for continued improvement, allowing the company to meet demands while preserving the craftsmanship and quality that define its reputation in the superyacht industry.

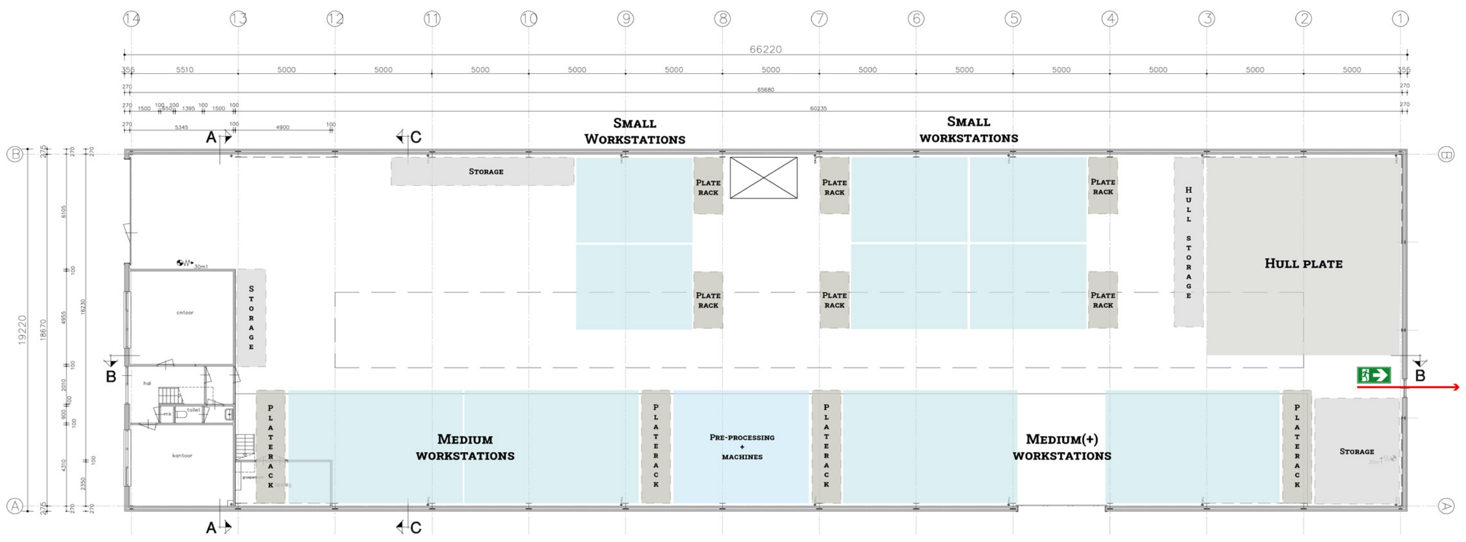


Figure 77: *The new lay-out of the hall in Katwijk.*

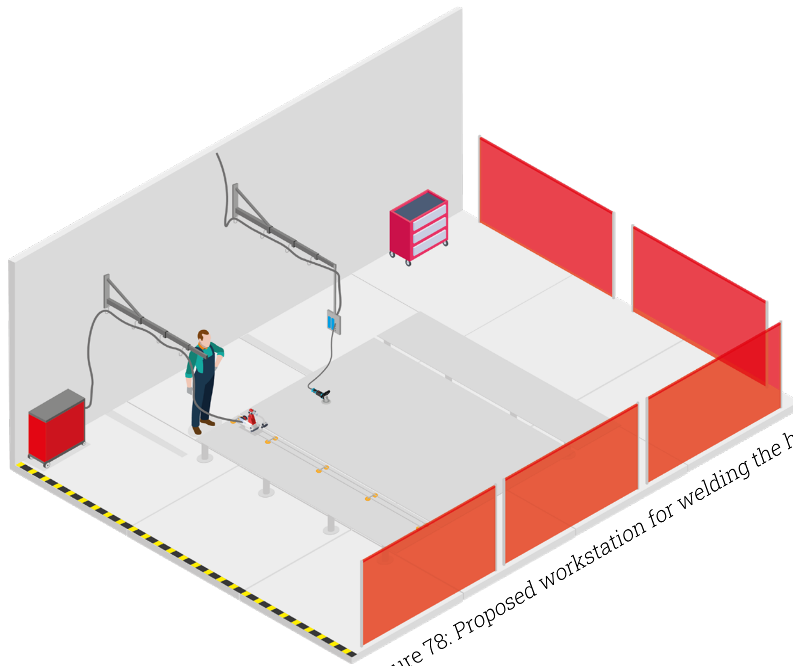


Figure 78: Proposed workstation for welding the hull plates.

Workstation **hull plate**

This workstation features a fixture designed to support large aluminum **hull plates** during welding. One end of the fixture includes a hinged section with a locking mechanism that allows the plate to be set at various angles. Furthermore, it is equipped with swiveling-extendable arms to keep power, pnuematic, and weld cables of the ground.

Workstation **pre-processing**

A dedicated area for welding and preparing smaller components such as portholes, **girders**, and scepter pots. This workstation is equipped with essential tools, including a band saw, table saw, and personal tool trolleys, to enable efficient material processing.

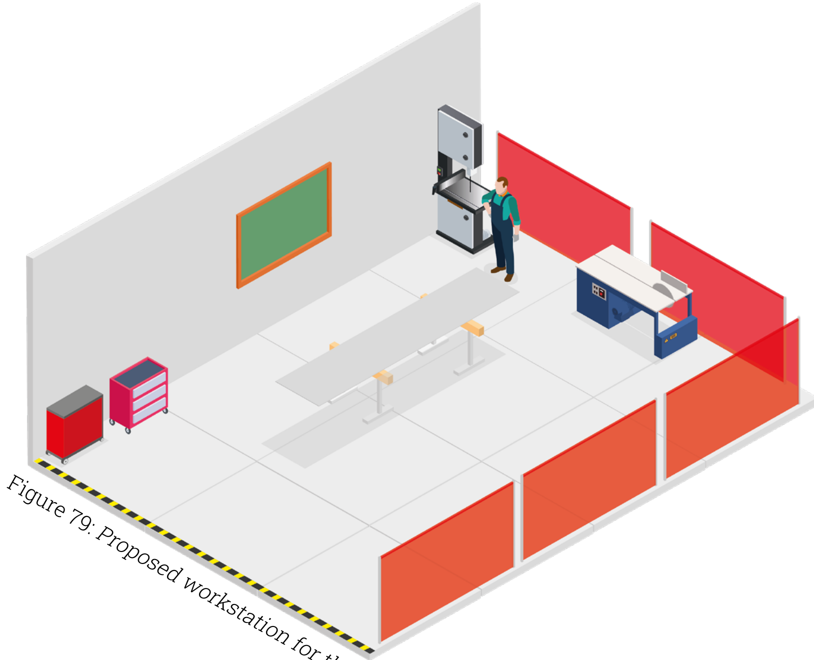


Figure 79: Proposed workstation for the pre-processing.

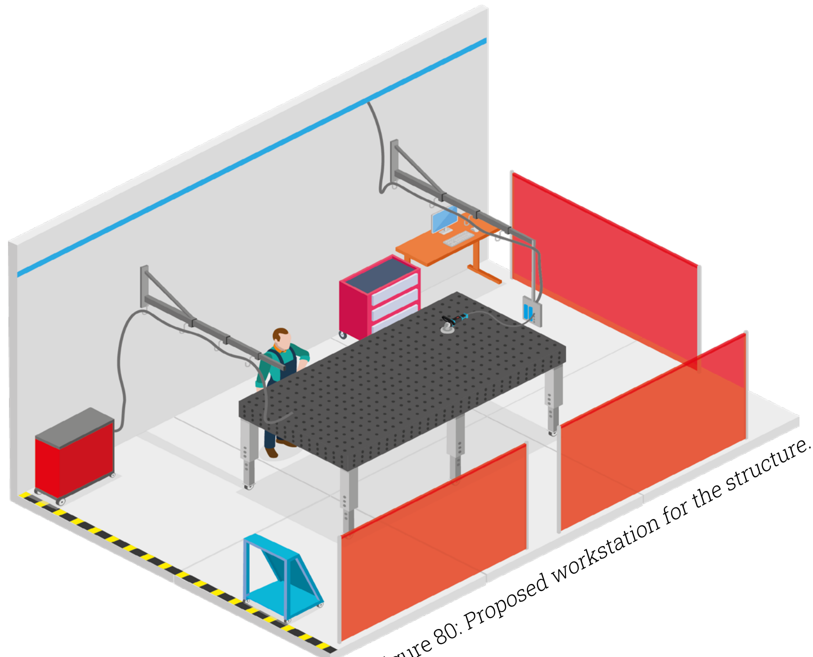


Figure 80: Proposed workstation for the structure.

Workstation **structure**

A modular and reconfigurable welding table setup for welding the **structure**. The surface includes standardized clamping points for quick setup, offering an efficient and standardized platform for structural welding activities. A desk and computer allow for quick checks of drawings when needed.

Figure 81: *A welder welding an H-beam.*

6

Recommendations

While this report presents a comprehensive concept for improving Akerboom's manufacturing process, several opportunities remain for further refinement and future development. This chapter outlines a series of recommendations. These recommendations are based on insights gathered throughout the project, feedback from stakeholders, and observations during testing and simulation.

Recommendations

Laser welding of hull plates

Significant improvements have already been made in welding the **hull plates**, however, further advancements remain possible. One promising development is the integration of laser welding into the manufacturing process. This technique could significantly increase efficiency, because due to its high heat input and precision, laser welding allows deeper seams to be welded (Vereniging FME-CWM et al., 2007). Thus the **hull plates** can be joined in a single pass, eliminating the need to turn them over for additional milling and welding.

Despite its advantages, laser welding also presents several challenges. First and foremost, the technology requires a dedicated, enclosed laser-safe environment and equipment to protect workers from hazardous radiation. Even reflected beams can cause permanent eye damage. Fortunately, the current placement of the **hull plate** workstation, offers a viable opportunity to construct such a controlled space.

Secondly, the investment costs are substantial. A complete laser welding installation, including laser source, automation, safety housing, and ventilation, is estimated to cost approximately [insert cost here]. While the initial investment is high, the long-term gains in productivity and quality should be researched and could justify the investment over time.

Figure 82: *Laserweld on a cornerweld.*

Robot welding of structure

Robotic welding involves the use of a programmable robotic arm equipped with a welding torch to perform precise, automated welds. These systems can operate continuously without breaks, reducing reliance on human labor and minimizing the risk of inconsistencies. By eliminating human variability in welding the **structure**, robotic welding could improve weld quality, reduce errors, and increase overall production efficiency.

Currently, robotic welding is predominantly used in high-volume, repetitive manufacturing due to its programming constraints, it is typically designed to perform the same weld repeatedly. At Akerboom, the diversity of **items** and one-off designs make this approach impractical in its current form. However, if components within the **items** can be standardized across all **items**, robotic welding could become a viable and cost-effective solution. Implementing such standardization would require close collaboration with the engineering department to ensure consistency in design and dimensions across projects.

Figure 83: *Example of a robotic welder.*

Katwijk offices

To maximize the success of this concept, it is essential to utilize the hall in Katwijk to its full potential. This includes not only the production space but also recommission the adjacent office. By permanently housing office staff from various departments on-site, the hall can evolve into a fully integrated and dynamic work environment instead of a secluded constuction hall.

Moreover, having office staff co-located with production teams encourages a stronger sense of ownership and shared responsibility for the workflow. Engineers, planners, and coordinators gain more direct insight into day-to-day operations, allowing them to respond more effectively to practical challenges and continuously refine processes. In the long term, such alignment contributes to a more agile, responsive, and resilient organization.

Implementation in Leiden

This concept has been developed with the specific context and requirements of the Katwijk hall in mind. However, the underlying strategy of establishing designated workstations at fixed locations is broadly applicable and can be readily replicated in the production halls in Leiden. By standardizing the workstation layout and workflows across both sites, the organization can benefit from greater consistency, improved training efficiency, and enhanced flexibility in workforce allocation.

As a next step, Akerboom should explore the implementation of this concept in the production halls in Leiden. This involves developing a layout based on the principles described in this report, like the fixed workstation locations, standardized workflows, and clear spatial separation of tasks.

Figure 84. *Render of Pure, a concept yacht from Feadship*

R

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Figure 85: *Flowchart of the workflow at Akerboom.*

X

Appendices

Appendix X

Project brief

CHECK ON STUDY PROGRESS
To be filled in **by SSC E&SA** (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total ______ EC

Of which, taking conditional requirements into account, can be part of the exam programme ______ EC

▯	YES	all 1st year master courses passed
	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

L. Boot Digitaal ondertekend door L. Boot Datum: 2025.04.23 09:13:36 +02'00'

Name Lisette Boot Date 23-04-2025 Signature

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES	▯	Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Based on study progress, students is ...

▯	**ALLOWED** to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Monique von Morgen Digitally signed by Monique von Morgen Date: 2025.04.23 09:21:45 +02'00'

Name Monique von Morgen Date 23/4/2-25 Signature

Personal Project Brief – IDE Master Graduation Project

TU Delft

Name student Jip Brouwer **Student number** 4664523

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Standardized Workplace Design for the Construction of Doors and Platforms for Yachts

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Feadship is a cooperative venture between two shipyards: Royal Van Lent Shipyard and Koninklijke De Vries Scheepsbouw. Together these companies create high-end luxury yachts. To design and construct these yachts, Van Lent and De Vries have subsidaries. One of these subsidiaries of De Vries is Akerboom Yacht Equipment. At Akerboom, they produce, among other things, hydraulically operated doors and platforms that are integrated into the hull of a yacht. These doors and platforms must meet the highest standards, and the luxury yachts they are placed on are each uniquely designed. Until a few years ago, all doors and platforms were custom-made and produced as one-offs.

In recent years, Akerboom, has adjusted its design approach after discovering that most doors and platforms share many similarities. This approach has led to significant savings in materials and welding work. The next step in this development is to standardize the production process. Currently, the entire production area is flexibly organized to meet all needs. However, in 80% of the cases, the work is standard and could be produced more efficiently with a standardized workstation. The work mainly consists of welding aluminium sheets together and post-processing them.

The main stakeholders are Akerboom and its parent company De Vries as a company and its employees who are responsible for the constuction of the doors and platforms.

introduction (continued): space for images

Figure 1: The obsidian, an example of one of the yachts of Feadship.

Figure 2: Example of a door on a Feadship, created by Akerboom.

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

Akerboom's construction hall in Leiden features a truss floor system, allowing employees to weld H-beams directly to the trusses to create flexible workspaces. In contrast, the construction hall in Katwijk only has a small section with a truss floor, limiting the activities that can be performed there. As a result, most construction/weld work—especially complex, non-standard projects—is carried out in Leiden due to its larger space and adaptable setup.

I aim to design a workplace for standard construction activities that is independent of the existing floor type. By doing so, standard work can be performed efficiently in Katwijk, freeing up the Leiden hall for specialized and custom projects.

The new workplace will not only increase flexibility between the two locations but also improve the efficiency, ergonomics, and safety of construction employees. In 100 working-days I will design a modular system that streamlines workflows, reduce physical strain, and enhance overall working conditions, contributing to a safer and more productive environment.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

Design a concept to improve the efficiency, ergonomics and safety of the construction employees in Akerboom's construction halls by means of creating a standardized workspace where 80% of all construction work can be done indepent of floor type. Additionally, validate the proposed concept and its integration in current workflow by means of a test setup.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

To gather essential information, I will interview as many construction employees as possible to gain insights into the current workflow and its bottlenecks. Additionally, I will observe daily operations by walking around the hall, taking notes, photos, and videos. To ensure compliance, I will also interview company experts on safety and regulations.

For idea generation, I will start with desk research on existing solutions to similar challenges. Using a morphological chart, I will break down the complex problem into smaller sub-challenges and generate multiple solutions. Creative sessions with company experts will further refine these ideas, leading to a diverse set of sub-solutions. These can then be combined into several complete concepts, which will be presented, iterated upon, and improved to develop the final design.

Project planning and key moments

To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a ***kick-off meeting****,* ***mid-term evaluation meeting****,* ***green light meeting*** *and* ***graduation ceremony****. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	March 26, 2025
Mid-term evaluation	May 16, 2025
Green light meeting	July 11, 2025
Graduation ceremony	August 27, 2025

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

This project is especially interesting to me because it integrates multiple aspects, making it a well-rounded challenge. Designing this workspace is not just a technical challenge; also ergonomics and safety play a crucial role. Moreover, the workspace should be more than just functional, it should also increase efficiency and workflow. Balancing these elements requires a combination of analytical thinking, creative problem-solving, and engineering expertise, making this project an ideal opportunity for me to apply my skills in a meaningful way.

One of my key ambitions is to bridge the gap between design and engineering, a connection I feel has not been fully explored during my IDE career. I believe that truly innovative solutions emerge when these two disciplines work together. To achieve this, I aim to develop the ability to mediate between design and engineering, ensuring that both creative vision and technical feasibility align effectively. By strengthening this skill set, I hope to become a valuable asset to companies that seek to integrate design-driven thinking with practical engineering solutions, ultimately contributing to the development of more efficient, user-friendly, and innovative products.

Appendix A

Full test scores of the Ergoscore tool - Worst-case

Ergonomische risico's

Selecteer

- Tillen (>3kg)
- Trekken en duwen
- Repetitief werken (>10x/min)
- Staand werken (<2m)
- Geknield werken
- Zittend werken
- Extreme houdingen (rug/schouders)
- Vermoeiend werk (>4u wandelen)

Tillen

Tijd (frequentie)
<1x/min | <480x/dag

Intensiteit (max. gewicht)
15-25kg

Houding rug
Licht gebogen EN gedraaid

Houding schouders (positie handen)
Boven ellebogen | Op halve armlengte

Omstandigheden (ruimte, grip)
Optimaal | vrije ruimte | krachtgreep

Risicoscore tillen
75

Trekken en duwen

Tijd
<10m/keer | <400m/dag

Intensiteit (gewicht + transpallet)
<400kg

Houding - rug en schouders
Licht gebogen of gedraaid

Omstandigheden - wielen, ondergrond
Optimaal | vloer vlak/hard | goede staat wielen | verticale handgreep

Risicoscore trekken en duwen
25

Repetitief werken

Duur (% taakduur)
50-75% | 4-6u/dag

Intensiteit (# handbewegingen / minuut)
>30x/min

Houding (polsen en schouders)
Sterk gebogen EN gedraaid

Omstandigheden (verlichting, trilling, tempo)
Beperkt | <500Lux | voelbare trilling | tempo met buffer

Risicoscore repetitief werken
125

Staand werken

Duur (ter plaatse staan)
50-75% | >4u/dag

Intensiteit (aan één stuk door ter plaatse staan)
>1u en >4u/dag

Houding (rug en nek)
Licht gebogen EN licht gedraaid

Omstandigheden (ondergrond, trilling, temperatuur, ruimte)
Optimaal | zachte ondergrond | stamatten | stasteun | (zadel)stoel

Risicoscore staand werken
105

Geknield werken

Tijd (duur of frequentie)
>30min/dag | >1x/min

Intensiteit (duur aan één stuk door op knieën)
>30 min

Houding (rug)
Licht gebogen EN gedraaid

Omstandigheden (vloer - ruimte)
Slecht | lokale druk op knie | <90x90cm

Risicoscore geknield werken
150

Zittend werken

Duur (% tijd zitten)
<25% | <2u/dag

Intensiteit (aantal uur zitten zonder onderbreking)
<1uur

Houding (rug en nek)
Licht gebogen of gedraaid

Omstandigheden (zetel, kussen, ondergrond)
Optimaal | stoel volledig verstelbaar | dik kussen | vlakke ondergrond

Risicoscore zittend werken
25

Extreme houdingen

Tijd (frequentie)
>1x/2min | >5% | >30min/dag

Intensiteit (kracht)
Redelijk | >5kg

Houding (rug/schouder)
Eén gewricht met torsie

Omstandigheden (omgeving, ruimte, grip)
Beperkt | beperkte grip | <90x90cm | voelbare trilling

Risicoscore ongunstige houdingen
95

Vermoeiend werken

Duur (%tijd op de voeten)
>6u/dag | >75%

Intensiteit (zwaarte werk)
Zwaar | werken met armen en romp | >15kg

Houding (rug/armen)
Matig | Licht gebogen

Omstandigheden (normale temperatuur)
Gewoon | 18-22°C

Herstel (zittende pauze van 15')
Elke 2u pauze | 3x/dag

Risicoscore vermoeiend werken
47.5

Full test scores of the Ergoscore tool - Typical daily

Ergonomische risico's

Selecteer
- Tillen (>3kg)
- Trekken en duwen
- Repetitief werken (>10x/min)
- Staand werken (<2m)
- Geknield werken
- Zittend werken
- Extreme houdingen (rug/schouders)
- Vermoeiend werk (>4u wandelen)

Tillen

Tijd (frequentie)
<1x/3min | <160x/dag

Intensiteit (max. gewicht)
15-25kg

Houding rug
Licht gebogen EN gedraaid

Houding schouders (positie handen)
Boven ellebogen | Op halve armlengte

Omstandigheden (ruimte, grip)
Gewoon | >90x90cm | haakgreep

Risicoscore tillen
75

Trekken en duwen

Tijd
<10m/keer | <400m/dag

Intensiteit (gewicht + transpallet)
<400kg

Houding - rug en schouders
Licht gebogen of gedraaid

Omstandigheden - wielen, ondergrond
Optimaal | vloer vlak/hard | goede staat wielen | verticale handgreep

Repetitief werken

Duur (% taakduur)
25-50% | 2-4u/dag

Intensiteit (# handbewegingen / minuut)
>15x/min

Houding (polsen en schouders)
Sterk gebogen EN gedraaid

Omstandigheden (verlichting, trilling, tempo)
Beperkt | <500Lux | voelbare trilling | tempo met buffer

Risicoscore repetitief werken
95

Staand werken

Duur (ter plaatse staan)
50-75% | >4u/dag

Intensiteit (aan één stuk door ter plaatse staan)
>1u

Houding (rug en nek)
Licht gebogen EN licht gedraaid

Omstandigheden (ondergrond, trilling, temperatuur, ruimte)
Gewoon | vlakke ondergrond | geen trilling | >90x90cm

Risicoscore staand werken
85

Geknield werken

Tijd (duur of frequentie)
>1u/dag | >2x/min

Intensiteit (duur aan één stuk door op knieën)
>30 min

Houding (rug)
Licht gebogen EN gedraaid

Omstandigheden (vloer - ruimte)
Slecht | lokale druk op knie | <90x90cm

Risicoscore geknield werken
175

Zittend werken

Duur (% tijd zitten)
<25% | <2u/dag

Intensiteit (aantal uur zitten zonder onderbreking)
<2uur

Houding (rug en nek)
Licht gebogen EN gedraaid

Omstandigheden (zetel, kussen, ondergrond)
Gewoon | stoel verstelbaar | dun kussen | kleine oneffenheden

Risicoscore zittend werken
50

Extreme houdingen

Tijd (frequentie)
>1x/min | >10% | >1u/dag

Intensiteit (kracht)
Redelijk | >5kg

Houding (rug/schouder)
Eén gewricht met torsie

Omstandigheden (omgeving, ruimte, grip)
Gewoon | haakgreep | >90x90cm | niet-voelbare trilling

Risicoscore ongunstige houdingen
95

Vermoeiend werken

Duur (%tijd op de voeten)
>4u/dag | 50-75%

Intensiteit (zwaarte werk)
Middelmatig | werken met handen en armen | 5-15kg

Houding (rug/armen)
Ongunstig | Sterk gebogen

Omstandigheden (normale temperatuur)
Gewoon | 18-22°C

Herstel (zittende pauze van 15')
Elke 3u pauze | 2x/dag

Risicoscore vermoeiend werken
52.5

Full test scores of the Ergoscore tool - Ideal

Ergonomische risico's

Selecteer
- Tillen (>3kg)
- Trekken en duwen
- Repetitief werken (>10x/min)
- Staand werken (<2m)
- Geknield werken
- Zittend werken
- Extreme houdingen (rug/schouders)
- Vermoeiend werk (>4u wandelen)

Tillen

Tijd (frequentie)
<1x/3min | <160x/dag

Intensiteit (max. gewicht)
10-15kg

Houding rug
Licht gebogen of gedraaid

Houding schouders (positie handen)
Onder ellebogen | Dichtbij lichaam

Omstandigheden (ruimte, grip)
Gewoon | >90x90cm | haakgreep

Risicoscore tillen
50

Trekken en duwen

Tijd
<10m/keer | <400m/dag

Intensiteit (gewicht + transpallet)
400-600kg

Houding - rug en schouders
Rechte rug

Omstandigheden - wielen, ondergrond
Optimaal | vloer vlak/hard | goede staat wielen | verticale handgreep

Risicoscore trekken en duwen
25

Repetitief werken

Duur (% taakduur)
50-75% | 4-6u/dag

Intensiteit (# handbewegingen / minuut)
>15x/min

Houding (polsen en schouders)
Licht gebogen EN gedraaid

Omstandigheden (verlichting, trilling, tempo)
Beperkt | <500Lux | voelbare trilling | tempo met buffer

Risicoscore repetitief werken
85

Staand werken

Duur (ter plaatse staan)
25-50% | <4u/dag

Intensiteit (aan één stuk door ter plaatse staan)
>30min

Houding (rug en nek)
Licht gebogen of gedraaid

Omstandigheden (ondergrond, trilling, temperatuur, ruimte)
Gewoon | vlakke ondergrond | geen trilling | >90x90cm

Risicoscore staand werken
40

Geknield werken

Tijd (duur of frequentie)
>30min/dag | >1x/min

Intensiteit (duur aan één stuk door op knieën)
>15min

Houding (rug)
Licht gebogen EN gedraaid

Omstandigheden (vloer - ruimte)
Gewoon | vlakke ondergrond | >120x120cm

Risicoscore geknield werken
85

Zittend werken

Duur (% tijd zitten)
25-50% | 2-4u/dag

Intensiteit (aantal uur zitten zonder onderbreking)
<1uur

Houding (rug en nek)
Licht gebogen of gedraaid

Omstandigheden (zetel, kussen, ondergrond)
Gewoon | stoel verstelbaar | dun kussen | kleine oneffenheden

Risicoscore zittend werken
35

Extreme houdingen

Tijd (frequentie)
>1x/2min | >5% | >30min/dag

Intensiteit (kracht)
Redelijk | >5kg

Houding (rug/schouder)
Eén gewricht met torsie

Omstandigheden (omgeving, ruimte, grip)
Optimaal | krachtgreep | vrije ruimte | geen trilling

Risicoscore ongunstige houdingen
75

Vermoeiend werken

Duur (%tijd op de voeten)
>4u/dag | 50-75%

Intensiteit (zwaarte werk)
Middelmatig | werken met handen en armen | 5-15kg

Houding (rug/armen)
Matig | Licht gebogen

Omstandigheden (normale temperatuur)
Gewoon | 18-22°C

Herstel (zittende pauze van 15')
Elke 3u pauze | 2x/dag

Risicoscore vermoeiend werken
41.25

Appendix B

Iterations on design brief

The original design brief as stated by Akerboom in the vacancy was as follows:

"**In this graduation project, a workstation must be designed that can be repeatedly set up in our manufacturing hall. This workstation should be suitable for both doors and platforms.**

Project objectives:

- 80% of doors and platforms must be able to be manufactured using the standardized workstation
- Achieve a 10% reduction in labor hours while maintaining at least the same quality
- Reduce the number of (near) accidents during work on and around platforms
- Improve ergonomics for employees

Deliverables:

- Build a test setup of the workstation that has been trialed with at least one platform
- Develop a final design for the workstation
- Prepare a cost estimate and payback period calculation for the designed workstation."

After an initial visit to Akerboom's facility in Leiden and getting more familiar with their manufacturing process, and a more in-depth conversation with the production manager, the design brief was made more condensed to the following:

"**Design a concept that improves the efficiency, ergonomics, and safety for manufacturing workers in Akerboom's production halls by creating a standardized workstation where 80% of all manufacturing work can be carried out. Additionally, validate the concept and it's integration in the current workflow by means of a test setup.**"

After the research phase, the goal of achieving a test setup seemed unrealistic in the given timeframe. Furthermore, with the additional research and new information, the design brief was change a second time:

"**Design a concept that enables the manufacturing of the eight most frequently produced items, regardless of the floor type(1), while simultaneously improving ergonomics by 15%, and serving as a foundation for a more efficient working method(2) that integrates seamlessly into the current workflow and enhances it(3)**"

Later in this project the goal of achieving a test setup seemed more realistic, however, the setup would be very minimalistic, but could still give valuable validation of the concept and was thus chosen to be added again:

"**Design a concept that enables the manufacturing of the eight most frequently produced items, regardless of the floor type(1), while simultaneously improving ergonomics by 15%, and serving as a foundation for a more efficient working method(2) that integrates seamlessly into the current workflow and enhances it(3). Additionally, validate the concept and it's integration in the current workflow by means of a test setup.**"

APPENDIX C

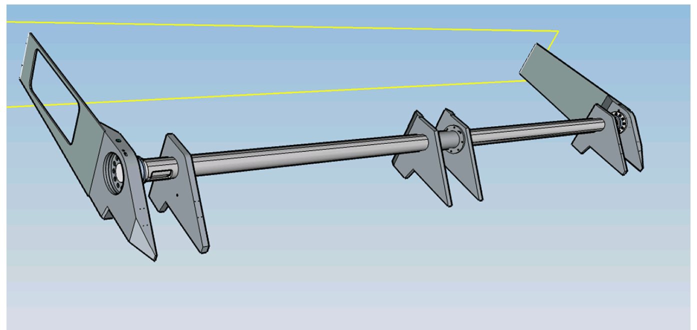
WBS & welding procedures

e schotten vertikaal:	116172 mm	9 stuks		Aantal lockings	5 stuks
e schotten horizontaal:	103500 mm	5 stuks		Aantal aandrijfmodules:	2 stuks
e contour/omtrek:	52608 mm				
te totaal:	272280 mm				

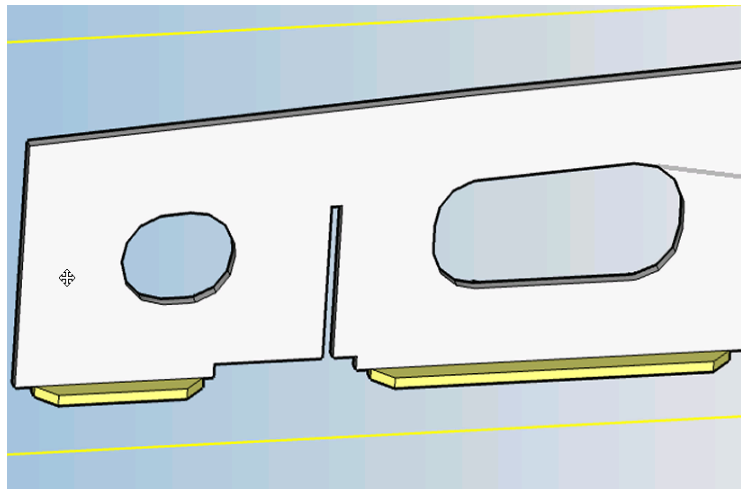
	Stap		Afdeling	Tijdnorm	Factor	Resultaat	Totaal	Factor bepaling
	specificeren	Specificatie en afstemming met de werf		200	1	200		
						Totaal:	200	
ring								
	Configuratie opzetten		Eng.	8	1	8		
	Beoordelen integratierisico		Eng.	8	1	8		
	Planning en kostpijs		Eng.	8	1	8		
						Subtotaal:	24	
	IF engineering	Platform & omgeving	Eng.	32	1	32		
		Vorm	Eng.	8	0	0		afh. complexiteit
		Portholes	Eng.	6	3 stuks	18		afh. aantal portholes
		Berghout	Eng.	8	0	0		Ja/Nee
						Subtotaal:	50	
	Detail engineering	Structure	Eng.	0,12	1862 kg	224		afh. gewicht (~grootte)
		Vorm	Eng.	32	0	0		afh. complexiteit
		Portholes	Eng.	12	3	36		afh. aantal portholes
		Berghout	Eng.	24	0	0		Ja/Nee
		Lockings	Eng.	3	5	15		afh. aantal lockings
		Aandrijfmodules	Eng.	6	2	12		afh. aantal aandrijfmodules
		Reviews	Eng.	8	1	8		
						Subtotaal:	295	
vering								
	Manual en totaalafronding		Eng.	8	1	8		
	As-build maken		Eng.	6	3 dagen	18		afh. aantal dagen (6 uur/dag)
						Subtotaal:	26	
						Totaal:	395	
planning								
	Planning item	Planning	Wvb.	8	1	8		
	Voorbereiden	Reviews	Wvb.	8	1	8		
	Bestellen/reserveren	Inlezen check structuur	Wvb.	4	1	4		
		Modules bestellen	Wvb.	16	1	16		
		Structure bestellen	Wvb.	4	1	4		
		Begeleiding productie	Wvb.	12	1	12		
						Totaal:	52	
ctie intern								
aniel	Module Structure	Opstellen/aanpassen mal/bouwfundatie.	Con.In.	3	5	15		afh. aantal "maldelen"
		Extra werk aan mallen i.v.m. ondersteuning t.b.v. Porthole(s)	Con.In.	1,5	3	4,5		afh. aantal portholes
		Schotten (langs + dwars) voorbewerken	Con.In.	0,35	220 m	77		afh. aslengte schotten
		Lockcilinder- flensplaten in de zijschotten lassen	Con.In.	2	5	10		afh. aantal lockings
		Langs en dwarsschotten plaatsen en aan elkaar hechten	Con.In.	2,85	14	39,9		afh. aantal schotten
		Lassen van doorvoerbuizen Elektra en Hydrauliek	Con.In.	2	7	14		afh. aantal lockings
		Schotten los maken van huidplaat en schotten aan elkaar lassen	Con.In.	0,15	45	7		afh. luikdikte en #kruispunten
		Lassen van porthole (onderdelen onderling en aan huidplaat)	Con.In.	20	3	60		afh. aantal portholes
		Schotten terugplaatsen en aan huid vastlassen	Con.In.	0,362	220 m	80		afh. aslengte schotten
		Inlassen van as-blokken	Con.In.	8	2	16		Altijd 2 assen (al dan niet aangedreven)
		Overlengte van schotten afhalen	Con.In.	1,24	14	17		afh. aantal schotten
		Sealprofiel recht + sealprofiel bochten plaatsen	Con.In.	2,65	15,1 m	40		afh. omtrek
		Zijschotten, ronde hoeken plaatsen	Con.In.	2,65	15,1 m	40		afh. omtrek
		Hijsproppen inlassen	Con.In.	4	2,0 m	8		
		Aan de binnenkant alles aflassen	Con.In.	6	13,3 m2	80		afh. opp.
		Binnnenkant nalopen voor inspectie.	Con.In.	16	1	16		
		Afname Lloyds en controle laswerk door de werf (binnen inspectie)	Con.In.	4	1	4		
		Randen montageluiken lockings	Con.In.	5	5 stuks	25		afh. aantal lockings
		Waterdichte luiken inlassen	Con.In.	8	2	16		afh. aantal aandrijfmodules
		Dekplaten plaatsen	Con.In.	3	13,3 m2	40		afh. opp.
		Railingpotten en teakrand inlassen	Con.In.	1,5	15,1 m	23		afh. omtrek
		Buitenkant aflassen.	Con.In.	3,9	15,1 m	59		afh. omtrek
		Platform richten	Con.In.	3	13,3 m2	40		afh. opp.
		Afwerken en afpersen	Con.In.	3	13,3 m2	40		afh. opp.
		AfnameQC, Lloyds, controle maatvoering & laswerk door werf, Overdracht	Con.In.	8	1	8		
		Berghout construeren	Con.In.	40	1	40		
		Voorman uren	Con.In.	0	1	0		
						Totaal:	778	
e intern								
rk, Fred, Sam		Checken en klaar leggen per order/ serienr. + Motoren	Mon.In.	8	1	8		per item/batch
	Module lockings	Lock cilinders monteren	Mon.In.	1	5	5		afh. aantal lockings
		Luikjes voormonteren/pasmaken	Mon.In.	1	5	5		afh. aantal lockings
		Hydrauliek leidingen monteren per locker vak	Mon.In.	1	5	5		afh. aantal lockings
		Junction boxen plaatsen en aansluiten	Mon.In.	0,25	5	1,25		afh. aantal lockings
		Monteren + aansluiten sensoren	Mon.In.	8	1	8		
						Subtotaal:	32,25	
	Module aandrijving	Monteren van diverse onderdelen complete module	Mon.In.	8	2	16		afh. aantal aandrijfmodules
		Passen van assen en bollen	Mon.In.	2	2	4		afh. aantal aandrijfmodules
		Monteren tweede as (indien slechts 1 aandrijfmodule)	Mon.In.	2	0	0		afh. aantal NIET-aandrijfmodules
		Electra in module aandrijving aansluiten	Mon.In.	6	2	12		afh. aantal aandrijfmodules
		Hydrauliek in module aandrijving aansluiten	Mon.In.	6	2	12		afh. aantal aandrijfmodules
		Waterdichte luiken actuator voormonteren/pasmaken	Mon.In.	1	2	2		afh. aantal aandrijfmodules
						Subtotaal:	84	
	Module airseal	Airseal luchtleiding(en) monteren	Mon.In.	4	1	4		
		Airseal monteren & testen op werking	Mon.In.	0,4	15,1 m	6		afh. omtrek
						Subtotaal:	10	
	Overige montage intern	Test/montage rig op maat zetten	Mon.In.	4	1	4		
		Spoelen hydrauliek leidingen + druk test (afhankelijk van vervuiling)	Mon.In.	16	1	16		

						Totaal:	164	
Constructie extern								
Leslie, Daniel		Meetrapport recess (inmeten door QC AYE)	QC	16	1	16		
		Overdracht naar constructie extern + kick-off	Con.Ext.	6	1	6		
Outer ring al gelast door werf		Bolkoppeling constructie in recess plaatsen (incl. plaatsen "reactiearm/lever")	Con.Ext.	8	2	16		2 assen
		Platform inmeten, en zo op maat maken dat hij er net in past.	Con.Ext.	1	15,1 m	15		afh. omtrek
		Platform "plaatsen" (=Tussen-assen uitschuiven) en geheel uitstroken/stellen	Con.Ext.	1	13,3 m2	13		afh. opp.
		Controle kier en vrij draaien platform	Con.Ext.	4	1	4		
		Strook afname werf QC en AYE QC	Con.Ext.	8	1	8		
		Berghout/rubrail definitief aanbrengen en aflassen	Con.Ext.	4	0,0 m	0		afh. van berghout Ja/Nee + lengte platform
		Stopblokken (open & gesloten positie) construeren / plaatsen	Con.Ext.	3	4	12		
		As-draag constructie vullen met Marine chocking (vacuumzuigen)	Con.Ext.	4	2	8		2 assen
		Positie locker bepalen tov lockpot (mbv dummies/hulpgereedschap)	Con.Ext.	3	5	15		afh. aantal lockings
		Lockpot ontvangers vastlijmen in potten	Con.Ext.	1,5	5	7,5		afh. aantal lockings
		Kier rondom platform aftekenen en slijpen	Con.Ext.	1	15,1 m	15		afh. omtrek
		Kier afname werf QC en AYE QC	Con.Ext.	8	1	8		
		Platform demonteren en restpunten	Con.Ext.	1	15,1 m	15		afh. omtrek
Hoe kan dit beter/sneller (bespreken met PM)???		Schilderklaar maken	Con.Ext.	24	1	24		
		Terug plaatsen en waterdicht maken en vastzetten i.v.m. transport schip.	Con.Ext.	16	1	16		
		Overdracht van constructie extern naar montage extern	Con.Ext.	4	1	4		
						Totaal "werk"uren:	203	
		Reistijd heen en weer naar werf (2uur/ werkman / dag)	Con.Ext.	4	12,7 dagen	51		afh. aantal dagen en reisafstand
		Project begeleiding & administratie & reistijd VOORMAN	Con.Ext.	10	12,7 dagen	127		afh. aantal dagen en reisafstand
						Totaal "extra"uren:	178	
						Totaal:	381	
Montage extern								
	Plamuur/schilder periode							
Erik, Mark, Fred, Sam	(zie regel 128) ???	Controle kier en vrij draaien platform	Mont.Ext.	4	1	4		
		Opmeten ruimte tussen platform en goot	Mont.Ext.	2	1	2		
		Aanslag blokken voor open positie inmeten	Mont.Ext.	1,5	2	3		afh. aantal aanslagblokken
		Afdekplaten voor lockers plaatsen ivm plamuur	Mont.Ext.	1	5	5		afh. aantal lockings
		Demontage platform voor schilder	Mont.Ext.	6	2	12		altijd met 2 monteurs
		Actuatoren demonteren	Mont.Ext.	1	2	2		
		Gietring afsmeren met Phillybon orange	Mont.Ext.	2	2	4		afh. aantal aandrijfmodules
						Subtotaal:	32	
	Final Assembly Platform							
		Top cleats monteren	Mont.Ext.	0,5	0	0		afh. Aantal cleats
		Waterdichte luiken plaatsen	Mont.Ext.	1	2	2		
		Tapgaten optappen	Mont.Ext.	0,05	38	1,9		
		Aanslagblokken voor open positie monteren	Mont.Ext.	1	2	2		afh. aantal aanslagblokken
						Subtotaal:	6	
	Final Assembly Recess							
		Lockpotten plaatsen	Mont.Ext.	0,5	0	0		afh. aantal lockings
		Aanslagblokken voor gesloten positie monteren	Mont.Ext.	1	2	2		
		Elektra plaatsen TURK sensor plaatsen op lever/as (indien van toepassing)	Mont.Ext.	4	1	4		
						Subtotaal:	6	
	General Assembly							
		Platform plaatsen (inclusief monteren reactie arm)	Mont.Ext.	6	2	12		Altijd met 2 monteurs
		Hydrauliek aansluiten	Mont.Ext.	3	1	3		
		Hydrauliek ontluchten en in bedrijf stellen	Mont.Ext.	1	7	7		
		Elektra aansluiten	Mont.Ext.	8	1	8		
		Airseal aansluiten op lucht en in bedrijf stellen	Mont.Ext.	4	1	4		
		Teakflap plaatsen (indien van toepassing / verantwoording AYE)	Mont.Ext.	20	0	0		afh. Teakflap AYE Ja/Nee
		In bedrijf stellen	Mont.Ext.	16	1	16		
		Montagedeksels lockers plaatsen	Mont.Ext.	0,5	5	2,5		afh. aantal lockings
		Motorluik platform plaatsen	Mont.Ext.	0,5	2	1		Altijd links en rechts een motorluik
						Subtotaal:	54	
	Afronding							
		Afname AYE	Mont.Ext.	4	1	4		
		Load test	Mont.Ext.	4	1	4		
		Hose stest AYE en werf	Mont.Ext.	2	1	2		
		Afname bij werf met klant	Mont.Ext.	4	1	4		
						Subtotaal:	14	
						Totaal "werk"uren:	111	
		Reistijd heen en weer naar werf (2uur/ werkman / dag)	Con.Ext.	4	7,0 dagen	28		afh. aantal dagen en reisafstand
		Project begeleiding & administratie & reistijd VOORMAN	Con.Ext.	10	7,0 dagen	70		afh. aantal dagen en reisafstand
						Totaal "extra"uren:	70	
						Totaal:	292	
						Totaal:	2263	

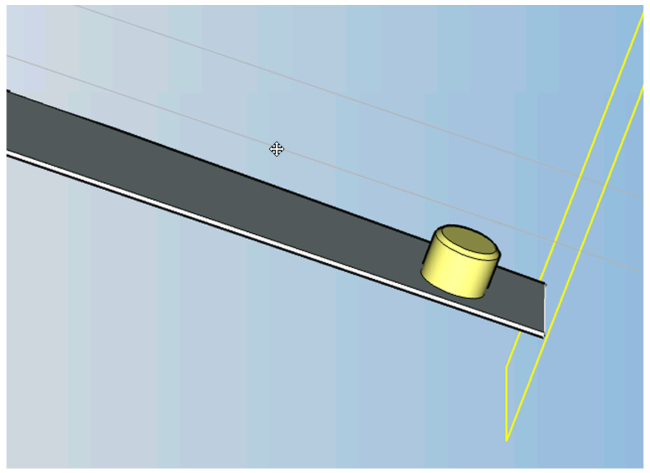
1. Procedure scharnierblokken uitlijnen.



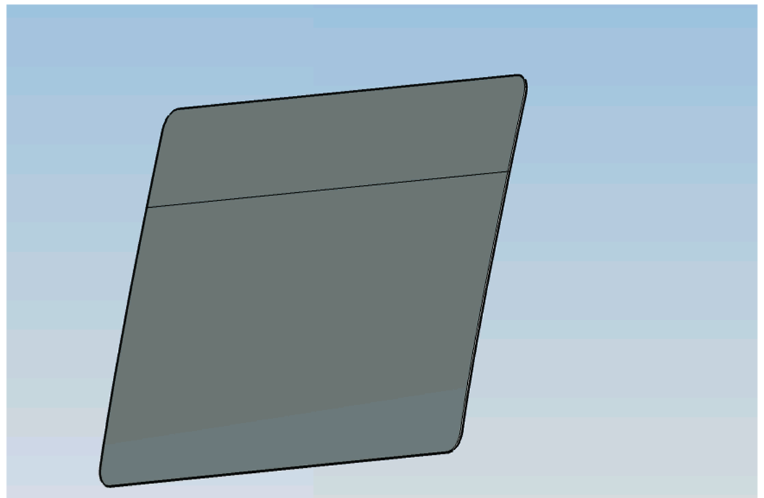
2. Strippen, hijsproppen en doorvoeren in langs en dwarsschotten lassen.
    - Voorbocht geven (kant van de strip bol)voor het lassen.



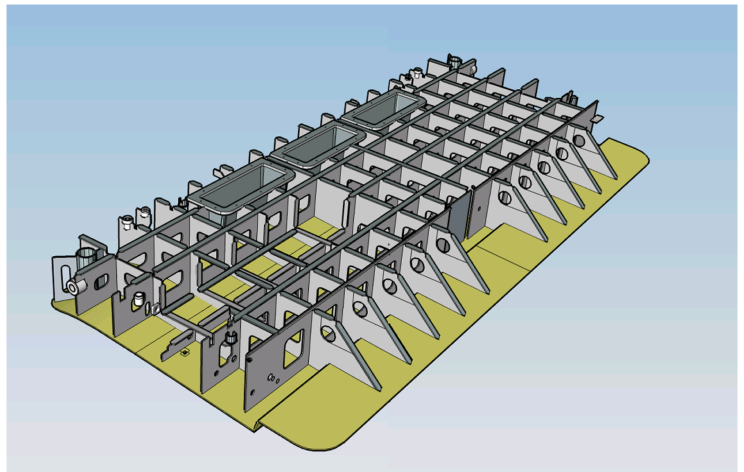
3. Lockpotten in zijkant lassen.
    - Hoeklas hechten
    - V-naad aflassen
    - Met lijmklemmen voorbocht geven
    - Hoeklas aflassen



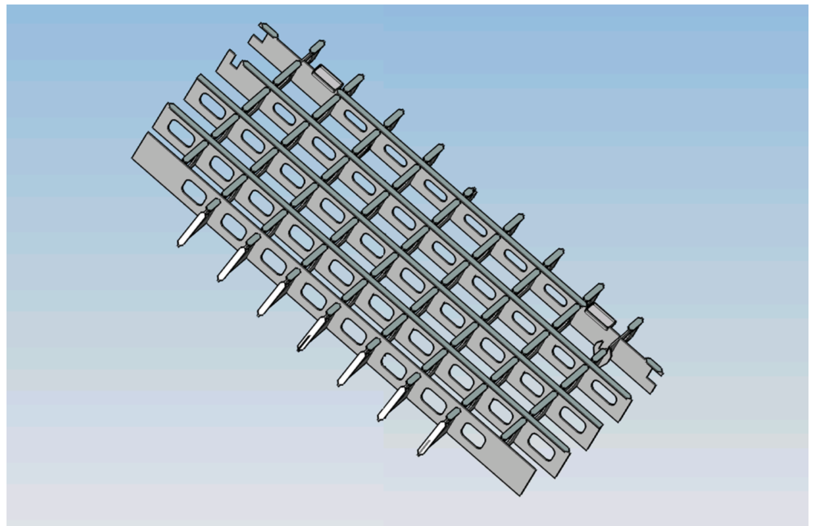
4. Huidplaat aan elkaar hechten en aflassen met buggy procedure.



5. Dwars en langsschotten plaatsen op huid met eventuele portholes en pijpleidingen.

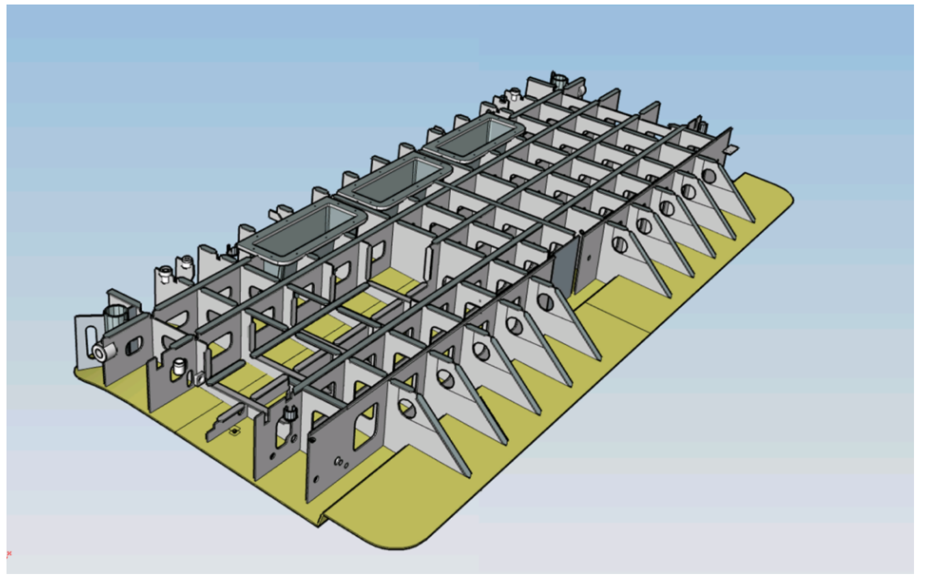


6. Framewerk van huidplaat afhalen en onder de hand aflassen richting de huidplaat.

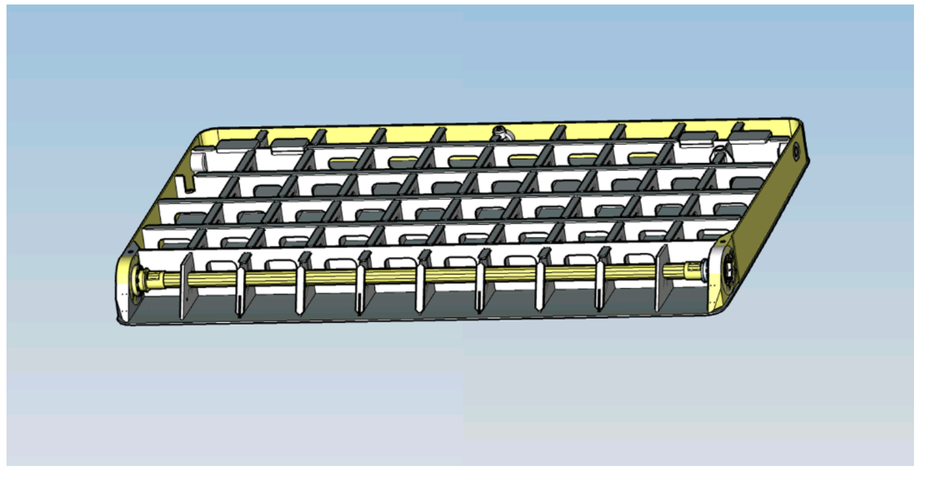


Bouvolgorde platform

7. Framewerk weer terug plaatsen op huidplaat en scheluwvrij opstellen.



8. As met scharnierblokken en zijkanten plaatsen.



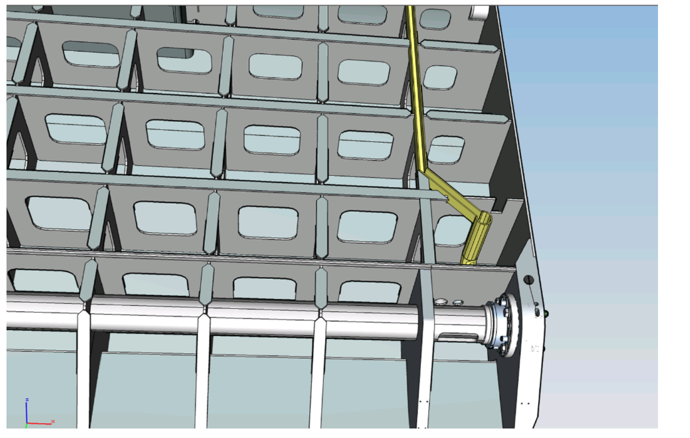
9. Stringers op zijkanten plaatsen.

10. Aan de binnenkant alles aflassen.

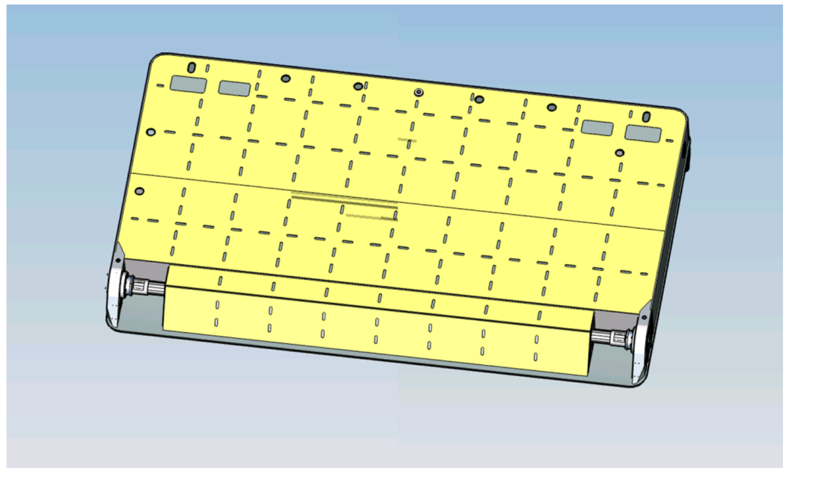
11. Plaatjes voor elektra en hydrauliek plaatsen.

12. Tussentijdse montagewerkzaamheden plus afnames klant en Lloyd's.

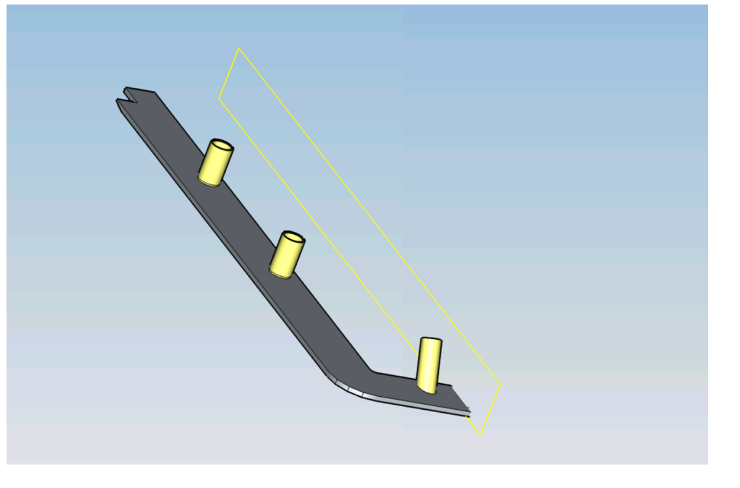
13. Eventuele lichtlijsten plaatsen.



14. Sluitplaat plaatsen en aflassen

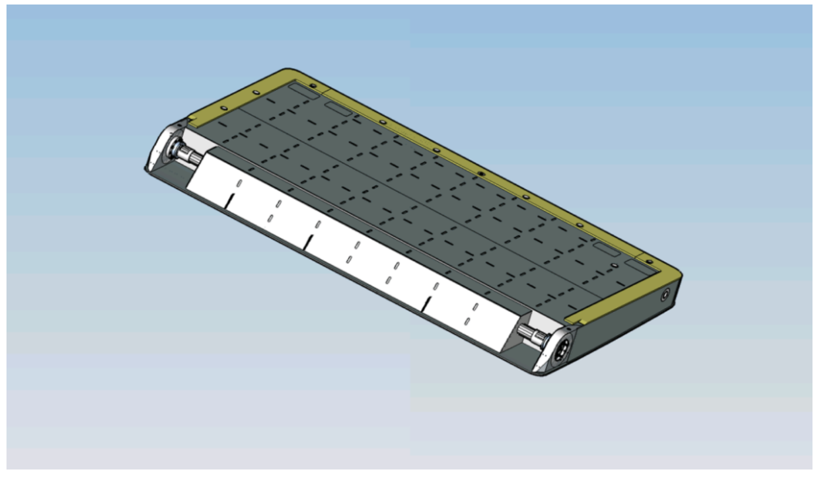


15. Potjes in sealedge lassen.



Bouwvolgorde platform

16. Sealedge plaatsen en aflassen.



17. Buitenkanten alles aflassen.

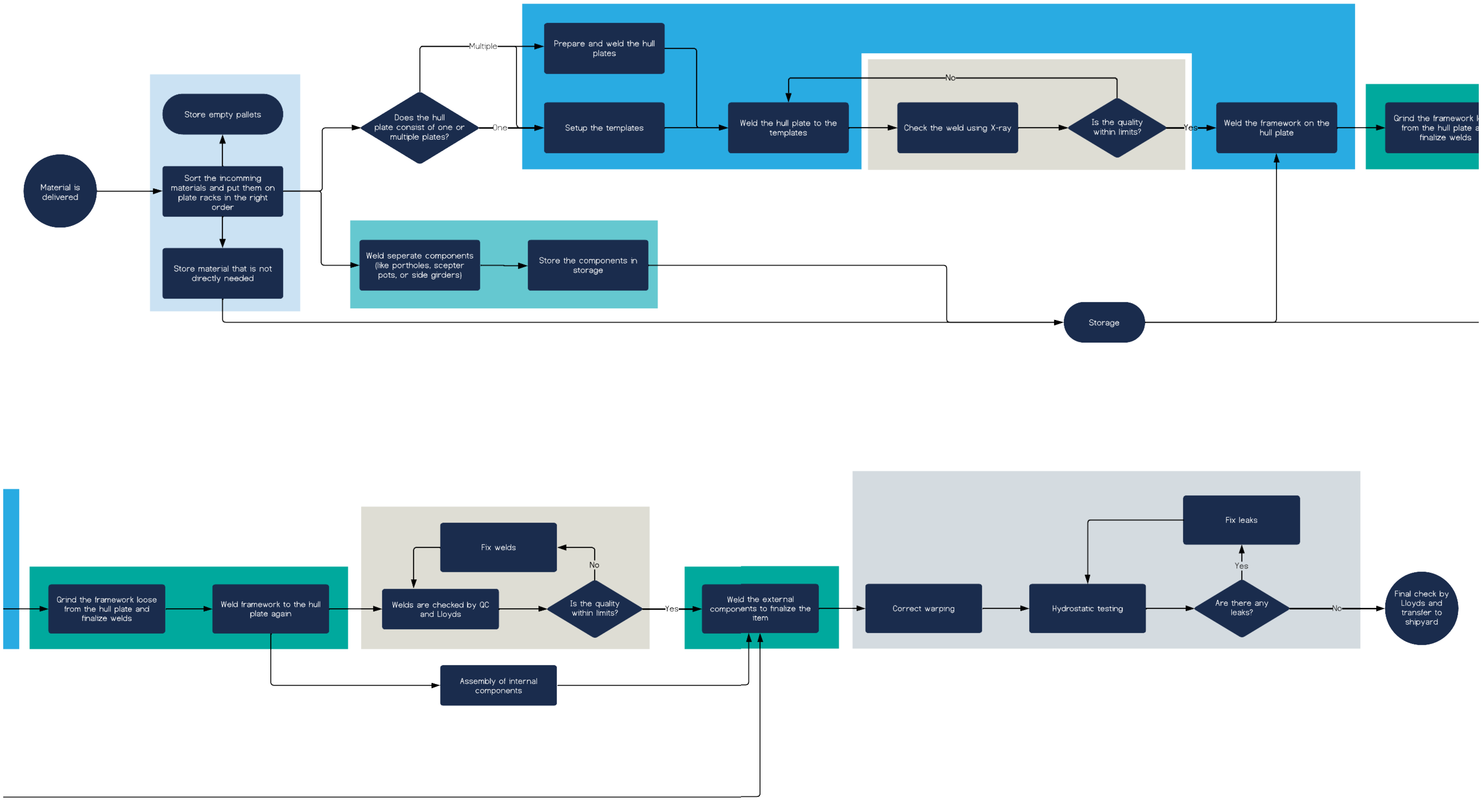
18. Richten en afwerken.

19. Afpersen.

20. Raamframes plus deksels plaatsen.

Appendix D

More in-depth flowchart of the welding process



Appendix E

Detailed list of challenges and bottlenecks

Ergonomics & working posture

- H-beams are too low for ergonomic work, forcing employees to work on their knees.
- Welding tables are slightly higher, but still force employees into awkward positions (cannot reach all spots) especially when finalizing welding the **structure**.
- Not all welding spots, during finalizing welding of the internal components, can be easily reached, forcing employees into unergonomic positions. In addition, this step in the process takes the most time (approximately 80 hours for a medium-sized **item**).
- Employees have to climb on top of the **items** to reach all welding spots.

Hall lay-out & logistics

- Leveling and aligning H-beams is time-consuming, requiring a full day of tedious work. Approximately 3 hours per beam, including setting up **templates**.
- H-beams are 'essential' to prevent **items** warping, due to their high structural strength.
- **Items** need to be flipped to access all welding spots, requiring hoist activities which could increase the risk of accidents.
- The crane system in Leiden, divided into two, lacks full-width coverage—creating a 'strip' in the middle of the hall where no hoisting is possible (unlike Katwijk's full-width crane).
- The **Stelcon slabs** in Katwijk are unstable and therefore unsuitable for manufacturing.
- They are unsuitable because these slabs do not provide a solid base to which can be welded (i.e. the slabs can move independently from each other).
- Katwijk's low ceiling height restricts the maximum dimensions of platforms, doors, and hatches that can be constructed.
- Cables for power, welding, etc. run all over the floor creating tripping hazards.
- In addition, this causes extra wear and tear on the cables which can result in dangerous situations.
- When the hall is full, there is no space to put the pallets with the materials so employees need to put the aluminum sheets in makeshift racks. These racks are not (yet) approved.
- In addition, the material on the pallets is not stacked in chronological order.
- The pallets have a deposit, so they need to be stored somewhere awaiting pick-up.
- When the racks are not in use, they take up valuable space.

Work-process & communication

- Tools need to be borrowed from the technical services No standard/modular toolbox.
- Tools should be registered and returned to Technical Support, but this does not always happen.
- Certain procedures, though feasible on paper, prove impractical in practice, necessitating extra steps that reduce time efficiency.
- There are, however, multiple reviews during the engineering of the **items**. These reviews give the Foremen the opportunity to address any difficulties/problems.
- employees cannot/are not allowed to contact engineers directly. Communication is routed through the foreman, which can result in delayed and inaccurate responses.
- There is no direct feedback/communication between engineering and employees which can have negative consequences.

Bottlenecks in the process, derived from discussions/conversations with the foreman:

- Waiting for materials - not all materials are delivered at the same time which means that employees sometimes need to wait up to a week before they can continue their work.
- The materials are delivered in reversed order - the **hull plate** is on the bottom of the pallet thus forcing the employees to move materials multiple times.

Appendix F

Complete overview of the dimensions & weights of the items

Crew Door	710	730	1585	
	712	830	1675	157
	715	1500	1760	167
	716	1875	1300	
	719	915	1900	232
	1012	900	1800	
	1014	900	2085	234
	Mean	1,1	1,7	198

Mooring Platform	UNKNOWN	1530	3224	126
	712	940	2360	208
	715	1260	2511	342
	1012	1490	2850	466
	1014	1440	3200	449
	1015	1180	2675	348
	Mean	1,3	2,8	323

Transom Door	UNKNOWN	2175	3200	508,5
	825	2010	3500	498
	828	2100	2145	351,5
	829	1600	3390	570,5
	Mean	2,0	3,1	482

Rescue Boat Hatch	714	3830	7270	2272
	716	4726	6751	1816
	1014	3730	7926	2662
	Mean	4,1	7,3	2250

Side Platform	712	2934	5260	2183
	715	2855	6495	2430
	716	3030	4650	1632
		2100	3500	1178
		2910	3369	1215
	826	3154	7785	2934
	1014	3346	6160	2136
		2,9	5,3	1958

Boat Store Door	712	3030	8850	3608
	713	3010	8850	2662
	716	2610	9685	
	717	2420	6875	1100
	1014	3135	11970	4271
	1015	3095	10740	2493
	Mean	2,9	9,5	2827

Stern Platform	JNKNOWN	3455	8000	3256
	711	3200	5460	3301
	714	5034	6590	4108
	826	5000	10700	4495
	830	4280	10630	
	1014	4930	7940	
	Mean	4,3	8,2	3790

Gangway Hatch	711	767	1246	66
	712	1255	2060	221
	714	1200	1400	172
	715	1150	1460	174
	716	1100	1280	173
	Mean	1,1	1,5	161

	Width (m)	Depth (m)	Approx. total weight (kg)	Surface
Mean CD	1,9	1,2	420	2,4
Mean MP	2,9	1,4	390	4,0
Mean TD	3,1	2,0	2593	6,0
Mean GP	4,3	2,9	2350	12,6
Mean RBH	6,3	3,1	3619	19,4
Mean BCP	7,3	4,2	2810	31,0
Mean TSD	9,5	2,5	3800	23,5
Mean SP	10,7	5,0	9325	53,5
Mean CD	1,9	1,2	420	2,4
Mean MP	2,9	1,4	390	4,0
Mean TD	3,1	2,0	916	6,0
Mean RBH	7,8	3,2	2955	24,8
Mean SiP	5,3	2,9	3011	15,4
Mean BSD	12,0	3,1	5200	37,5
Mean SP	9,4	4,2	9325	39,5

Appendix G

Complete overview of the amount of items produced

An overview of the **items** produced in the past seven years was created to gain insight in the manufacturing quantities of the **items** manufactured at Akerboom. These manufacturing quantities were extracted from reports of QC, which state yard number, type of **item**, and dates from start of the project up until the final check.

Table X shows all the manufactured **items** over the past seven year. Red means that **item** has not been manufactured in that year, and the darker blue the cell the more it was manufactured.

Tender Store Doors are the most frequently produced **items**, with a total of 35 manufactured over the past seven years—an average of five per year. Following closely are Beach Club Platforms, with 27 units, averaging approximately four per year.

Although these **items** are named based on their intended use, many of them share structural and functional similarities despite having different names. For example, Rescue Boat Doors, Toy Store Doors, and Boathouse Doors are nearly identical in design and function to Tender Store Doors—the primary difference lies in the type of object stored behind them.

To create a clearer and more comprehensive overview (see the table on the next page, these similar **items** have been grouped into categories. Tender Store Doors and their equivalents are now collectively referred to as Boat Store Doors. Platforms similar to Beach Club Platforms, which are typically located along the port and starboard sides of the yacht, are grouped under the category Side Platforms. Lastly, Stern Platforms now serve as a combined category for Swim Platforms, Stern Platforms, and Transom Platforms, as they all serve a similar function at the rear of the vessel.

Based on the newly defined categories, Side Platforms are the most frequently produced **items**, with a total of 41 units manufactured over the past seven years—an average of approximately 5.9 units per year. Boat Store Doors follow closely, with 36 units produced during the same period, resulting in an average annual manufacturing rate of 5.1 units.

Mooring Platforms, Gangway Hatches, Rescue Boat Hatches, and Crew Doors rank third, fourth, fifth, and sixth in manufacturing volume. Collectively, they have been manufactured 69 times in the past seven years, averaging almost ten units per year.

Together with the Transom Doors and Stern Platforms these **items** make up a little over 80% of total manufacturing. All these **items** are, in average, produced at least one time per year in the past seven years.

Table 5: *Overview of the amount of manufactured items.*

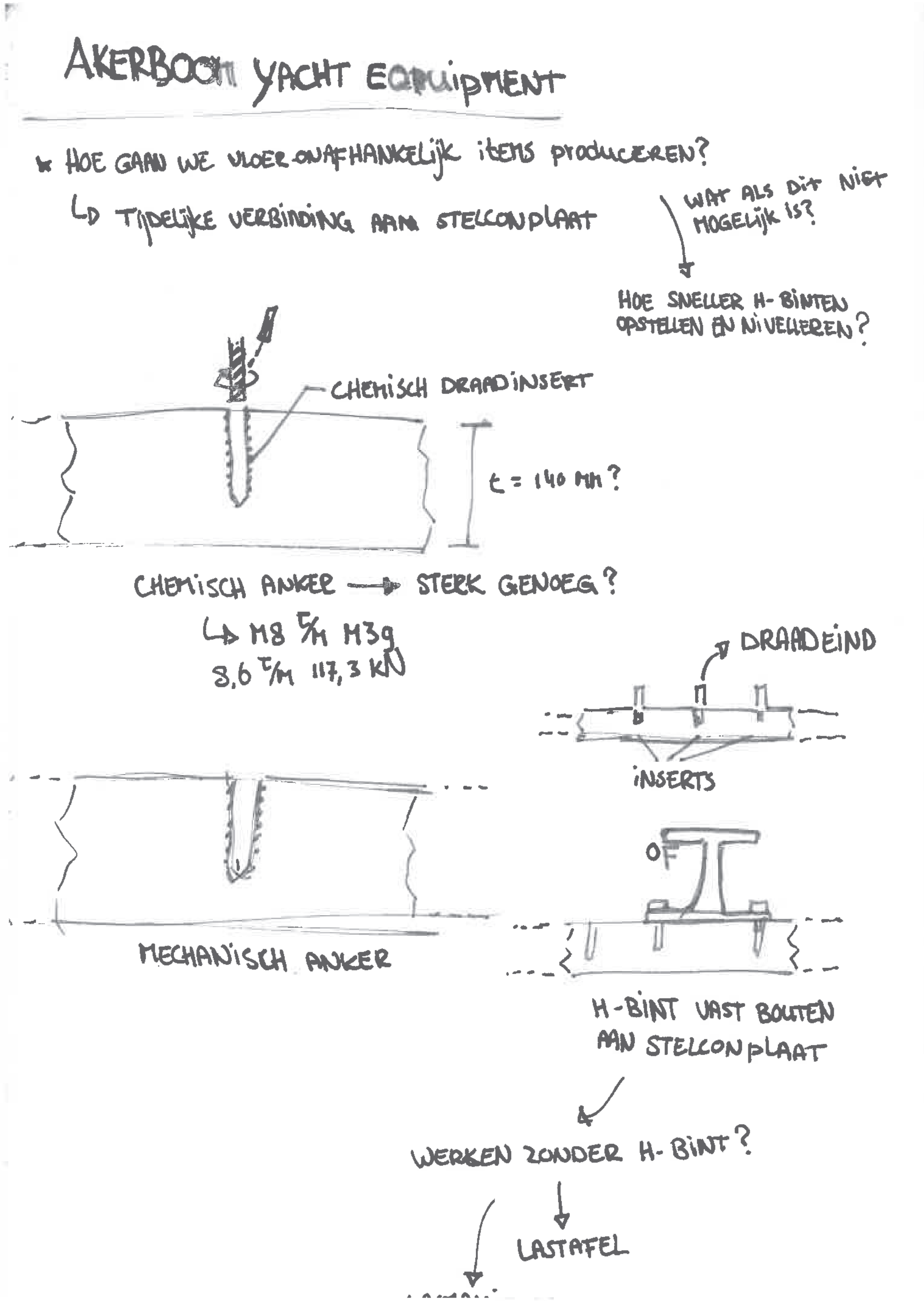
								Totaal	Gemiddeld per jaar
Tenderstore Door	6	5	4	3	7	7	3	35	5,0
Beachclub Platform	4	3	4	2	4	6	4	27	3,9
Mooring Platform	2	2	4	2	6	4	2	22	3,1
Gangway Hatch	3	3	3	2	3	3	2	19	2,7
Crew Door	3	2	1	1	3	2	2	14	2,0
Rescue Boat Hatch	1	2	1	1	3	5	1	14	2,0
Transom Door	2	2	0	3	1	3	0	11	1,6
Gym Platform	0	1	1	1	3	1	1	8	1,1
Transom Hatch	1	0	3	0	2	0	0	6	0,9
Life Raft Hatch	0	2	2	0	0	1	0	5	0,7
Swim Platform	1	1	1	1	0	0	0	4	0,6
Side Boarding Ladder Hatch	0	2	0	0	2	0	0	4	0,6
Stern Platform	0	0	0	0	1	1	1	3	0,4
SwimLift Hatch	1	1	0	0	0	0	0	2	0,3
Heli Hatch	0	0	0	0	2	0	0	2	0,3
Rescue Door	0	0	0	0	0	0	2	2	0,3
Gangway Siding Hatch	0	1	0	0	0	0	0	1	0,1
Guest Boarding Platform	0	0	1	0	0	0	0	1	0,1
Folding Hatch	0	0	0	0	1	0	0	1	0,1
Boarding Ladder Hatch	0	0	0	0	0	1	0	1	0,1
Boarding Platform	0	0	0	0	0	1	0	1	0,1
Boathouse Door	0	0	0	0	0	0	1	1	0,1
Bunkering Platform	0	0	0	0	0	0	1	1	0,1
Terace Platform	0	0	0	1	0	0	0	1	0,1
Atrium Platform	0	0	0	1	0	0	0	1	0,1
Owners Office Platform	0	0	0	0	0	0	1	1	0,1
Accommodation Ladder Hatch	1	0	0	0	0	0	0	1	0,1
Sliding Hatch	0	1	0	0	0	0	0	1	0,1
SPA Platform	0	0	1	0	0	0	0	1	0,1
Massage Platform	0	0	1	0	0	0	0	1	0,1
Toy Store Hatch	0	0	0	1	0	0	0	1	0,1
Totaal	27	31	29	22	40	37	23	193	

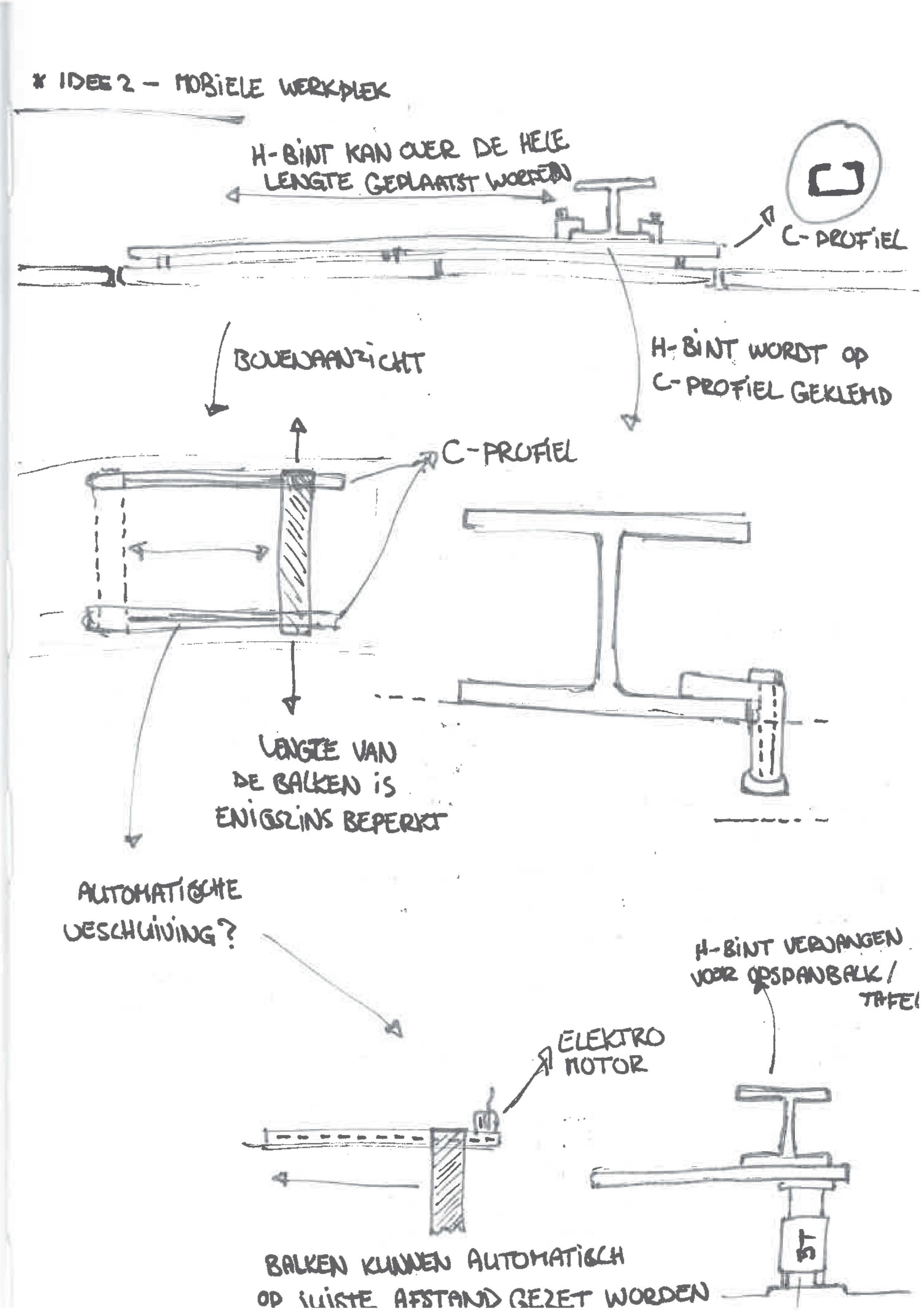
Table 6: *Overview of the amount of manufactured items with new categories.*

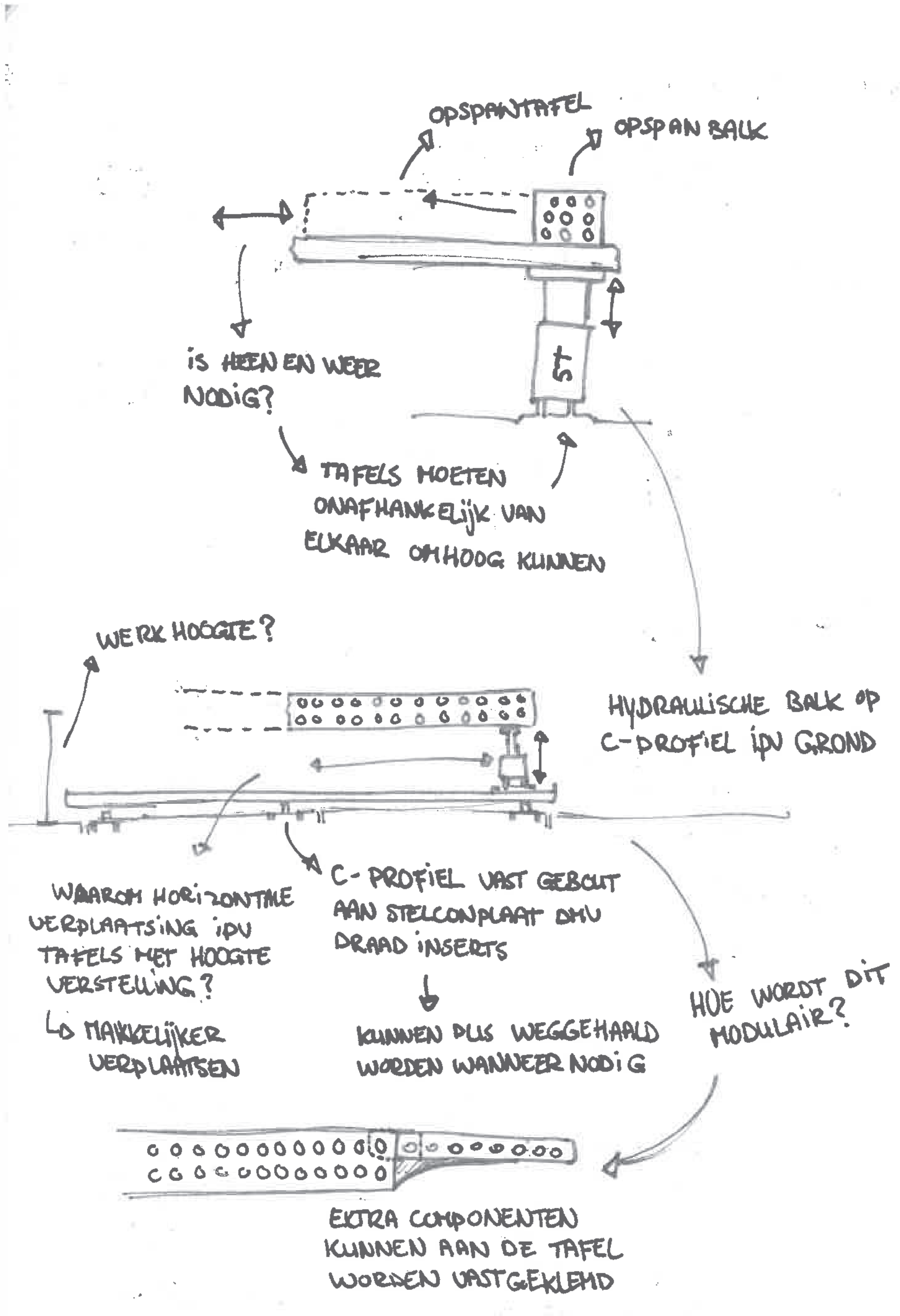
	2018	2019	2020	2021	2022	2023	2024	Total	Average per year
Side Platforms	4	4	7	5	7	7	7	41	5,9
Boat Store Doors	6	5	4	3	7	7	4	36	5,1
Mooring Platform	2	2	4	2	6	4	2	22	3,1
Gangway Hatch	3	3	3	2	3	3	2	19	2,7
Rescue Boat Hatch	1	2	1	1	3	5	1	14	2,0
Crew Door	3	2	1	1	3	2	2	14	2,0
Transom Door	2	2	0	3	1	3	0	11	1,6
Stern Platforms	1	1	1	1	1	1	1	7	1,0

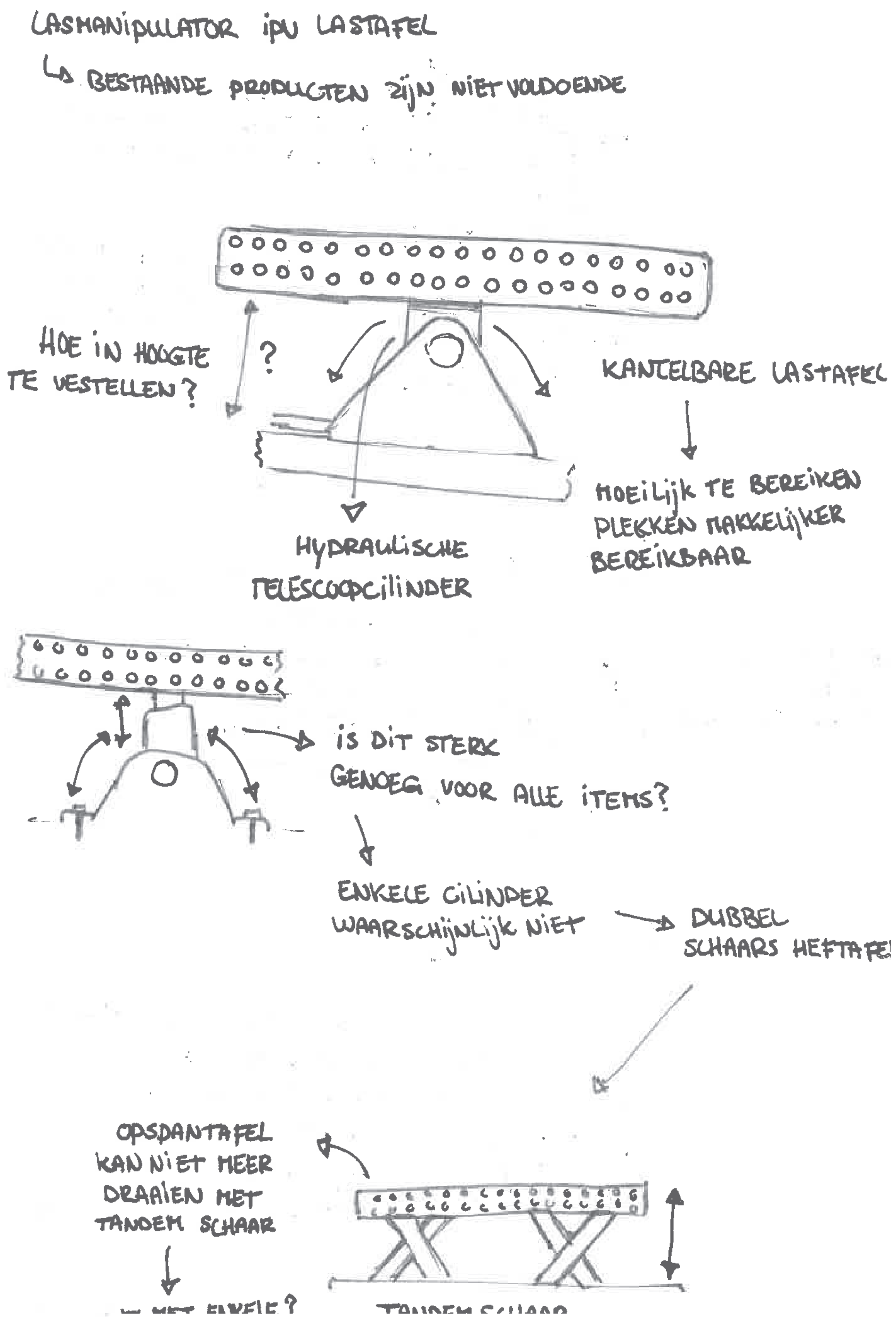
Appendix H

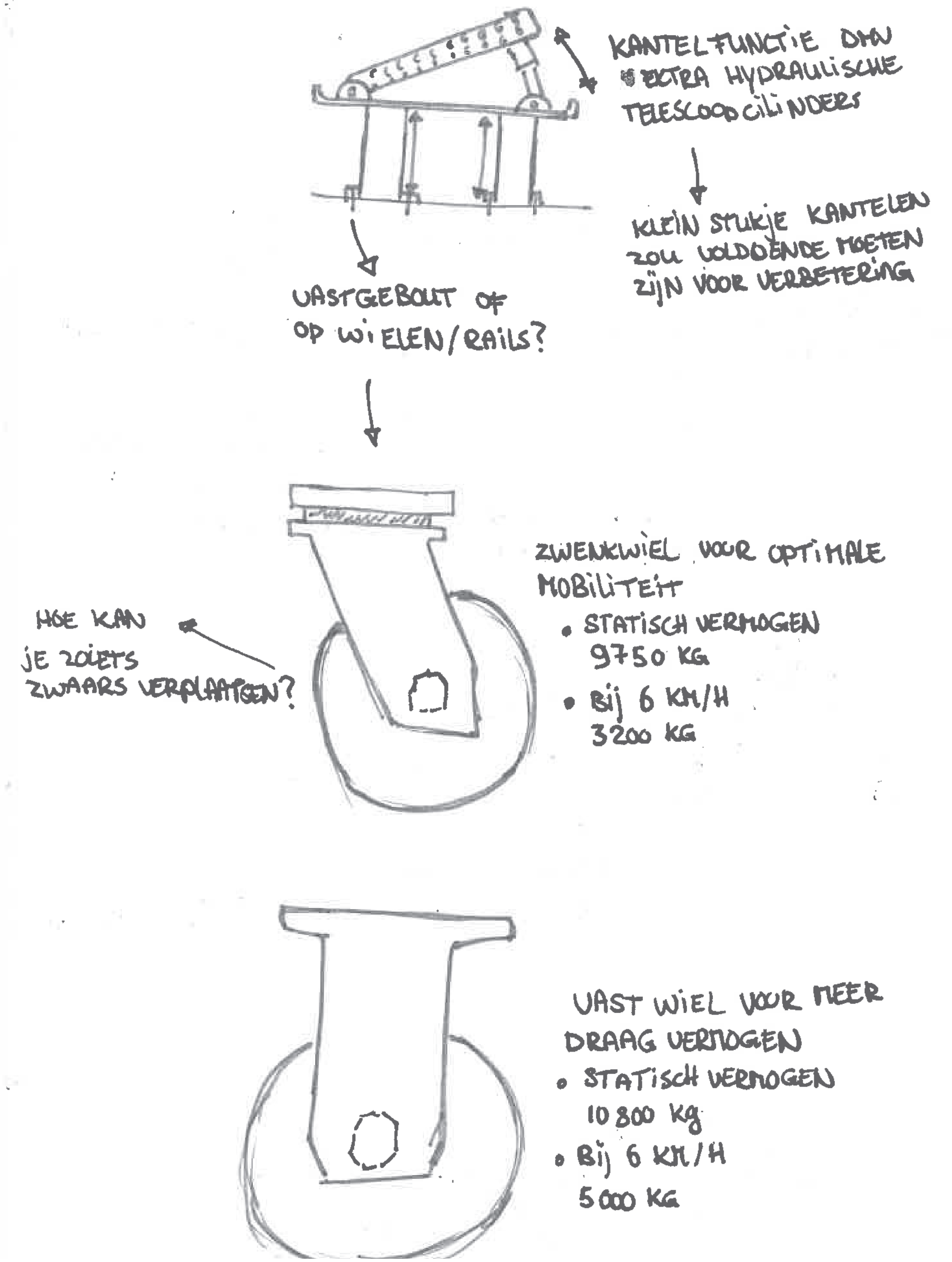
Ideation sketches

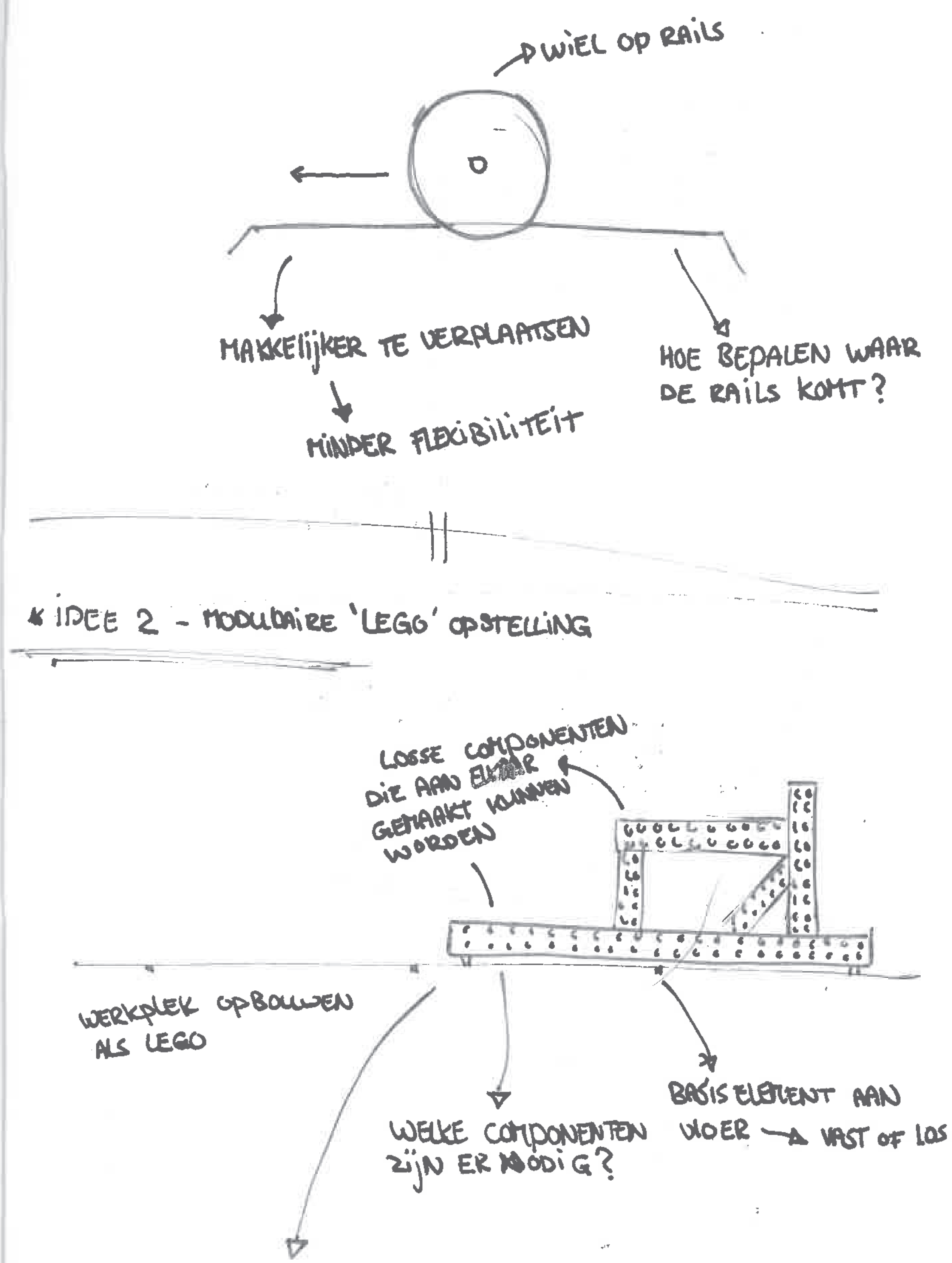


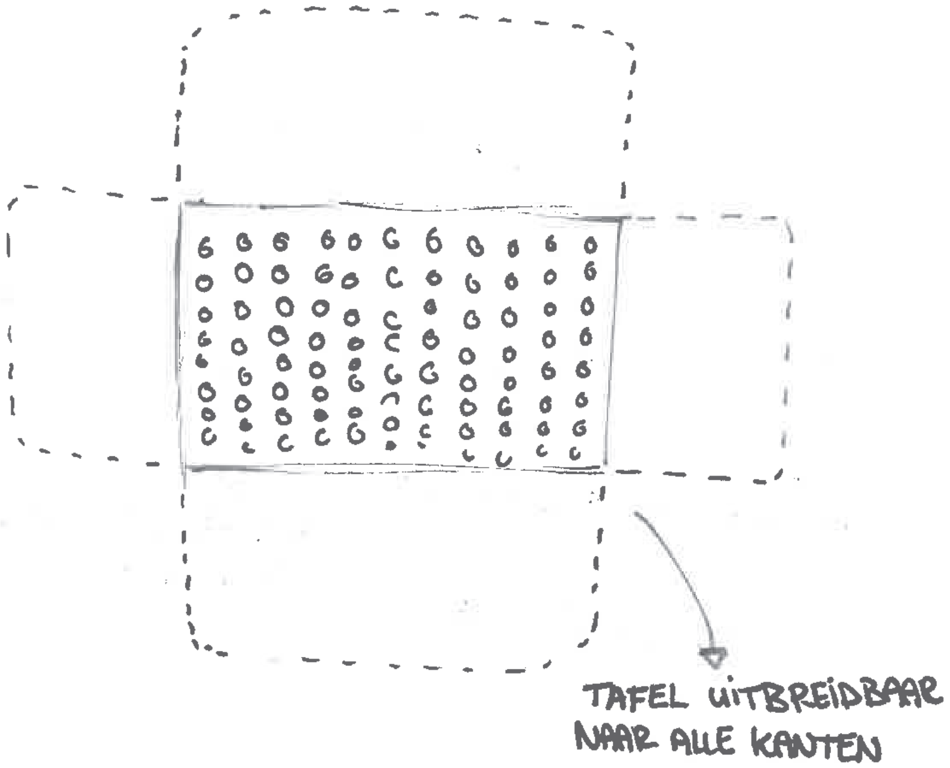


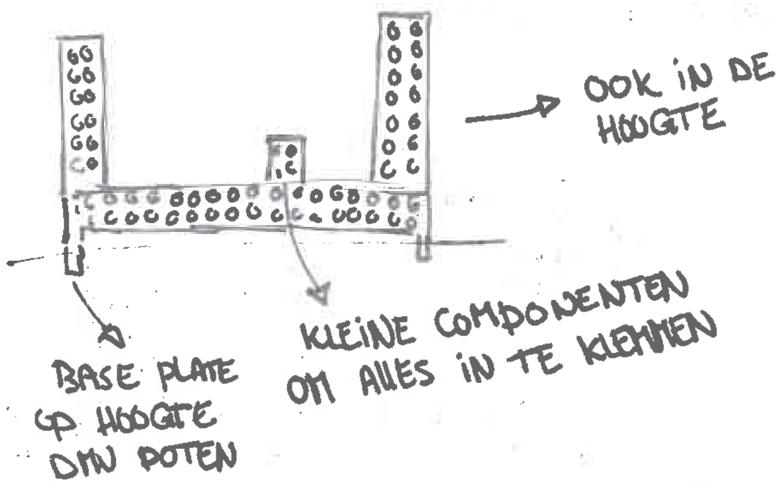

OPSPANTAFEL
OPSPAN BALK
IS HEEN EN WEER NODIG?
TAFELS MOETEN ONAFHANKELIJK VAN ELKAAR OMHOOG KUNNEN
WERK HOOGTE?
HYDRAULISCHE BALK OP C-PROFIEL IPV GROND
WAAROM HORIZONTALE VERPLAATSING IPV TAFELS MET HOOGTE VERSTELLING?
↳ MAKKELIJKER VERPLAATSEN
C-PROFIEL VAST GEBOUT AAN STELCONPLAAT DMV DRAAD INSERTS
KUNNEN DUS WEGGEHAALD WORDEN WANNEER NODIG
HOE WORDT DIT MODULAIR?
EXTRA COMPONENTEN KUNNEN AAN DE TAFEL WORDEN VASTGEKLEMD


LASMANIPULATOR IPV LASTAFEL
↳ BESTAANDE PRODUCTEN ZIJN NIET VOLDOENDE
HOE IN HOOGTE TE VESTELLEN?
?
KANTELBARE LASTAFEL
MOEILIJK TE BEREIKEN PLEKKEN MAKKELIJKER BEREIKBAAR
HYDRAULISCHE TELESCOOPCILINDER
IS DIT STERK GENOEG VOOR ALLE ITEMS?
ENKELE CILINDER WAARSCHIJNLIJK NIET
DUBBEL SCHAARS HEFTAFE
OPSPANTAFEL KAN NIET MEER DRAAIEN MET TANDEM SCHAAR

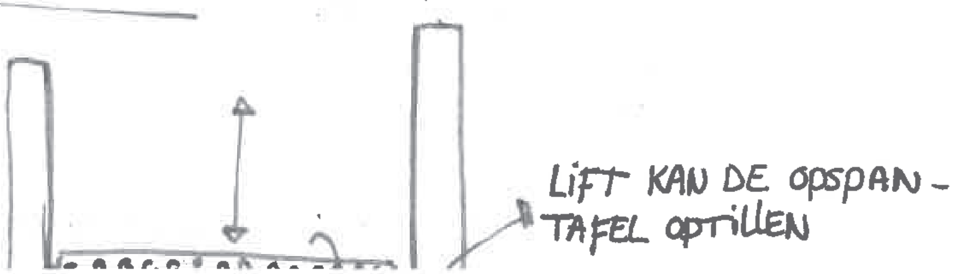

KANTELFUNCTIE DMV EXTRA HYDRAULISCHE TELESCOOPCILINDERS
KLEIN STUKJE KANTELEN ZOU VOLDOENDE MOETEN ZIJN VOOR VERBETERING
VASTGEBOUT OF OP WIELEN/RAILS?
ZWENKWIEL VOOR OPTIMALE MOBILITEIT
• STATISCH VERMOGEN 9750 KG
• BIJ 6 KM/H 3200 KG
HOE KAN JE ZOIETS ZWAARS VERPLAATSEN?
VAST WIEL VOOR MEER DRAAG VERMOGEN
• STATISCH VERMOGEN 10 800 kg
• BIJ 6 KM/H 5 000 KG

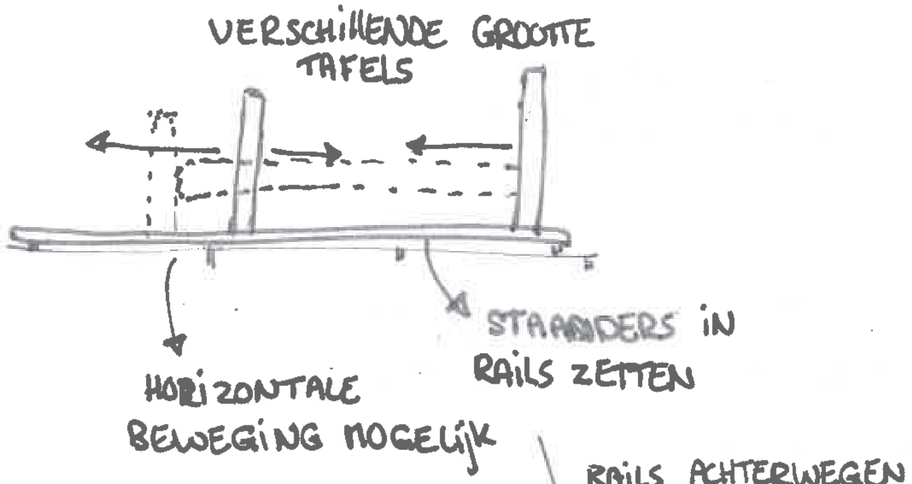

WIEL OP RAILS
MAKKELIJKER TE VERPLAATSEN
MINDER FLEXIBILITEIT
HOE BEPALEN WAAR DE RAILS KOMT?
* IDEE 2 - MODULAIRE 'LEGO' OPSTELLING
LOSSE COMPONENTEN DIE AAN ELKAAR GEMAAKT KUNNEN WORDEN
WERKPLEK OPBOUWEN ALS LEGO
WELKE COMPONENTEN ZIJN ER NODIG?
BASIS ELEMENT AAN VLOER → VAST OF LOS

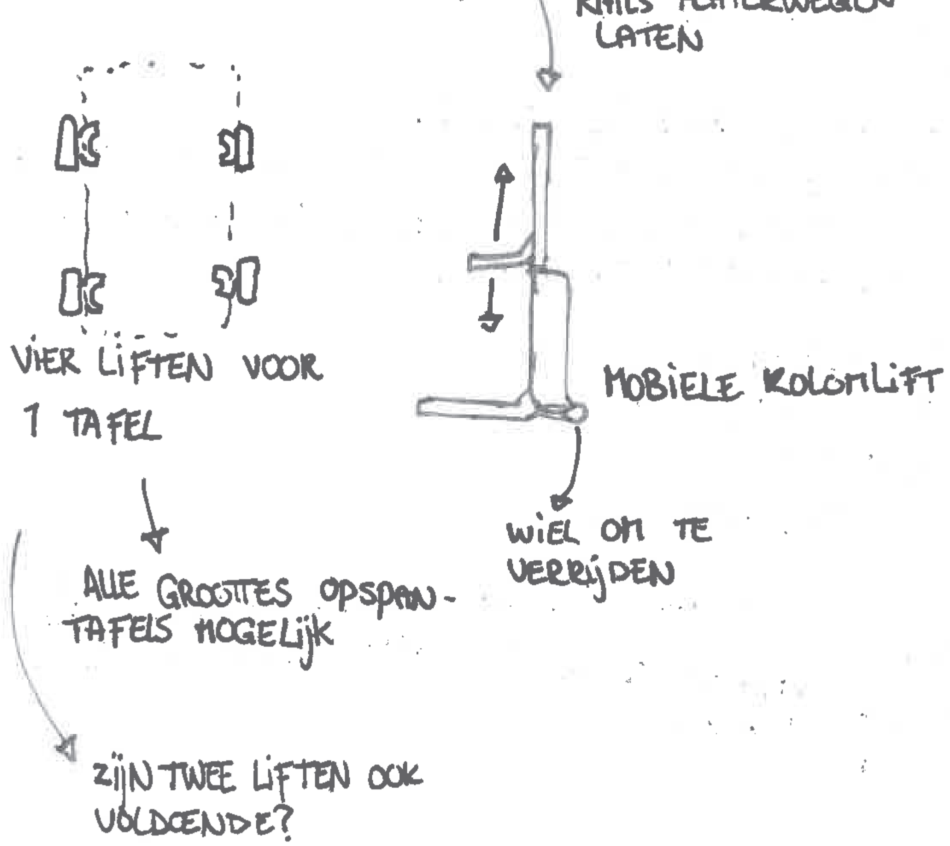




AUTOLIFT PRINCIPE







MORFOLOGISCHE KAART

1. BLIJVEN WERKEN MET H-BINTEN
2. ANDERE OPLOSSINGEN VOOR H-BINTEN

1. H-BINTEN
 * BEVESTIGINGSWIJZE
 * DEMONTEERBAARHEID
 * HOOGTEVERSTELLING
 * HORIZONTALE VERPLAATSING
 * NIVELLEREN
 * FLEXIBILITEIT → * MAKKELIJK/SNEL OPBOUWEN
 * MODULARITEIT → HOE MAKKELIJK SCHALEN VOOR GROTE/KLEINE ITEMS

HEBBEN MET ELKAAR TE MAKEN

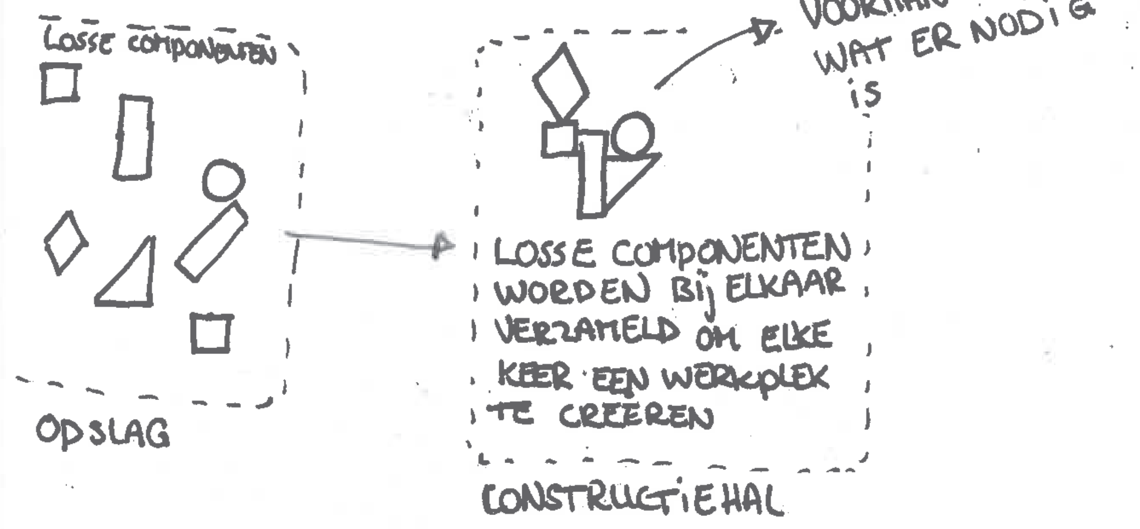
H-BINT KAN ONDERDEEL ZIJN VAN ONDERSTEUNING/ FRAME

2. ANDERE OPLOSSINGEN
 * ONDERSTEUNING / FRAME
 * FIXATIE / VERVORMING TEGENGAAN
 * HOOGTE VERSTELLING
 * HORIZONTALE VERPLAATSING
 * NIVELLEREN
 * FLEXIBILITEIT → KAN OOK GAAN OVER DE FLEXIBILITEIT MET HET WERKSTUK ZELF
 * MODULARITEIT
 * VLOERIMPACT
 * SET-UP TIJD

AFHANKELIJK VAN ELKAAR

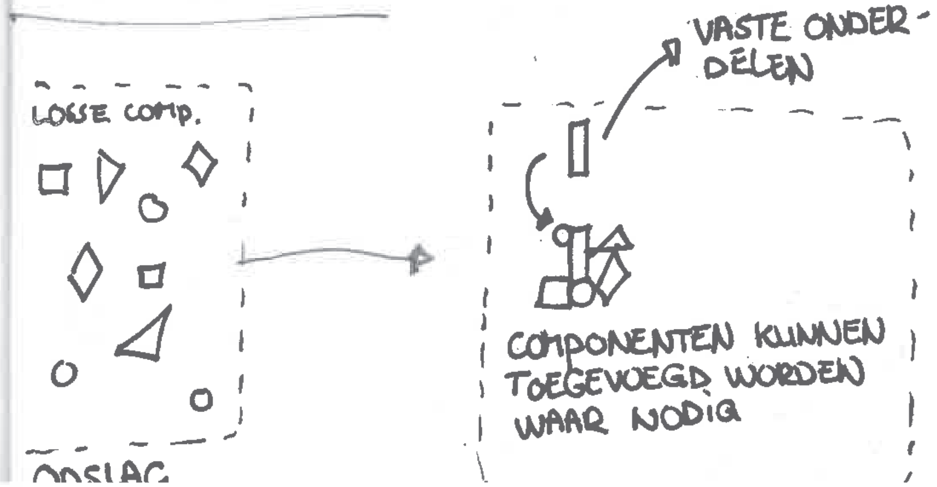
* LAY-OUT/WERKMETHODE IDEEËN

VOLLEDIG MODULAIR



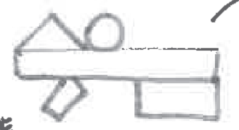
+ OPTIMAAL GEBRUIK VAN DE BESCHIKBARE RUIMTE
+ VEEL FLEXIBILITEIT
– HET CREËREN VAN DE WERKPLEK KOST MEER TIJD

SEMI MODULAIR



ONE-STATION-FITS-ALL

+ GEEN TIJD NODIG OM OP TE ZETTEN
+ ALLE ITEMS KUNNEN GELIJK OP HETZELFDE STATION GEMAAKT WORDEN
- ALS HET NIET IN GEBRUIK IS STAAT HET IN DE WEG



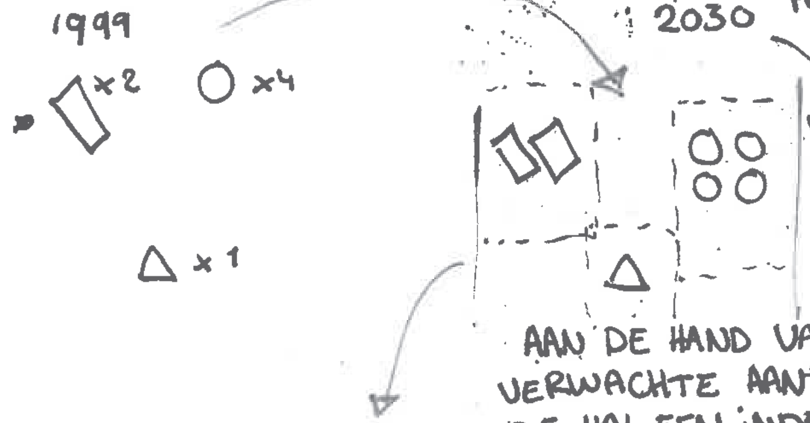
MISSCHIEN WEL GENOEG RUIMTE VOOR?

1 STATION WAAR ALLE ITEMS GEMAAKT KUNNEN WORDEN

FUTURE PREDICTION - ITEM BASED

INDELING OP BASIS VAN VOORGAANDE JAREN

+ KORTE SET-UP TIJD
+ HAL KAN OPTIMAAL INGEDEELD WORDEN
- NA DE VOORSPELLING KAN DE INDELING NIET MEER PASSEN



WELKE ITEMS KOMEN ER AAN?

AAN DE HAND VAN DE VERWACHTE AANTAL ITEMS DE HAL EEN INDELING GEVEN

DE WORKSTATIONS KRIJGEN EEN VASTE PLEK IN DE HAL

CAPACITY BASED

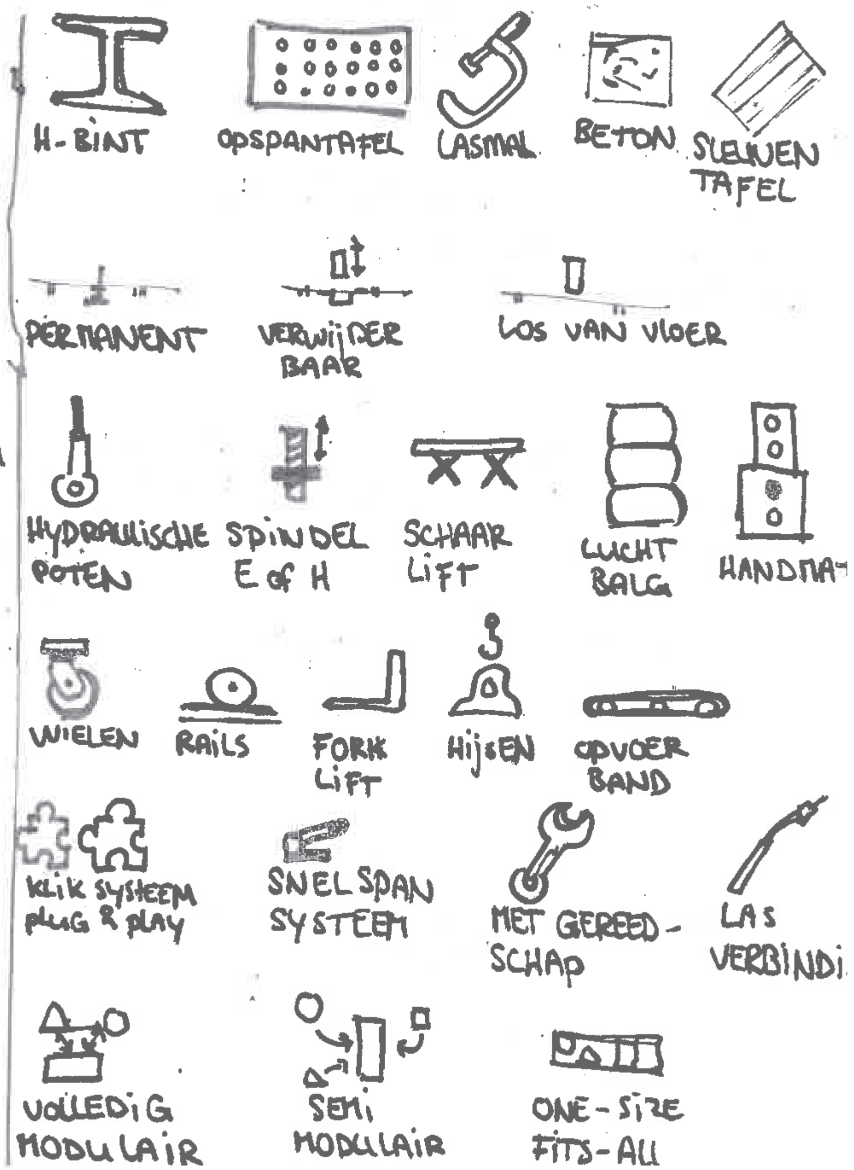
KATWIJK HAS THE CAPACITY FOR SMALL ITEMS AND SOME MIDDLE SIZED ITEMS. (MAX. LARGEST DIMENSION = 5,75M)

LEAN 5S + 2

* SORTEREN
* SCHIKKEN
* SCHOONMAKEN
* STANDAARDISEREN
* STANDHOUDEN

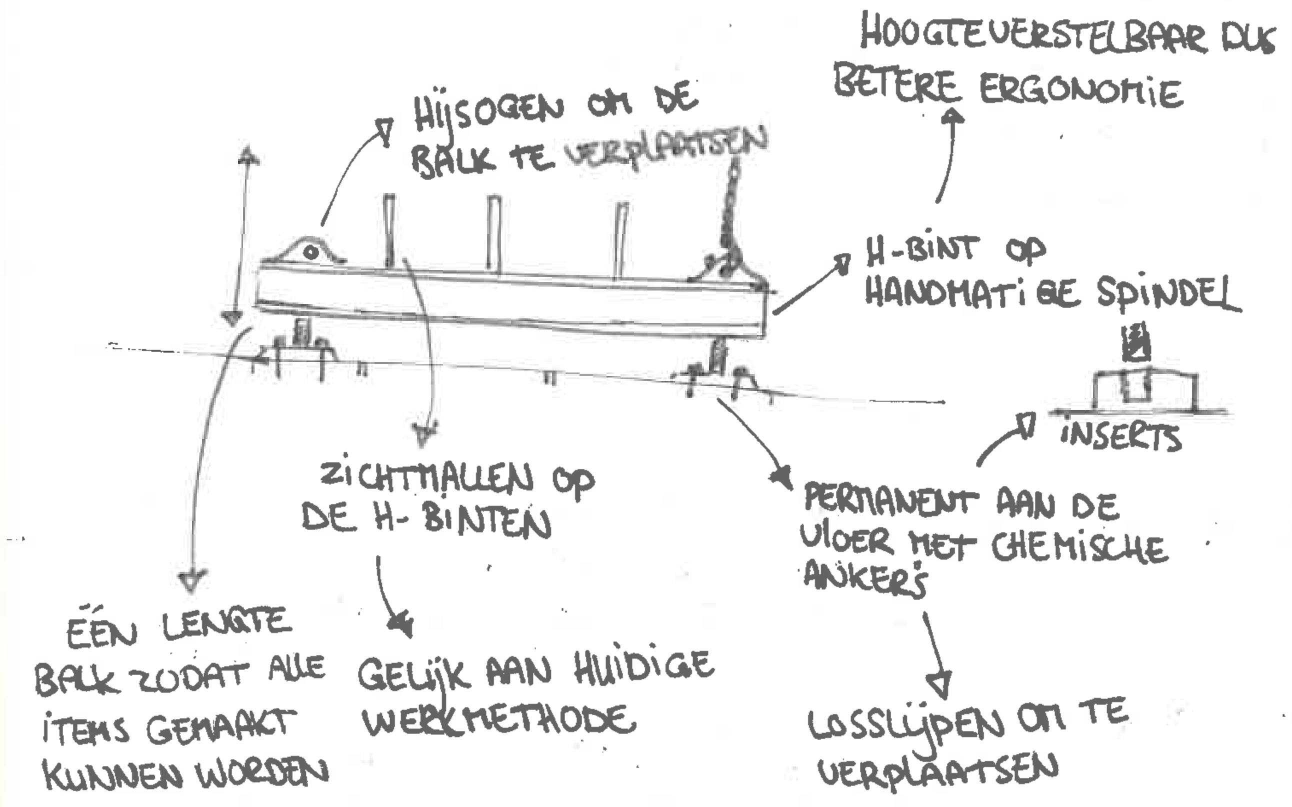
+ * SAFETY
  * SATISFACTION

MORFOLOGISCHE KAART

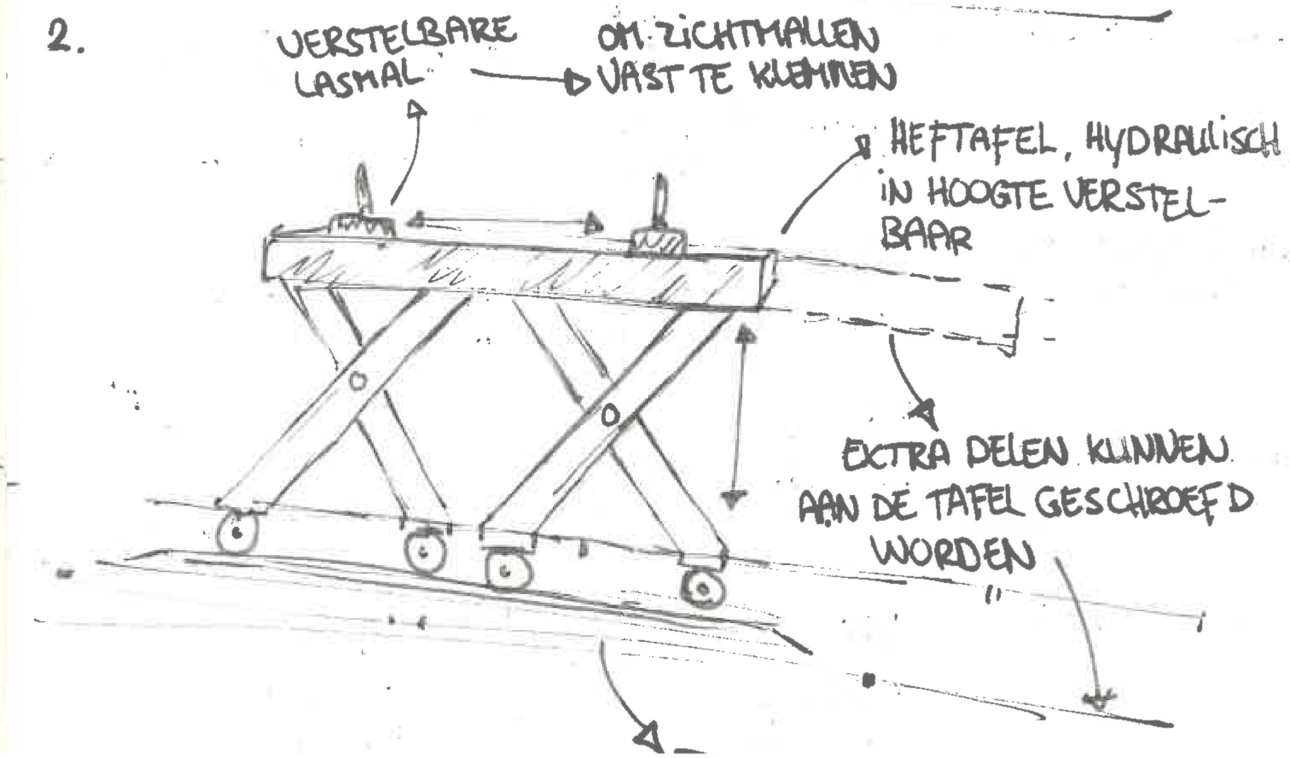


IDEE SCHETSEN

1.



2.



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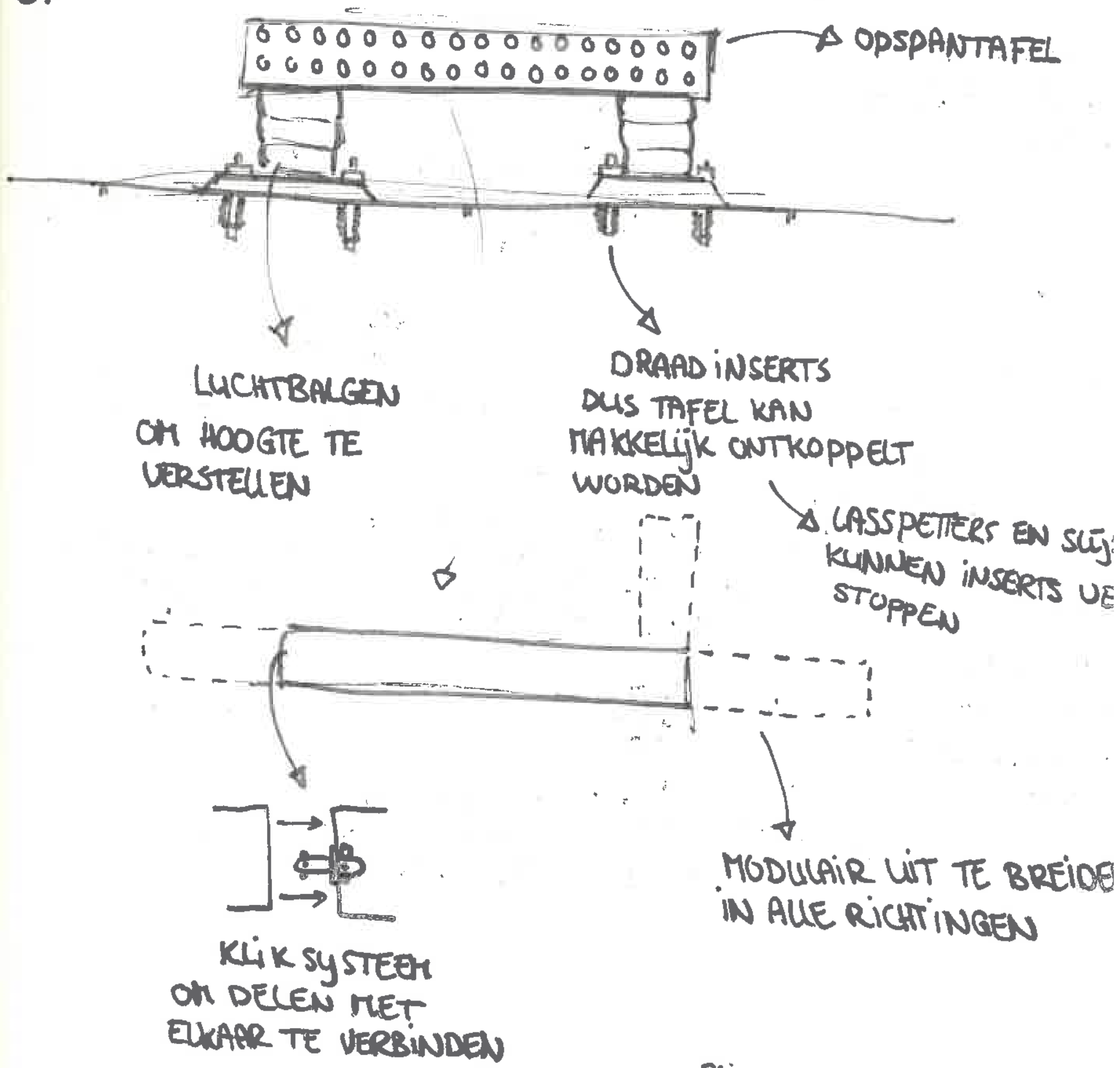
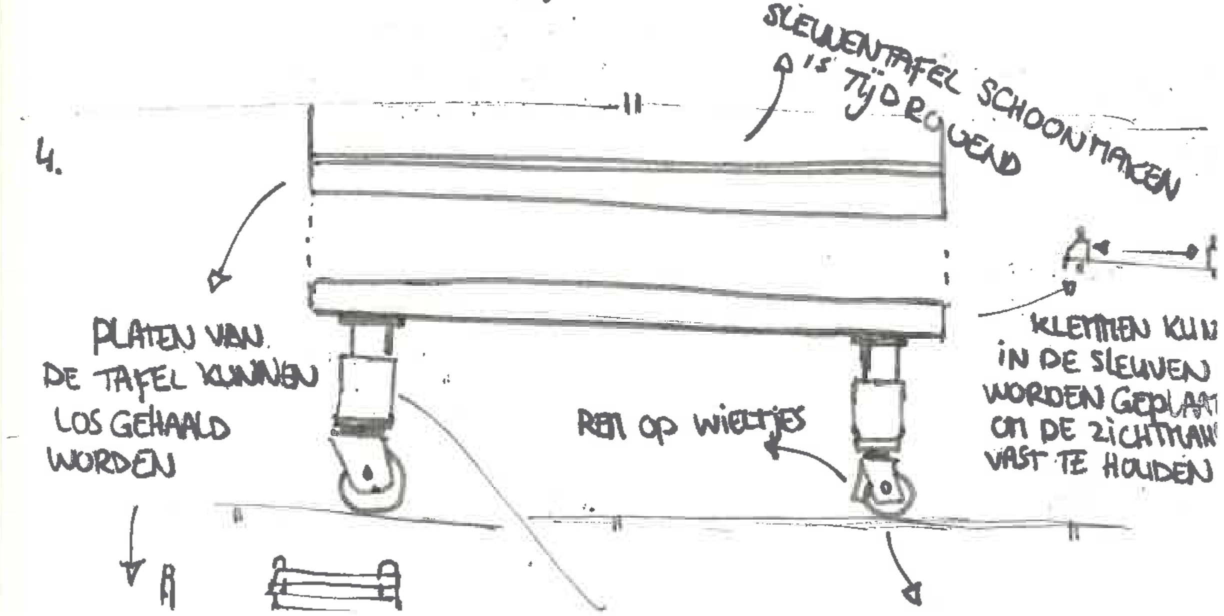
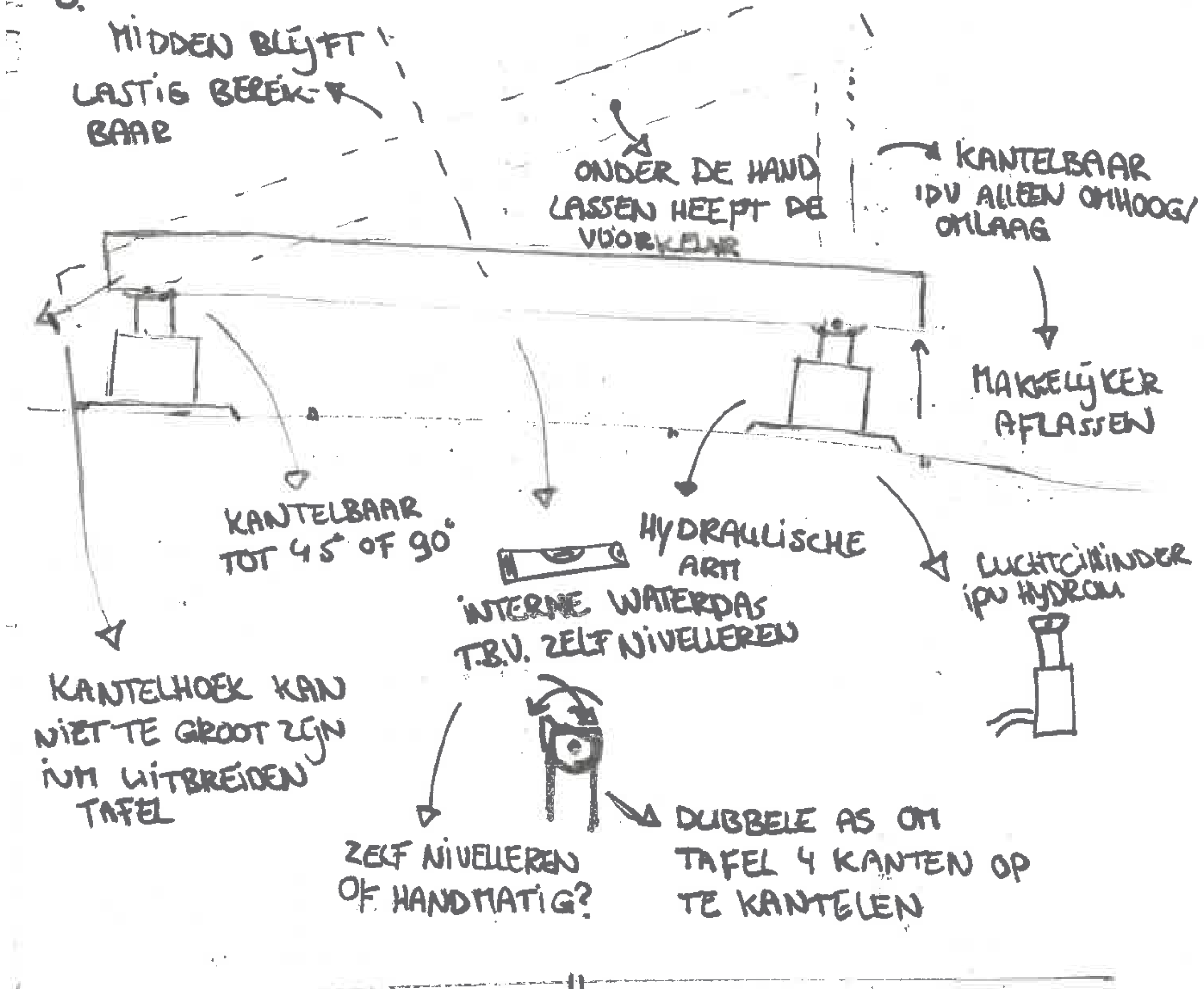


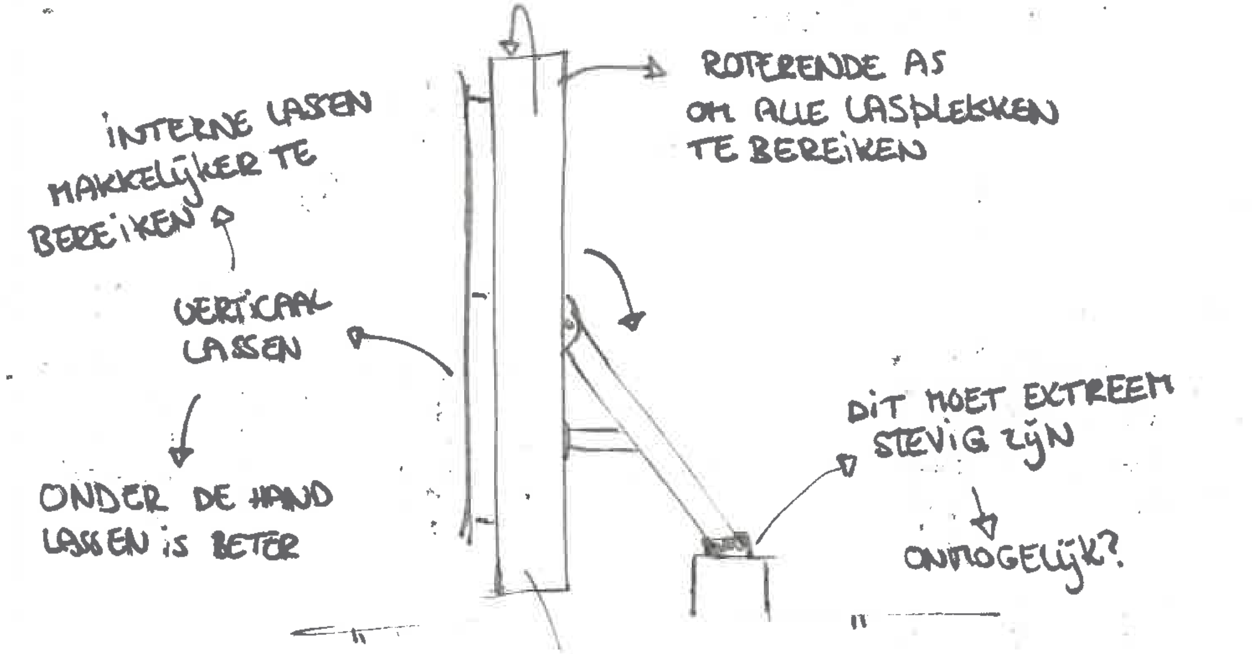
4.



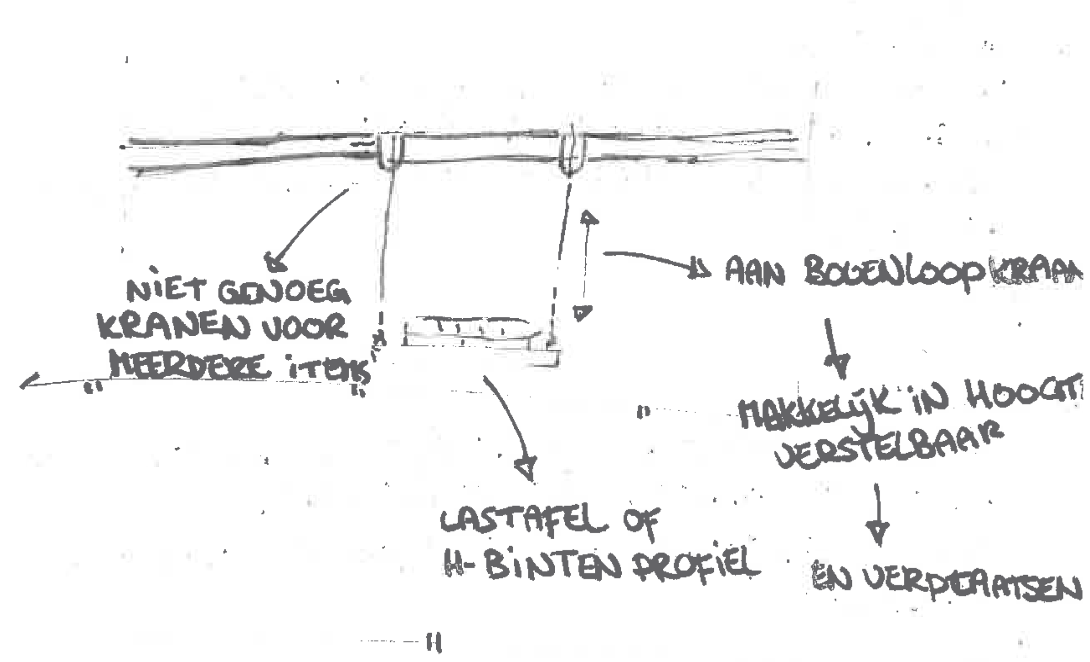
5.


MIDDEN BLIJFT LASTIG BEREIKBAAR
ONDER DE HAND LASSEN HEEFT DE VOORKEUR
KANTELBAAR IPV ALLEEN OMHOOG/OMLAAG
MAKKELIJKER AFLASSEN
KANTELBAAR TOT 45 OF 90°
HYDRAULISCHE ARM
LUCHTCILINDER IPV HYDRO
INTERNE WATERPAS T.B.V. ZELF NIVELLEREN
KANTELHOEK KAN NIET TE GROOT ZIJN IVM UITBREIDEN TAFEL
ZELF NIVELLEREN OF HANDMATIG?
DUBBELE AS OM TAFEL 4 KANTEN OP TE KANTELEN

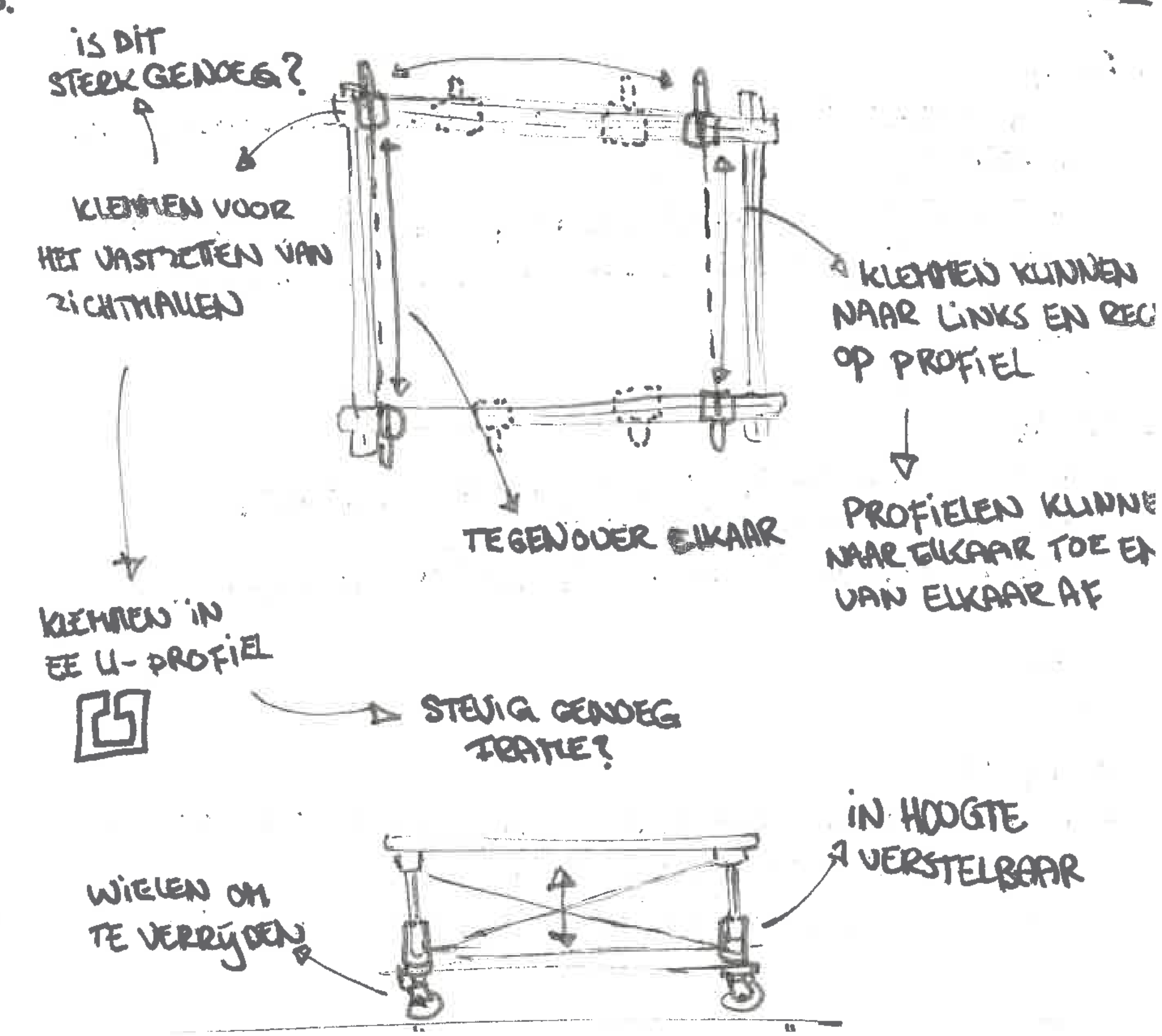
6.


INTERNE LASSEN MAKKELIJKER TE BEREIKEN
ROTERENDE AS OM ALLE LASPLEKKEN TE BEREIKEN
VERTICAAL LASSEN
ONDER DE HAND LASSEN IS BETER
DIT MOET EXTREEM STEVIG ZIJN
ONMOGELIJK?

7.

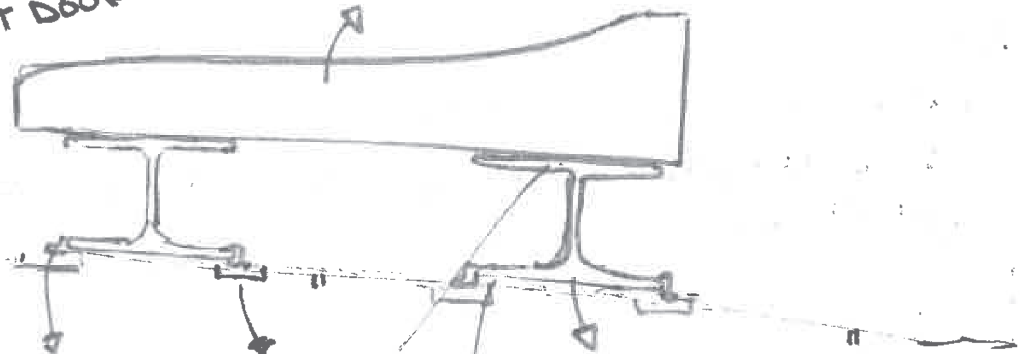

NIET GENOEG KRANEN VOOR MEERDERE ITEMS
AAN BOVENLOOPKRAAN
MAKKELIJK IN HOOGTE VERSTELBAAR
EN VERPLAATSEN
LASTAFEL OF H-BINTEN PROFIEL

8.


IS DIT STERK GENOEG?
KLEMMEN VOOR HET VASTZETTEN VAN ZICHTMALLEN
KLEMMEN KUNNEN NAAR LINKS EN REC
OP PROFIEL
TEGENOVER ELKAAR
PROFIELEN KUNNE NAAR ELKAAR TOE EN VAN ELKAAR AF
KLEMMEN IN EE U-PROFIEL
STEVIG GENOEG FRAME?
IN HOOGTE VERSTELBAAR
WIELEN OM TE VERRIJDEN

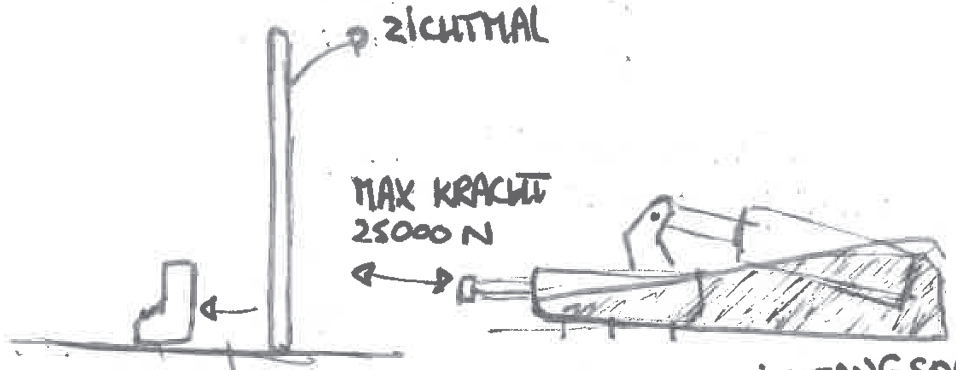
* KAN DE HUIDPLAAT OP EEN ANDERE MANIER VASTGEKLEMD WORDEN?
- VACUUM
- MAGNETISCH → ALU IS NIET MAGNETISCH
- KLEMMEN
- MECHANISCH

HUIDIGE SITUATIE



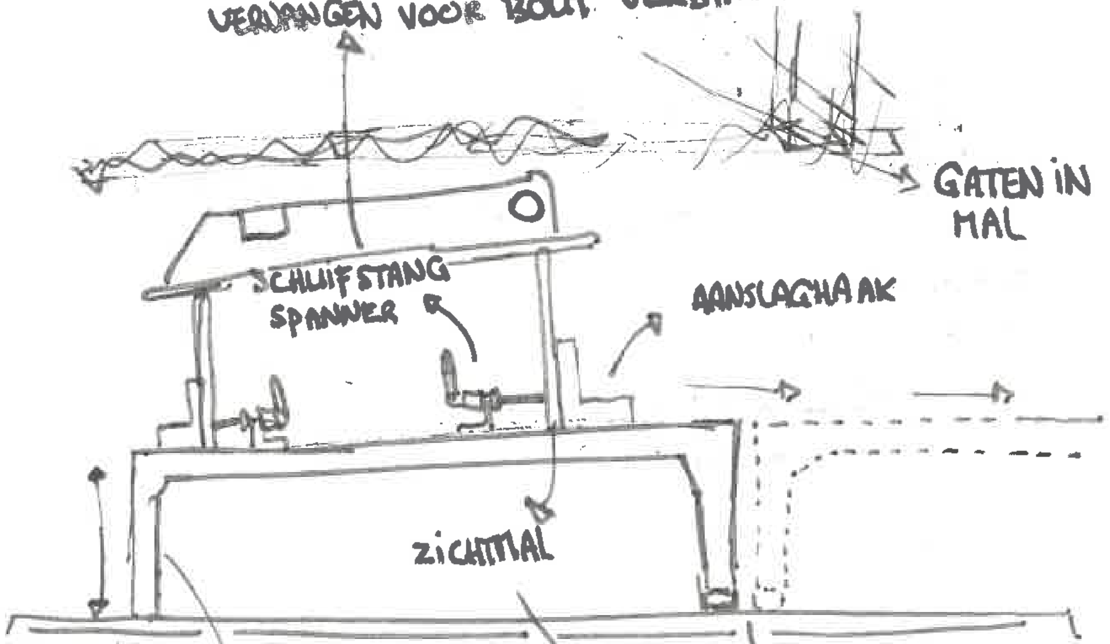
VRAGEN

* HOEVEEL KRACHT OP H-BINT DOOR VERVORMING VAN MATERIALEN?
* DIENT DE ZICHTMAL ALLEEN ALS MAL OF OOK OM VERVORMING TEGEN TE GAAN?



VOORDEEL: MEER SLIJ AFSCHUIF-WEERSTAND

SCHUIFSTANGSPANNER VERVANGEN VOOR BOUT VERBINDING



TAFEL MOET LAGER VOOR BETERE ERGONOMIE

HOE VERBETEREN WE DE ERGO?

- HEFTAFEL?
- KANTELEN?

ZICHTMAL LAGER MAKEN → KAN DAT?

MEERDERE TAFELS OP RAILS → KUNNEN TEGEN ELKAAR GESCHOUVEN WORDEN OM GROOT OPPERVLAK TE CREËREN

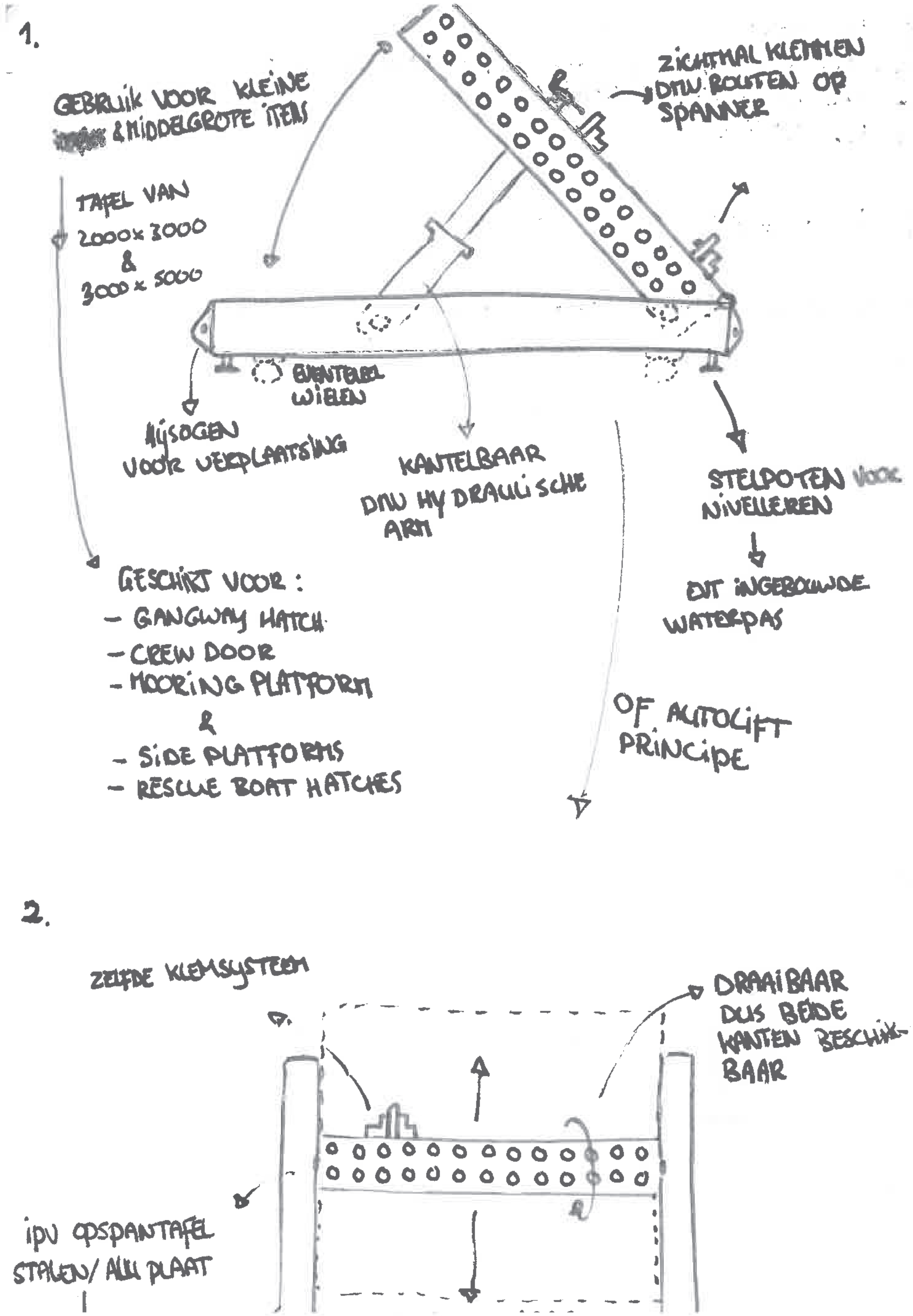
SCHUIFSTANGSPANNER & AANSLAGHAAK KUNNEN OVERAL OP DE TAFEL GEPLAATST WORDEN.

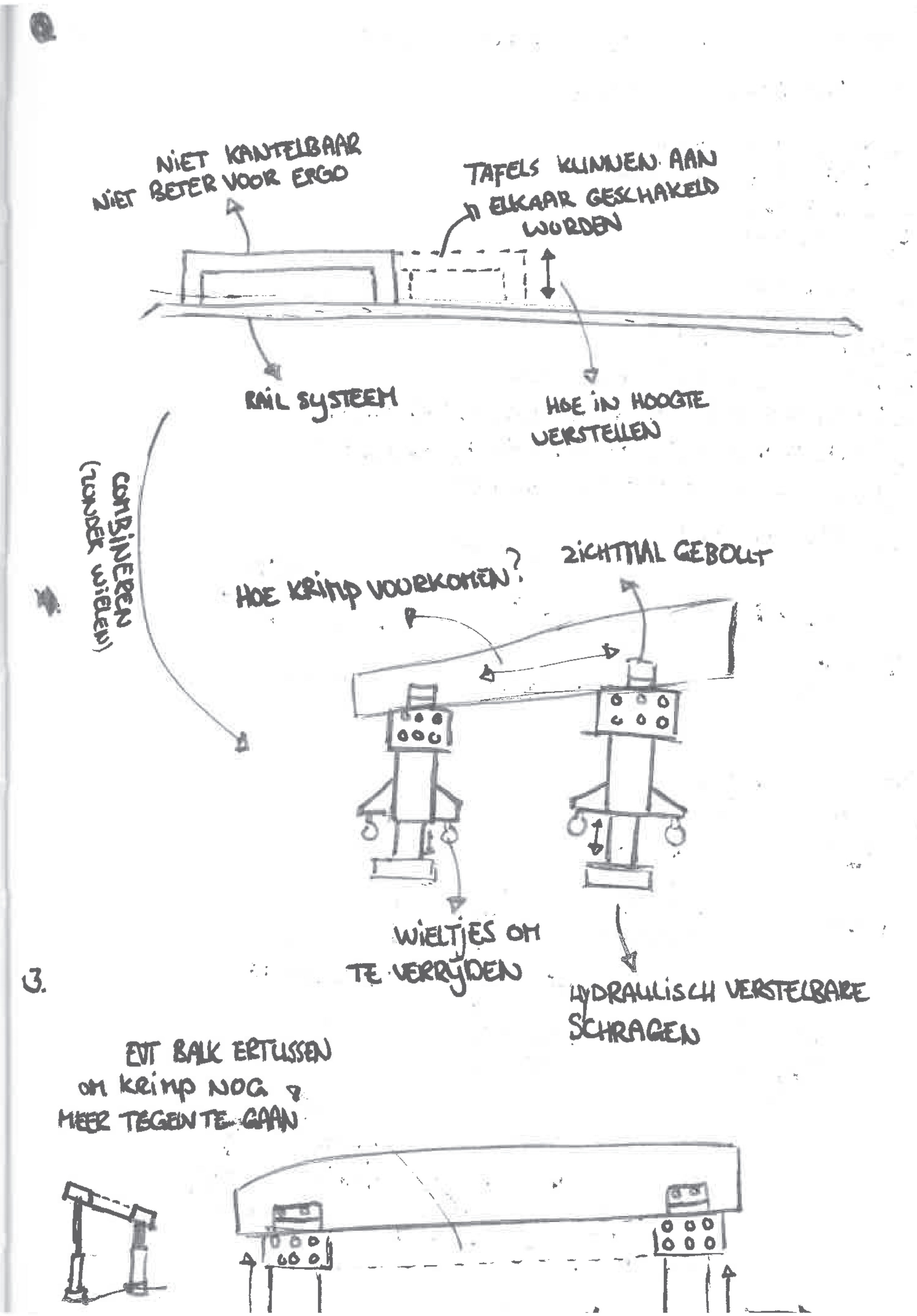
VLOERONAFHANKELIJK LASSEN

* SIEGMUND TAFEL OP RAILS → KANTELBAAR MAKEN
* GPPH UITSCHUIFBARE TAFEL
* DERDE OPTIE?

5S IN DE HALLEN

LEIDEN HAL 1 - WAT IS OVERBODIG?


1.
GEBRUIK VOOR KLEINE
& MIDDELGROTE ITEMS
TAFEL VAN
2000 x 3000
&
3000 x 5000
ZICHTMAL KLEMMEN
DMV BOUTEN OP
SPANNER
EVENTUEEL
WIELEN
HIJSOGEN
VOOR VERPLAATSING
KANTELBAAR
DMV HYDRAULISCHE
ARM
STELPOTEN VOOR
NIVELLEREN
EVT INGEBOUWDE
WATERPAS
GESCHIRT VOOR:
- GANGWAY HATCH
- CREW DOOR
- MOORING PLATFORM
&
- SIDE PLATFORMS
- RESCUE BOAT HATCHES
OF AUTOLIFT
PRINCIPE
2.
ZELFDE KLEMSYSTEEM
DRAAIBAAR
DUS BEIDE
KANTEN BESCHIK-
BAAR
IPV OPSPANTAFEL
STALEN/ALU PLAAT


NIET KANTELBAAR
NIET BETER VOOR ERGO
TAFELS KUNNEN AAN
ELKAAR GESCHAKELD
WORDEN
RAIL SYSTEEM
HOE IN HOOGTE
VERSTELLEN
COMBINEREN
(ZONDER WIELEN)
HOE KRIMP VOORKOMEN?
ZICHTMAL GEBOUT
WIELTJES OM
TE VERRIJDEN
HYDRAULISCH VERSTELBARE
SCHRAGEN
3.
EVT BALK ERTUSSEN
OM KRIMP NOG
MEER TEGEN TE GAAN

WAAROM WORDT ALLES OP DEZELFDE GEMAAKT?

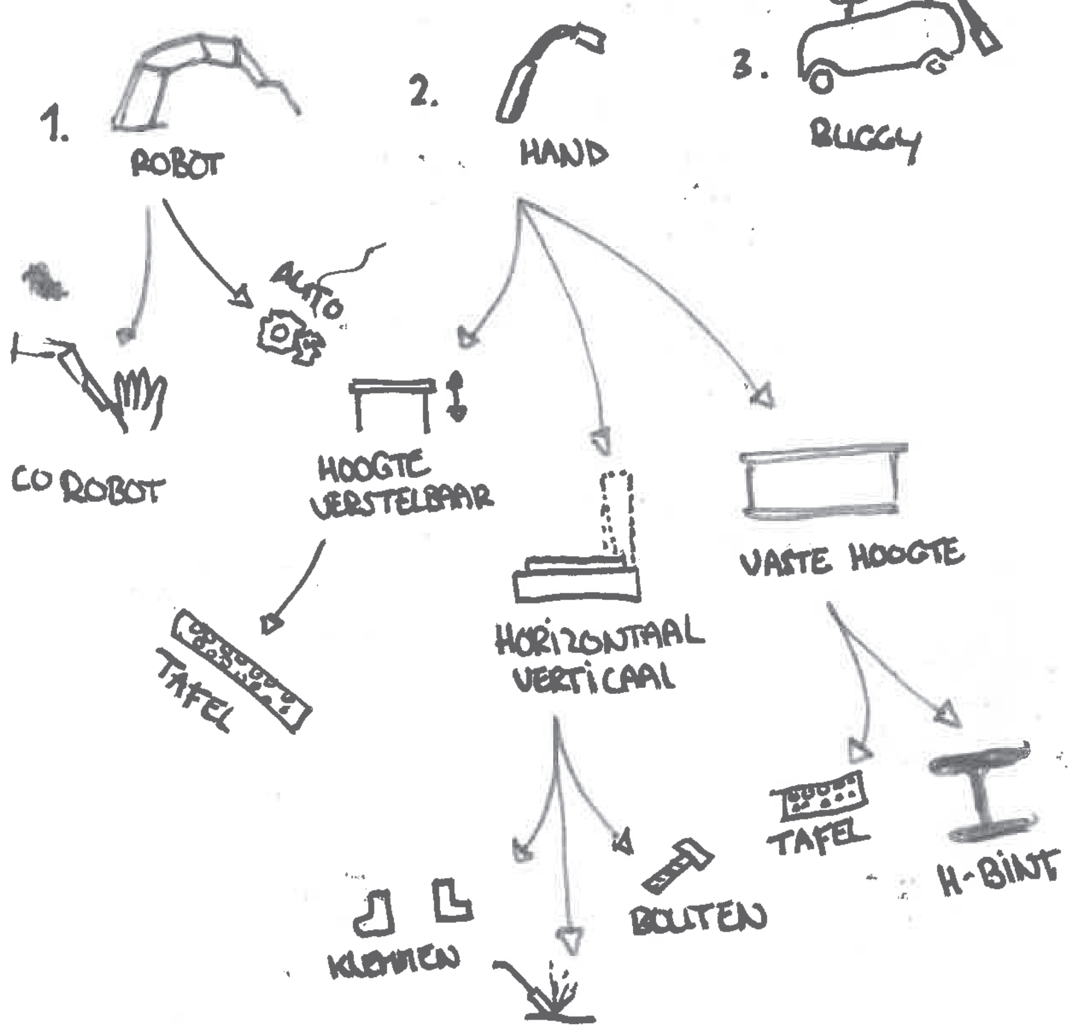
↳ WELKE STAPPEN ZIJN ER?

1. HUIDPLAAT LASSEN
2. INTERNE FRAMEWERK
3. BUITENKANT
4. SLUITPLAAT

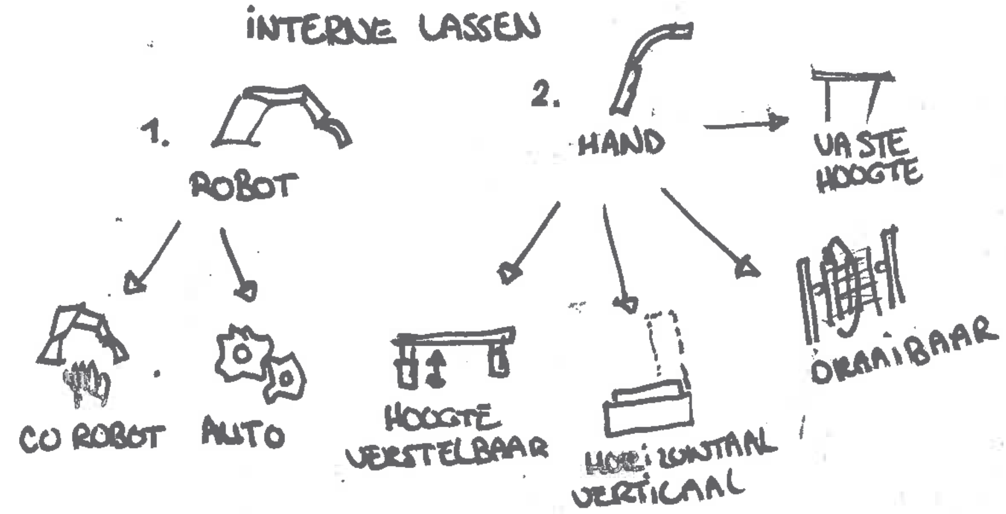
↓ UITGEBREIDER

1. HUIDPLAAT LASSEN
2. INTERNE FRAME OP HUIDPLAAT
3. INTERNE FRAME VAN HUIDPLAAT EN AFLASSEN
4. INTERNE FRAME OP HUIDPLAAT EN AFLASSEN
5. EXTERNE COMPONENTEN LASSEN
6. SLUITPLAAT LASSEN

HUIDPLAAT



INTERNE LASSEN

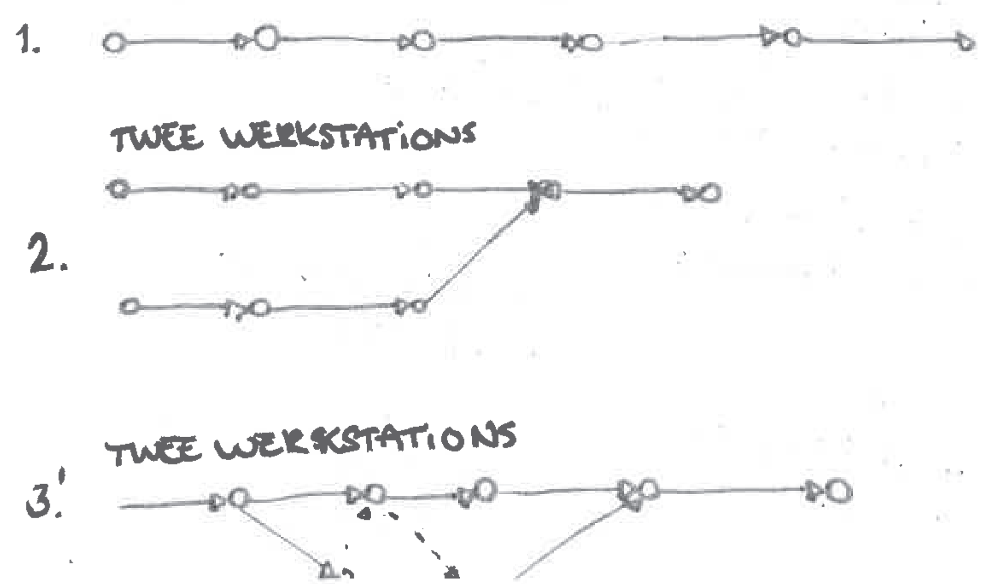


★ IS HET MOGELIJK OM DE HUIDPLAAT TE LASSEN MET DAAROP DE BUITEN COMPONENTEN ZODAT DE INTERNE LASSEN TEGELIJK OP EEN ANDERE PLEK GEDAAN KAN WORDEN?

KUNNEN DE BOUWMETHODES AANGEPAST WORDEN ZODAT ER PROCESSEN TEGELIJK KUNNEN VERLOPEN?

→ DAT KAN HOE TEKENING BESCHIKBAAR MAKEN?

ÉÉN WERKSTATION VOOR ALLE WERKZAAHEDEN



Appendix I

Detailed overview of proposed workflow option A

To determine how the process can be split, the existing workflow was first analyzed and broken down into its core steps. These core steps can be divided into three phase which can happen concurrently:

1. Preparation & hull plate
- a. Setting up the **templates**.
- b. Welding the **hull plate**.
- c. Welding the **hull plate** to the **templates**.

2. **Internal structure**
- a. Welding the internal components (like conduits, portholes, and/or strips) to the **girders**.
- b. Welding the longitudinal- and transverse **girders** to create a **structure**.

3. **External structure & closure plate**
- a. Welding the external components (like seal-edge and stringers) to the **closure plate**.

Each of these steps has has it own needs in terms of workspace lay-out, including different working heights and desired orientation of the **item**. Currently, the working height is relatively fixed: **items** can be constructed either on the H-beam frame, on a welding table, or directly on the ground. While working on different heights is possible, doing so typically requires the creation of custom-made frames built from H-beams, making it a time-consuming and less flexible process.

To adjust the orientation of the **items**, the overhead cranes are used. **Items** can be lifted, rotated, and positioned at various angles, after which they are secured using a custom-built supporting **structure**. Although it is technically possible to position the **item** at any desired angle, in practice, two primary orientations are most commonly used: flat (horizontal) and upright (vertical).

When placed upright, the internal welds are easier to reach, but require employees to use ladders to reach higher sections. Conversely, when the **item** is positioned flat, no ladder is needed but the middle of the **item** is harder to reach, and, in addition, employees need to weld in a vertical direction while horizontal is

Table 7: *Dimensions and weights of the three categories of sized of items.*

	Height	Orientation	Desired height	Desired orientation
Step 1	Ground/H-beam	Horizontal	Standing/ sitting	Horizontal
Step 2	H-beam/welding table	Horizontal /vertical	Standing	All orientations
Step 3	Ground/H-beam	Horizontal	Standing/ sitting	Horizontal

As can be seen in the table above, step one and three share similar needs in height and orientation of the **item** to ensure comfortable and efficient work. In a workflow where the process is divided into two processes, it would therefore be most beneficial to have steps one and three take place at the same workstation. As step one and three cannot take place in reverse order and step three is always the finals step, the most logical choice would be to have step one and two happen concurrently.

Step one and three share similar needs in terms of working height and orientation in contrast to step two which has its own needs. These different needs need to be taken into account when designing a concept that allows floor-independent welding. The ideas for this concept can be found later in this report.

A proposal of the the division of available space in Katwijk can be found in Figure 86.

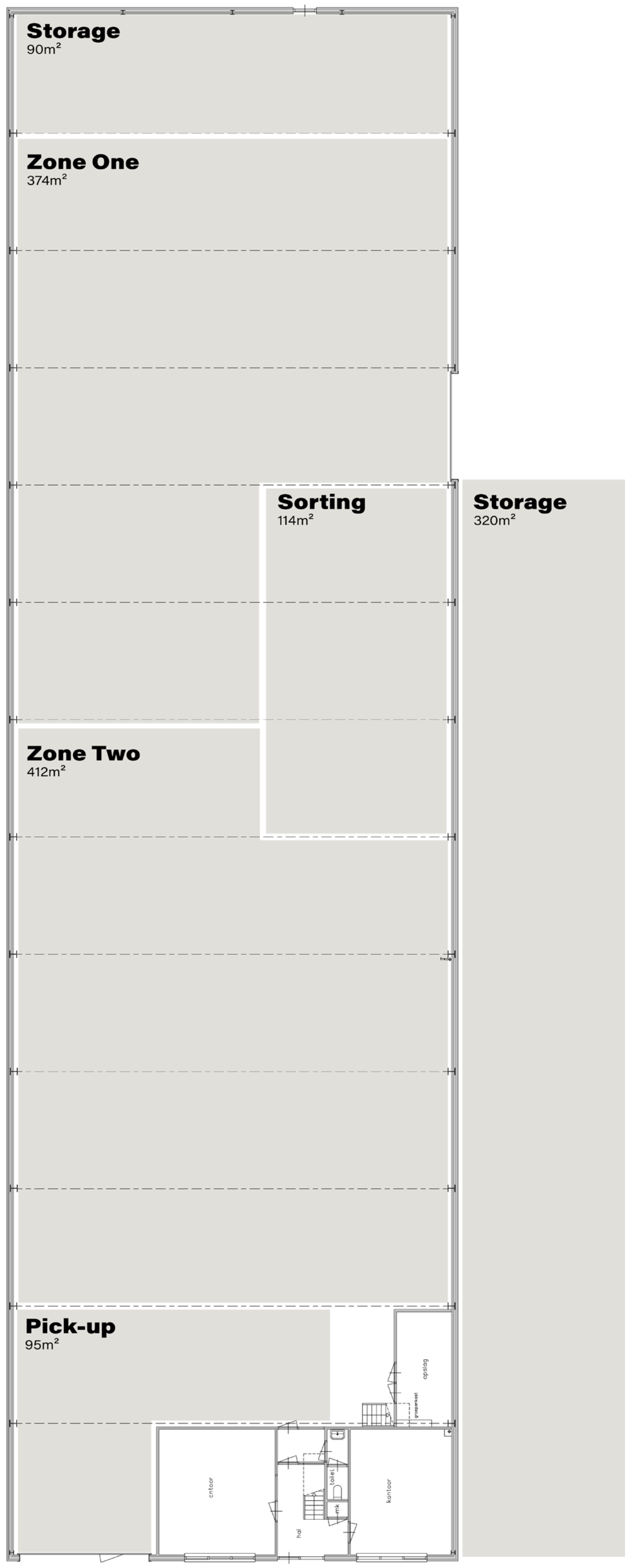


Figure 86: *Hall lay-out of the proposed workflow*

Challenges

However, this workflow also introduces a challenge. The challenge concerns the planning and synchronization of activities between the two zones. When a completed **structure** is moved from zone One to zone Two, space in zone One is freed up, allowing the manufacturing of the next **structure** to begin. However, the workstation for the **templates** and **hull plates**—which is then used to finish the manufacturing of the **item**—in zone Two is still occupied with the previous **item**, and thus starting the preparation of a new set will not yet be possible.

This bottleneck can be minimized if the combined lead time of finishing the previous **item** (including welding of external components and the **closure plate**) and setting up new **templates** and **hull plates** is shorter than the time needed to manufacture a new **structure**. Careful coordination and planning are therefore crucial to ensure a continuous and efficient production flow. Another approach to tackle this challenge is to introduce a third workstation specifically designed for the finalization of the **items** (see Figure X). By doing so, the manufacturing of a new **item** can begin immediately after the **structure** is moved. However, this additional workstation would occupy valuable space that could otherwise be used for other activities. As a result, the number of **items** that can be manufactured simultaneously decreases. Nevertheless, if the overall lead time is reduced sufficiently, this limitation should not become a significant issue.

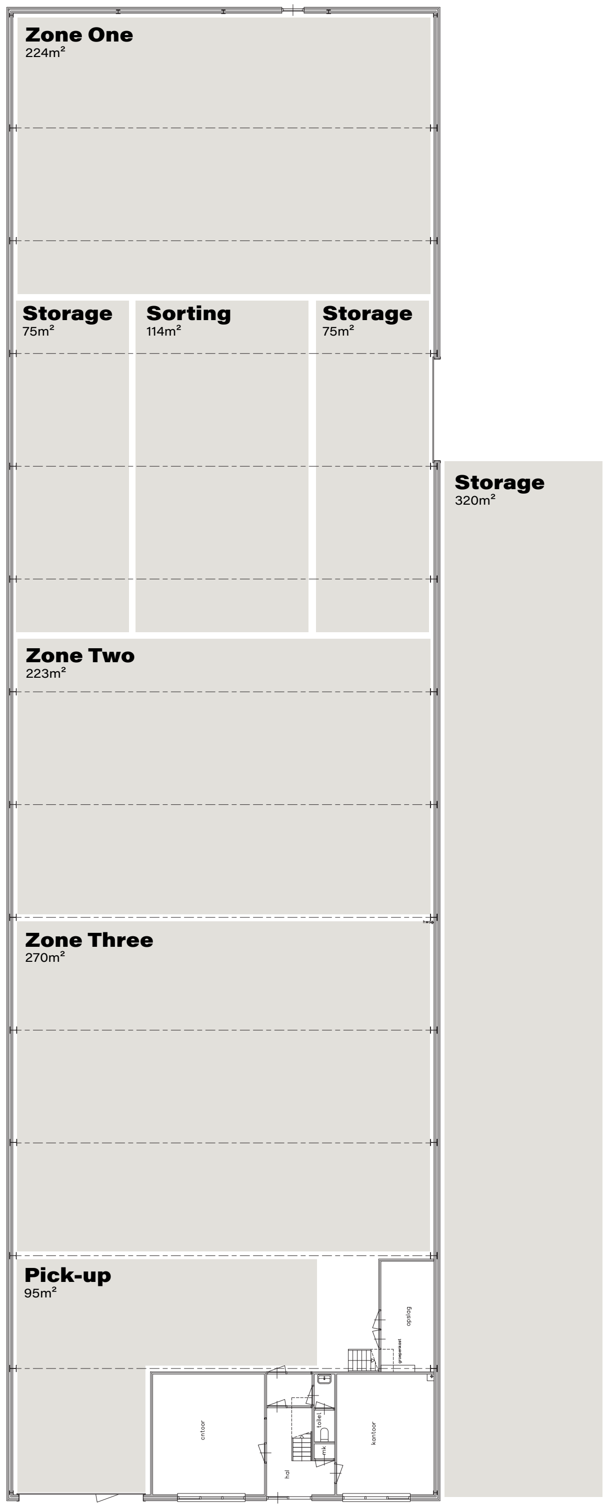


Figure 87: *Relevant risks from the RI&E conducted by QHSSE.*

Appendix J

Detailed overview of proposed workflow option B

In the proposed workflow, the manufacturing halls are configured in a quadrant-based layout. To support this system, the **items** being manufactured must either be movable or the halls themselves must be equipped with rails to facilitate transportation between quadrants. Each quadrant is dedicated to a specific phase of the manufacturing process and equipped with the tools and setup needed for that stage:

- **Quadrant 1–Setup**
In this quadrant, the **template** and **hull plate** are prepared. This includes positioning, clamping, and any initial adjustments required to begin manufacturing.

- **Quadrant 2 – Internal Structure**
Here, the **girders** and internal components are attached to the **hull plate**. As emphasized in earlier workflow proposals, it is essential that the **item** can be rotated into an upright position. This ensures welds are easily accessible and takes away the need for grinding the **structure** loose, improving both ergonomics and efficiency.

- **Quadrant 3 – External Welds**
This section is used for attaching the external components and welding the **closure plate** to complete the structural form of the **item**.

- **Quadrant 4 – Finishing & Buffer**
The final quadrant functions as a buffer or finishing zone. It is designated for final touches, quality control, and any adjustments required before the **item** is moved out of the hall.

A proposal of the the division of available space in Katwijk can be found in Figure 88.

Challenges
Despite its potential benefits, this workflow also introduces several challenges.

Larger **items** require a lot of space when moving between quadrants. When the occupancy is high, this can become problematic. To mitigate this issue, the halls must be organized with efficiency in mind. Implementing Lean principles—particularly the 5S methodology—can help reduce clutter and optimize the use of available space, making it possible to manage even the largest **items** within this setup.

Another challenge involves the different lead times of **items**. Depending on size and complexity, manufacturing durations can range from four to twelve weeks or even more. When a shorter lead-time **item** is positioned behind a longer one, production flow may be disrupted. To address this, careful planning is required, ideally grouping **items** with similar lead times within the same hall. In the long term, planning could be done by Machine Learning to automate scheduling.

If the spatial requirements for this layout prove too demanding, a hybrid solution is possible: one hall could adopt the quadrant-based workflow, while the other continues using the current fixed position workflow. This would provide flexibility and allow for the accommodation of larger or less standard **items** when needed.

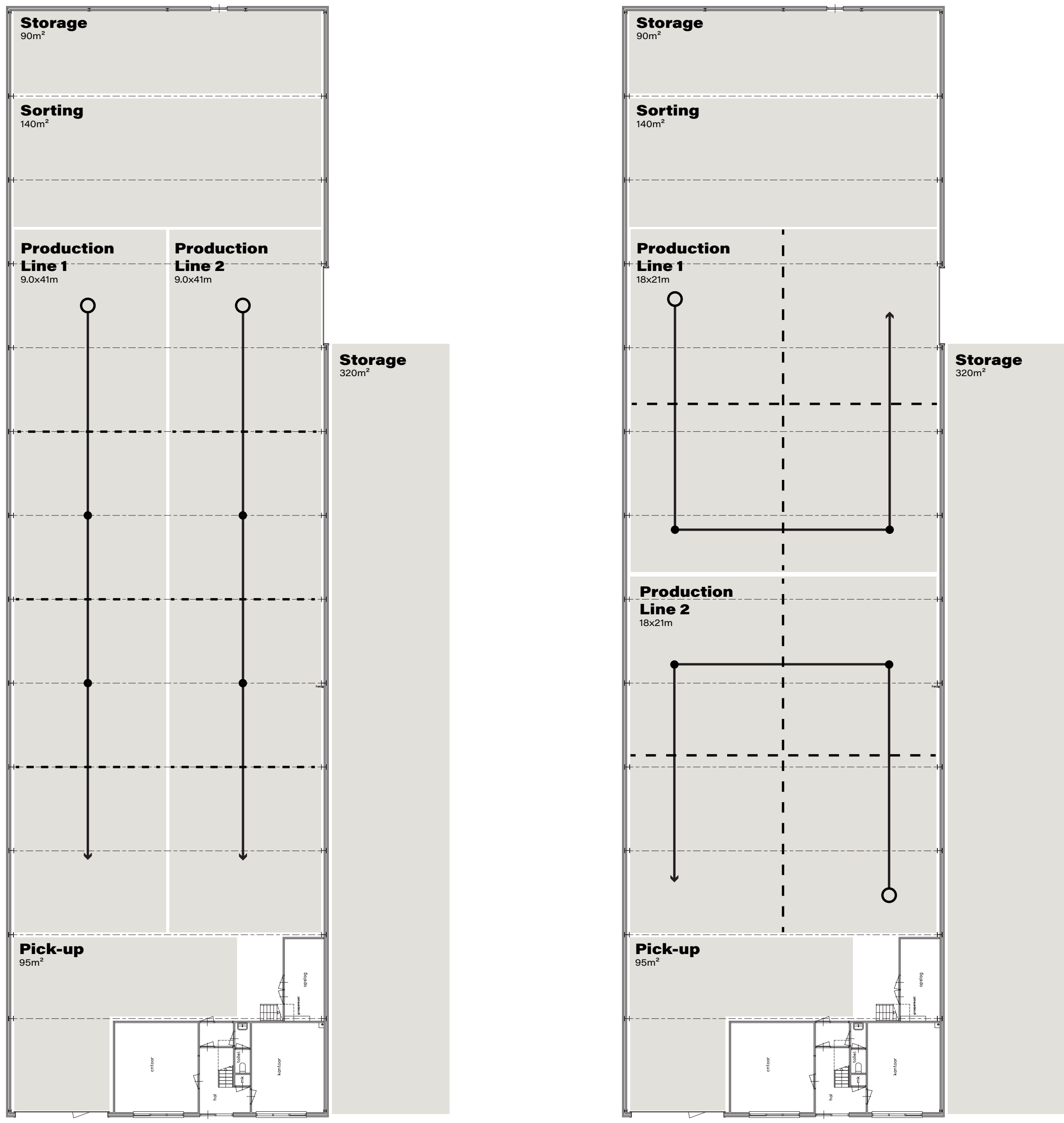


Figure 88: *Hall lay-out of the proposed workflow*

Appendix K

Detailed overview of proposed workflow option C

Synergy can defined as: "*The interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects.*". According to the theory of synergy, the cooperation between the halls could lead to better result than the combined results of the halls individually.

In this third workflow proposal, **hull plate**s are produced in Leiden. The sections are delivered directly to here, eliminating the need for additional sorting. A workstation can be created in the hall specifically designed for pre-processing and welding **hull plate**s. This focused workstation will significantly increase efficiency. Meanwhile, the internal **structure**, which generally has a longer lead time, can be manufactured in Katwijk. While the **structure** is being manufactured, the completed **hull plate**s can be temporarily stored in Leiden. Once a sufficient number of plates are ready, or when they are needed in Leiden, a batch can be transported and stored there, lowering transportation costs.

Challenges

As with previous workflows, this workflow also has its challenges. The first challenge is the transportation costs. Whereas this workflow can save time and consequently costs in manufacturing time, the transportation costs are increased, resulting in a lower net profit. Ultimately, and logically, these costs may not be higher than the profit.

Another challenge is communication. As the **hull plate** is made at a different location than the rest of the **item**, the communication between the two manufacturing parties is made more difficult and direct communication is not possible. This can result in problems and miscommunications if not addressed properly.

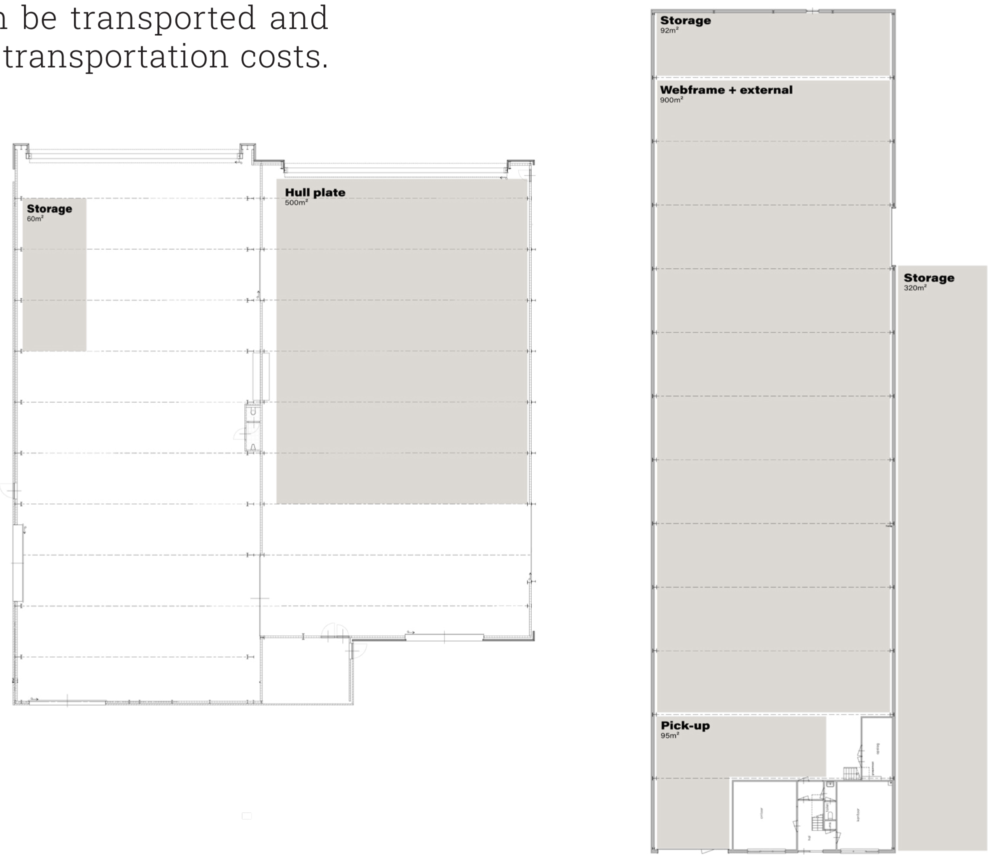


Figure 89: *Hall lay-out of the proposed workflow*

Appendix L

Modularity concepts

Five distinct modularity approaches were identified. To make these approaches more relatable, the metaphor of a living room with tables and chairs is used.

Imagine you have a limited-size living room that occasionally needs to accommodate guests for dinner. Depending on the number of visitors, you'll need to rearrange the space to fit more or fewer tables and chairs. Each approach to managing this space offers a different strategy for balancing flexibility, efficiency, and predictability.

Fully modulair

In the fully modular approach, you keep multiple compact table-and-chair sets in storage. On a regular day, you might only use one set—a table with two chairs. When guests arrive, additional sets can be brought out and connected to form a larger table arrangement. This allows for maximum flexibility: the living room layout can expand or contract depending on demand. However, it requires a dedicated area for storing unused sets, and setting them up takes time and effort.

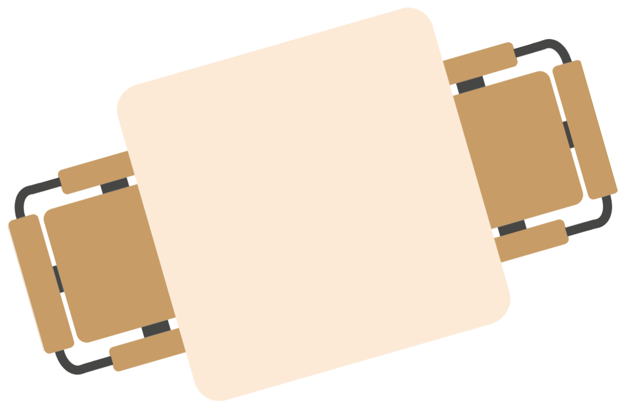


Figure 90: *Table and chairs.*

Semi modulair

With the semi modular layout, you keep a medium-sized table in the room at all times—one that comfortably seats six people. For most occasions, this setup is sufficient. When more guests arrive, you can extend the table by adding a modular unit from storage. This approach reduces setup time and storage needs compared to the fully modular method. However, it may occupy unnecessary space when fewer people—or in this case, fewer **items**—are present.

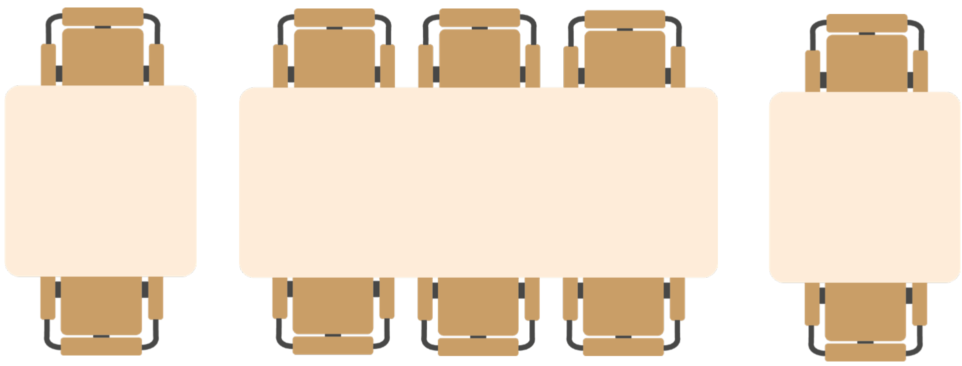


Figure 91: *Table and chairs*

One-size-fits-all

The one-size-fits-all strategy assumes you have plenty of space. In this case, you place a large table in the living room that can seat twelve people, even though the usual number of guests is only ten. This layout is always ready for maximum capacity. While this approach eliminates the need for storage or setup time, it's space-inefficient—especially when not all seats are in use. It also lacks adaptability for smaller-scale needs.

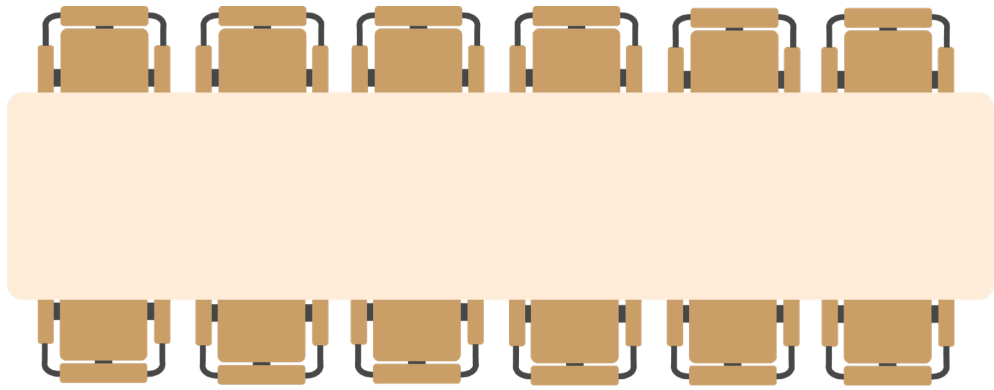


Figure 92: *Table and chairs*

Prediction based

The prediction-based approach uses past attendance trends to forecast how many guests are likely to come. Based on this data, you arrange the living room layout in advance. For instance, if historical patterns suggest an average of eight guests, you set up the space accordingly. This method offers an efficient, data-driven solution that works well when patterns are stable. However, it's not foolproof. Unexpected surges or drops in attendance (or workload) can lead to either overcrowding or wasted space. The predictions must be regularly updated to stay relevant.

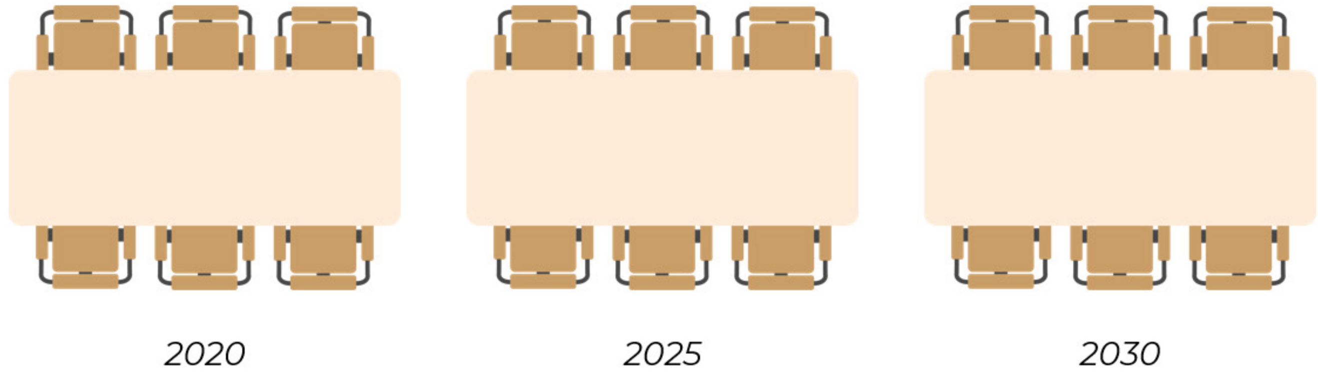


Figure 93: *Table and chairs.*

Capacity based

The capacity-based layout focuses strictly on the available space in the living room. It divides the room into pre-defined zones—some for small tables, some for medium, and others for large tables—regardless of how many guests are expected. This method ensures that every type of table has a reserved spot, but may not respond efficiently to fluctuating demand. Some zones may sit unused while others become overcrowded.

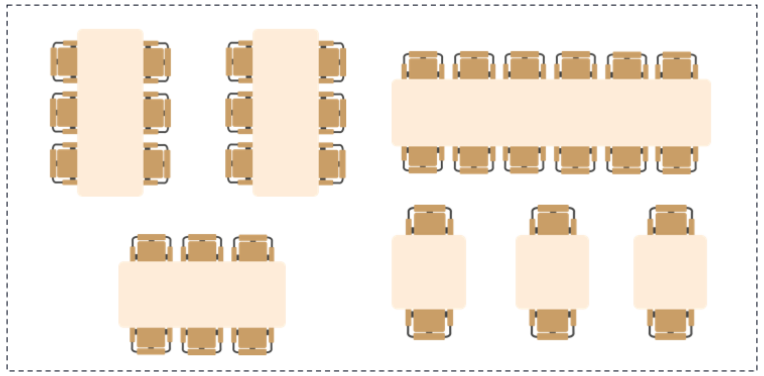
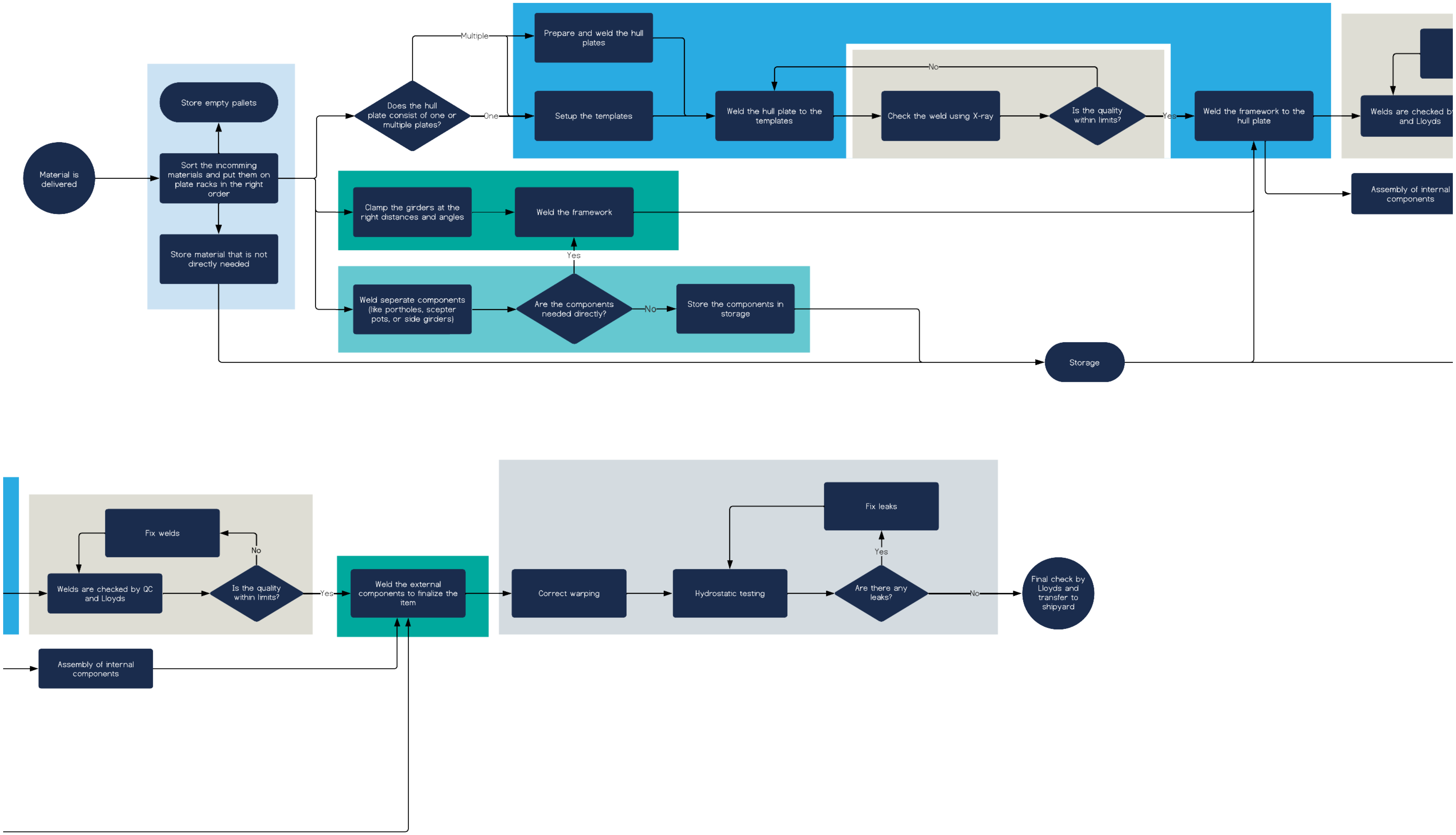


Figure 94: *Table and chairs.*

Appendix M

Flowchart of the Parallel Process Workflow



Appendix N

Lead time calculation of Beachclub Platform of project 830

Steps	Time (min.)
Adapt template	40
Weld hull plate	55
Weld hull plate to template	60
Pre-process girders	60
Pre-process & weld portholes	100
Place & tack weld girders	45
Weld hinges	50
Weld scepter pots	40
Pre-process & weld side girders	40
Place & weld piping	35
Grind frame loose	15
Weld frame	55
Quality control	10
Weld frame to hull plate	45
Weld insides of frame	80
Quality control	10
Lloyds	4
Tack weld closure plate	55
Weld outsides and closure plate	45
Finish & hydrostatic test	50
Lloyds	8

Appendix O

Time division based on observations

Tijd	Activiteit	Duur (min.)
13:45	Naden huidplaat voorbereiden voor lassen	5
13:50	Gereedschap wisselen	1
13:51	Spanen wegblazen	1
13:52	Gereedschap zoeken	2
13:54	Borstelen van de naden	2
13:56	Spanen wegblazen	1
13:57	Wachten op werkzaamheden collega	2
15:59	Overleggen/voorbereiden	**3**
14:02	Borstelen van de naden	1
14:03	**Lassen**	**3**
14:06	Borstelen van de naden	1
14:07	Voorbereiden buggy	1
14:08	**Lassen d.m.v. buggy**	**24**
14:32	**Opfrissen + rusten**	**4**
14:36	Controleren + schoonmaken lassen	4
14:40	Overleggen/praten met collega's	4
14:44	Schoonmaken lassen	2
14:46	Praten met collega's	1
14:47	Overleggen met voorman	3
15:50	**Einde**	
Totale tijd		**66**
Totale tijd nuttig		**34**
Totale tijd Muda		**32**
Percentage		**48%**

Tijd	Activiteit	Duur (min.)
13:55	Lassen	9
14:04	Overleggen/praten met collega	2
14:06	Lassen	1
14:07	Schoonmaken werkstuk	2
14:09	Toilet bezoek	20
14:29	Werkstuk orienteren	3
14:32	Materialen pakken	1
14:33	Overleggen/praten met collega	3
14:36	Materialen pakken	2
14:38	Lassen	4
14:42	Telefoon	1
14:43	Overleggen/praten met collega	7
Einde		
Totale tijd		**55**
Totale tijd nuttig		**16**
Totale tijd Muda		**39**
Percentage		**71%**

Tijd	Activiteit	Duur (min.)
07:05	**Lassen**	**5**
07:10	Controleren en corrigeren	2
07:12	**Lassen**	**1**
07:13	Nieuw materiaal pakken en uitlijnen	2
07:16	Tekeningen bekijken	1
07:17	Uitlijnen nieuw materiaal	10
07:27	Nieuw materiaal pakken	3
07:30	Overleggen/praten met collega	6
07:36	Gereedschap pakken voor collega	1
07:37	Overleggen/praten met collega	10
07:47	Tekeningen bekijken	2
07:49	Overleggen/praten met collega	6
07:55	Uitlijnen nieuw materiaal	3
07:58	**Water drinken + toilet bezoek**	**2**
08:00	Slijpen + passen & klemmen	5
08:05	**Einde**	
Totale tijd		**61**
Totale tijd nuttig		**8**
Totale tijd Muda		**53**
Percentage		**87%**

Tijd	Activiteit	Duur (min.)
08:05	Hechten huidplaten	**5**
08:10	Overleggen/praten met collega	**1**
08:11	(Ver)plaatsen contragewicht	2
08:13	Uitfrezen naad	**34**
08:47	Controleren + overleggen	**1**
08:48	Rusten + supervisie	**4**
08:52	Uitfrezen naad	**8**
09:00	**Einde**	
Totale tijd		**55**
Totale tijd nuttig		**53**
Totale tijd Muda		**2**
Percentage		**4%**

Tijd	Activiteit	Duur (min.)
12:00	Schotten positioneren	3
12:03	Overleggen met collega	1
12:04	Lassen (hechten)	1
12:05	Gereedschap opruimen	2
12:07	Schotten positioneren	11
12:18	Lassen (hechten)	6
12:24	Overleggen met collega	6
12:30	**Einde**	
Totale tijd		**30**
Totale tijd nuttig		**21**
Totale tijd Muda		**9**
Percentage		**30%**

Tijd	Activiteit	Duur (min.)
13:05	Overleggen/praten met college	2
13:07	Lassen	4
13:11	Gereedschap pakken	1
13:12	Heet stoken	3
13:15	Lassen	5
13:20	Lastoorts schoonmaken	2
13:22	Collega helpen	2
13:24	Lassen	6
13:30	Overleggen met collega	1
13:31	Lassen	8
13:39	Overleggen/praten met college	1
13:40	Lassen	2
13:42	Overleggen/praten met college	2
13:44	Lassen	9
13:53	Overleggen/praten met college	7
14:00	Eind	
Totale tijd		**55**
Totale tijd nuttig		**34**
Totale tijd Muda		**21**
Percentage		**38%**

Totale tijd	322
NVA (Muda)	93
Percentage	**29%**

Totale tijd	322
VA	88
Percentage	**27%**

Totale tijd	322
Overleggen/praten	60
Percentage	**19%**

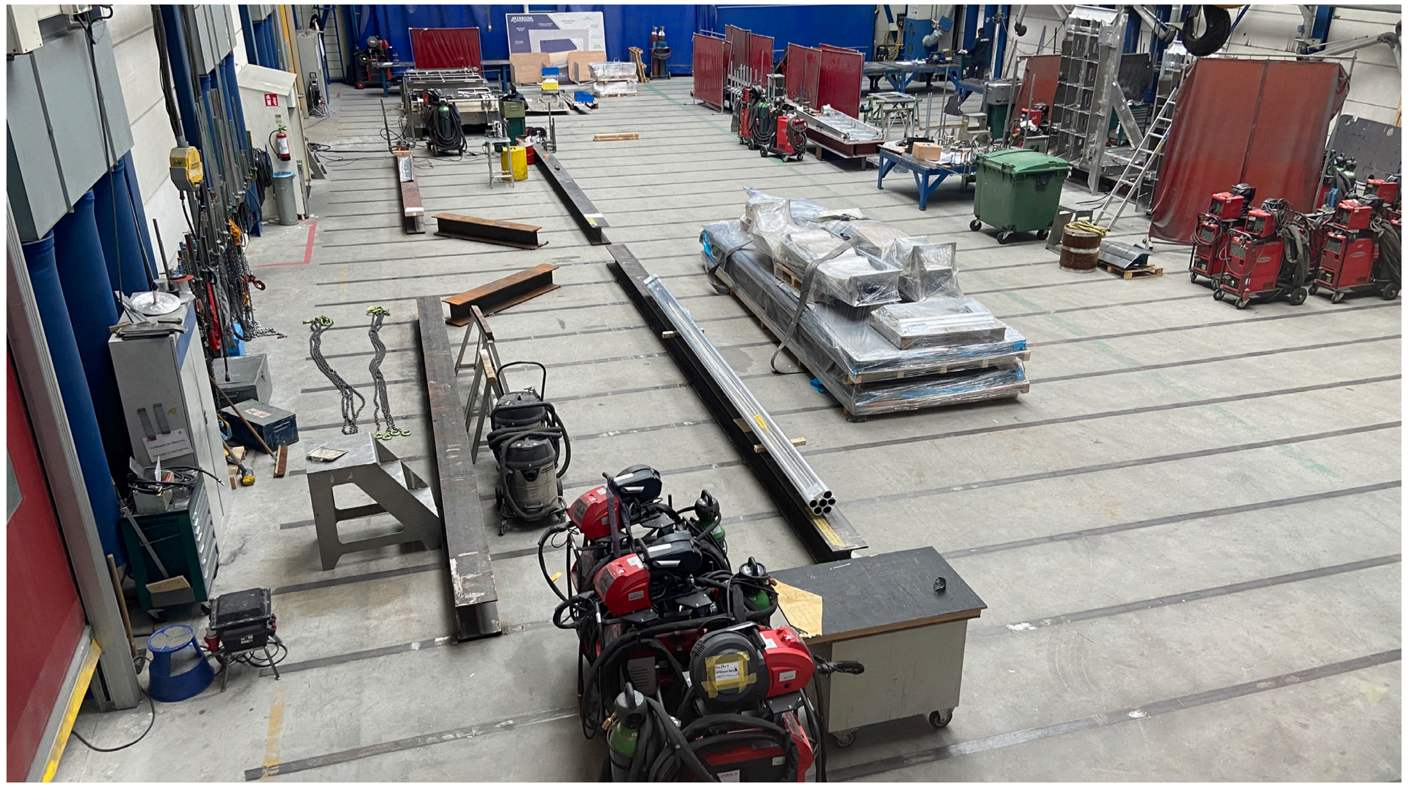
Percentage praten	**65%**

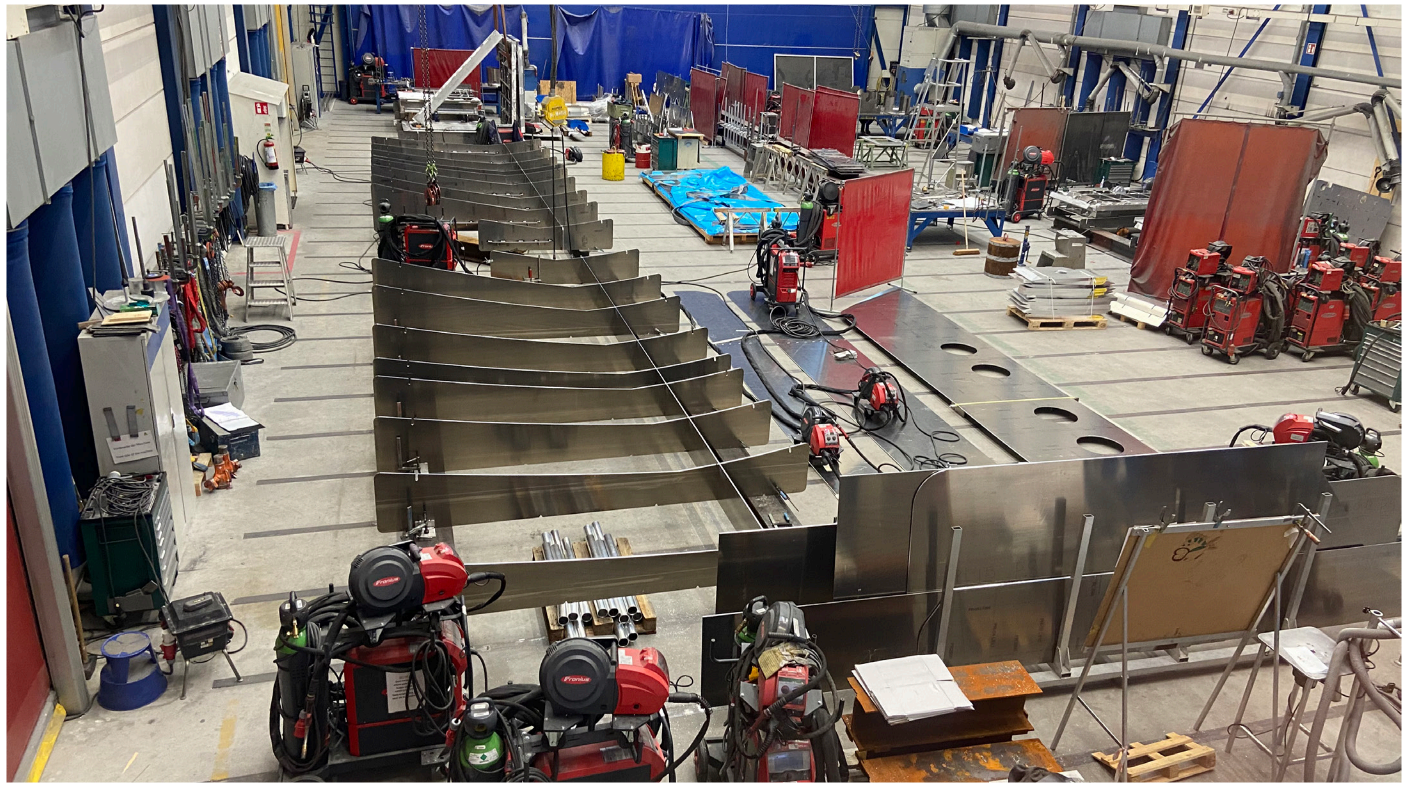
Totale tijd	322
NNVA	111
Percentage	**34%**

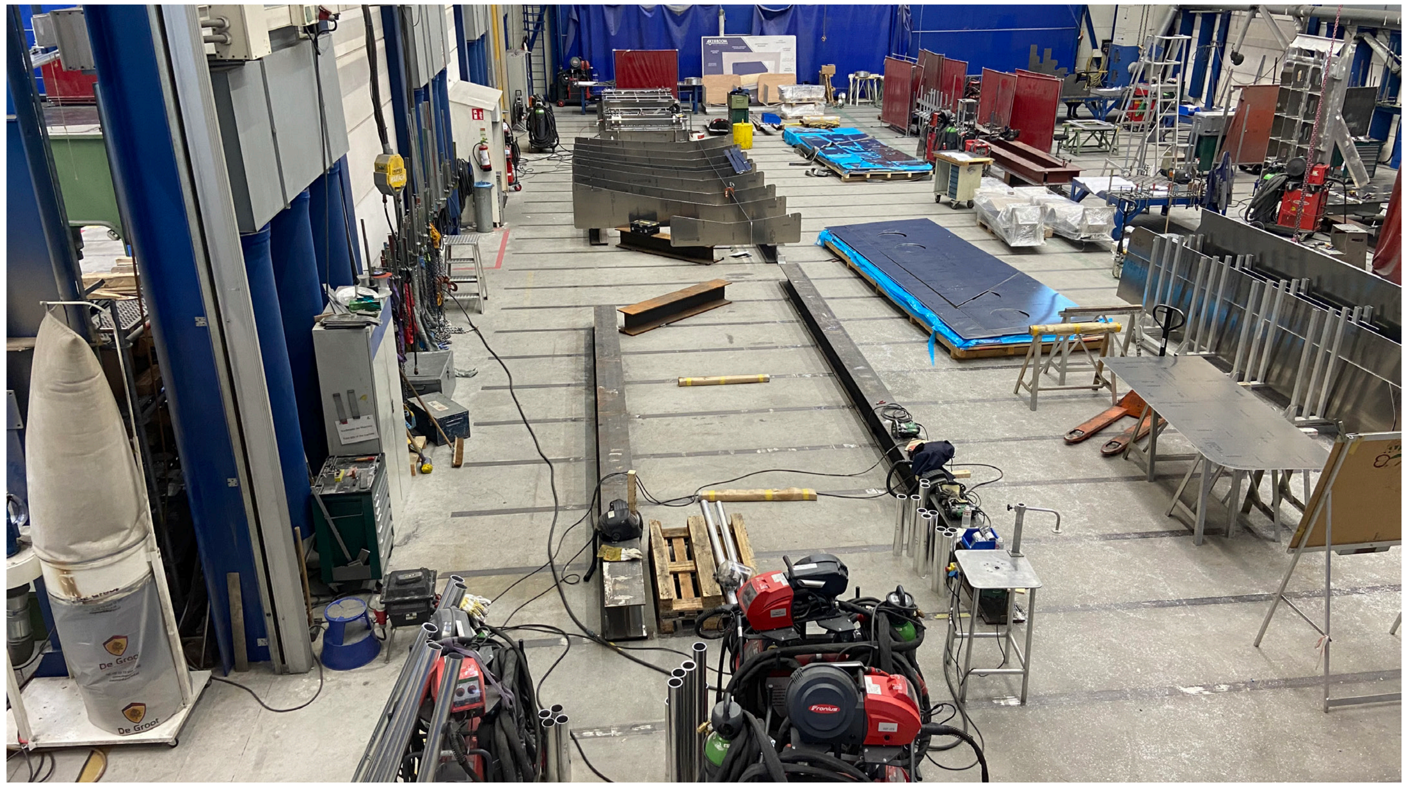
Totale tijd	322
Rusttijd	30
Percentage	**9%**

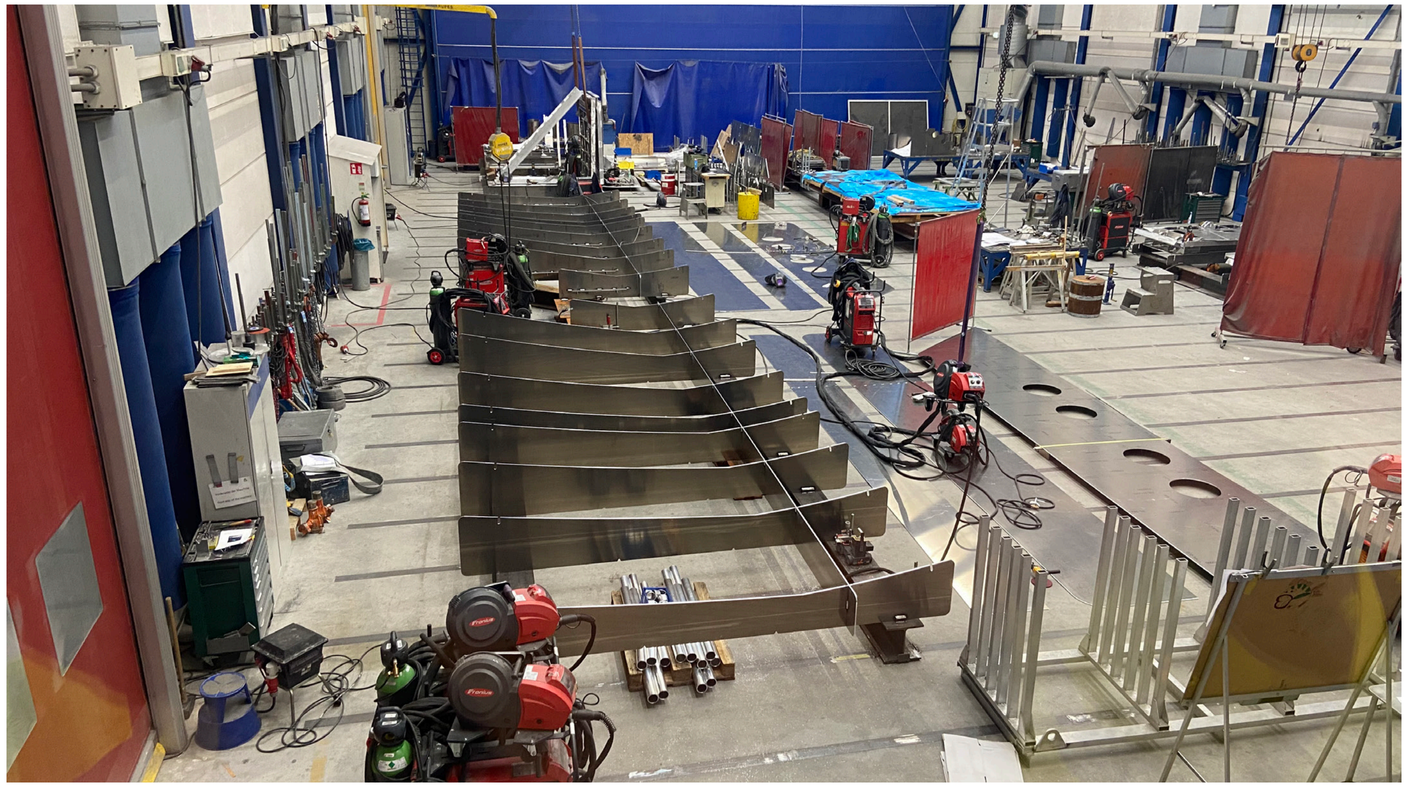
Appendix P

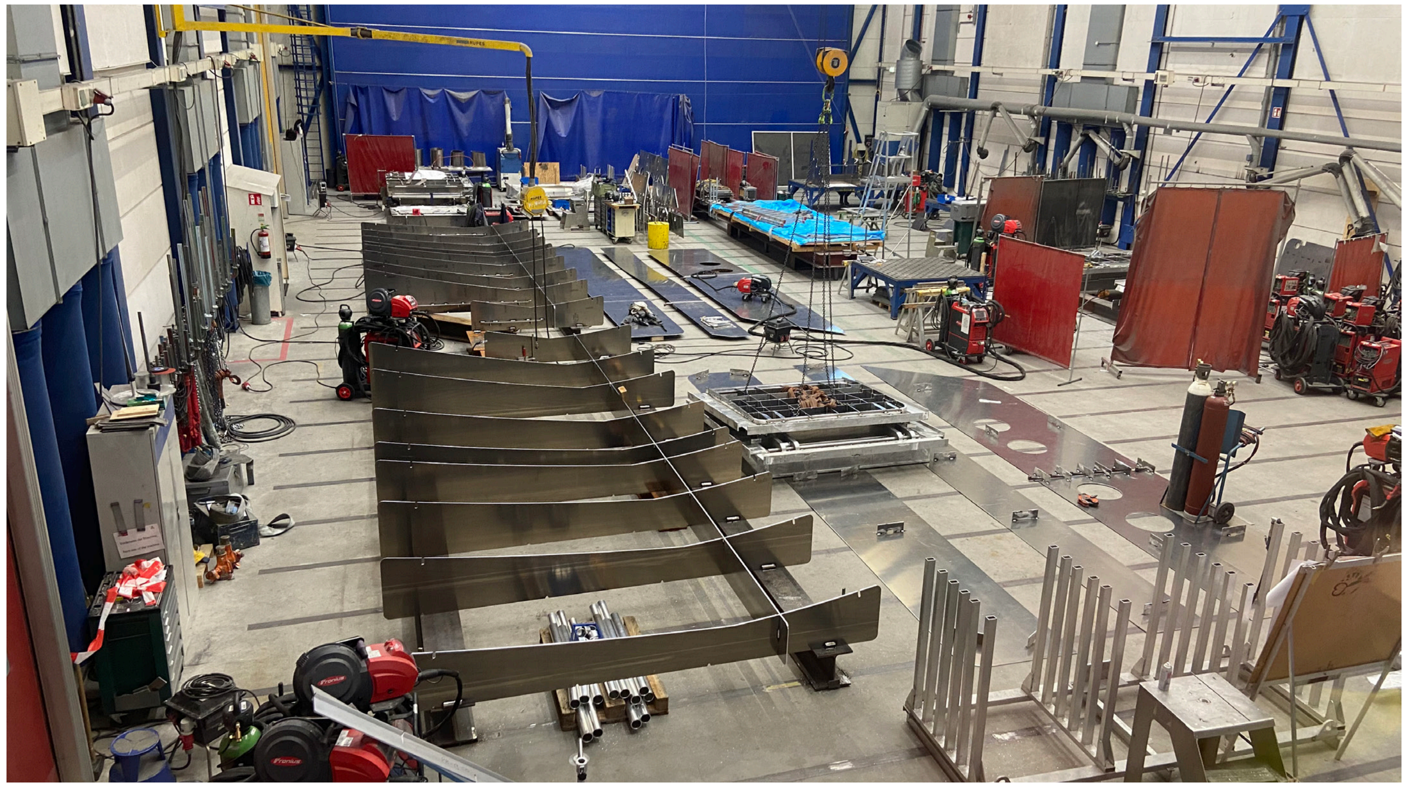
Timelapse photos of the hall in Leiden

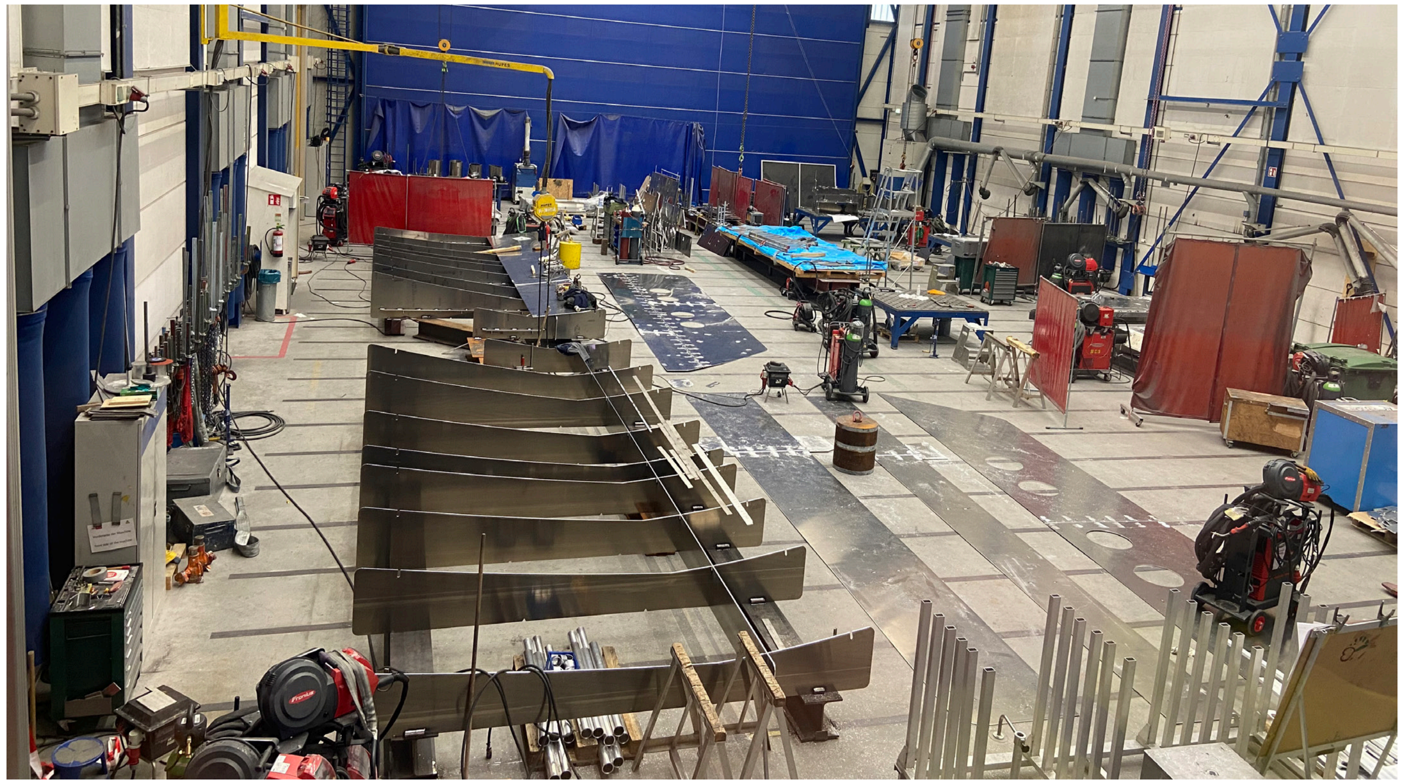


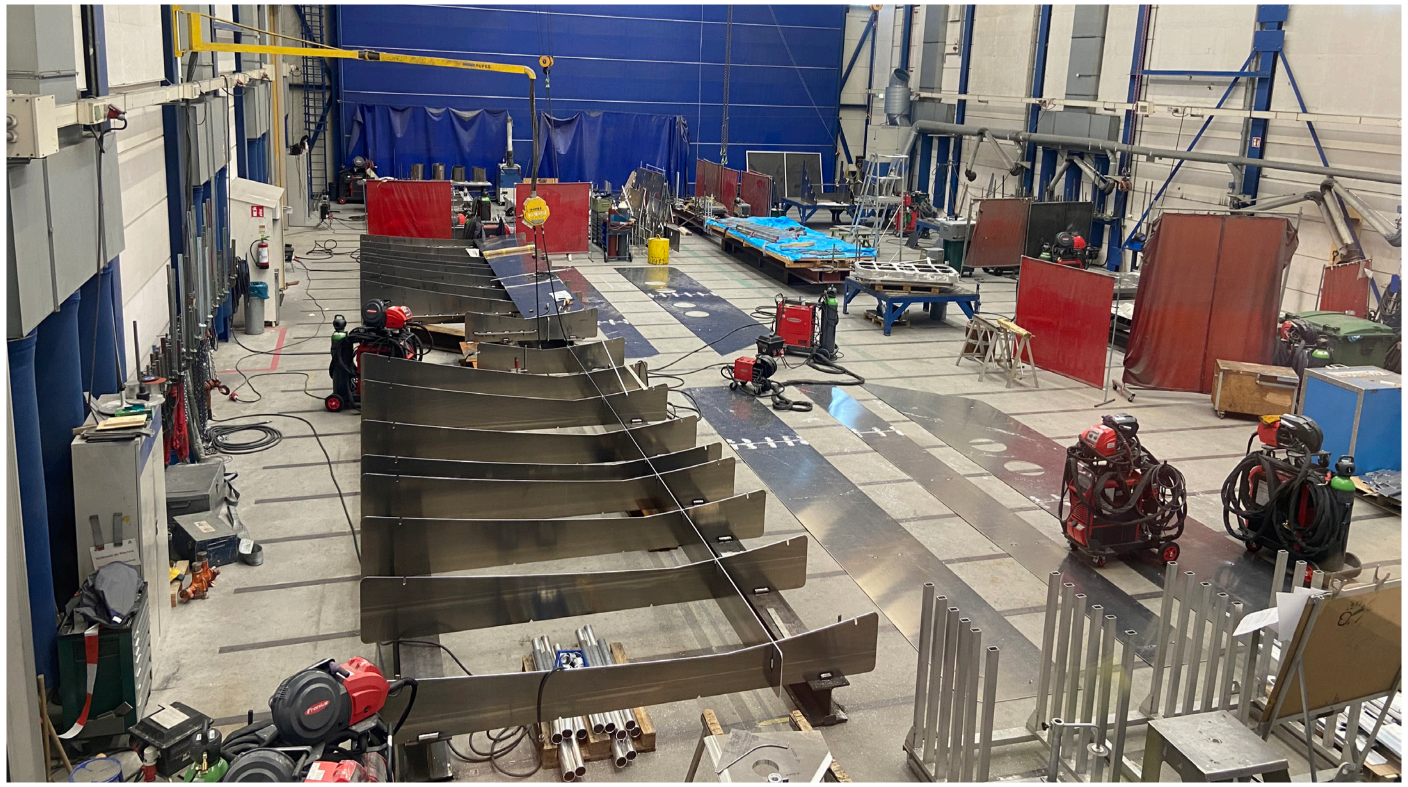


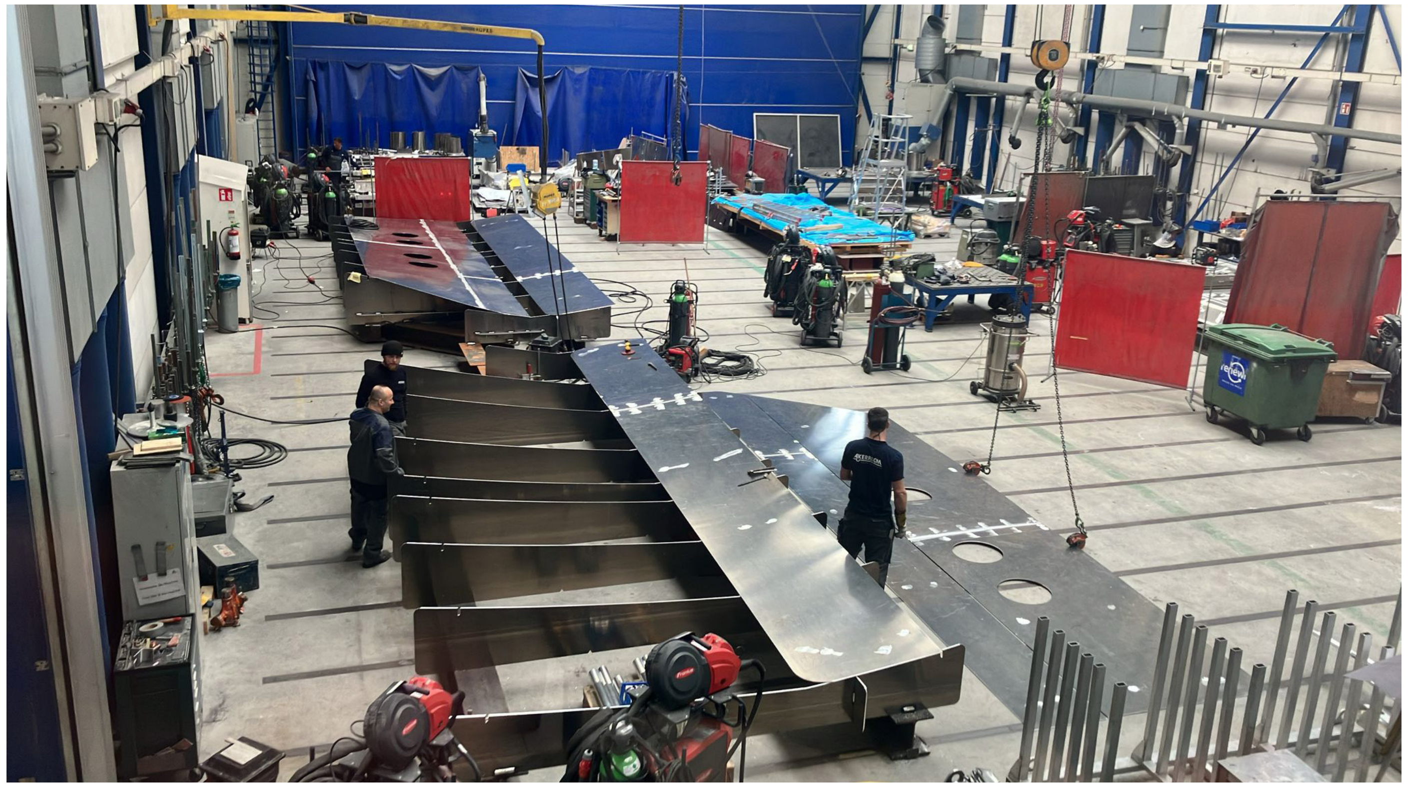


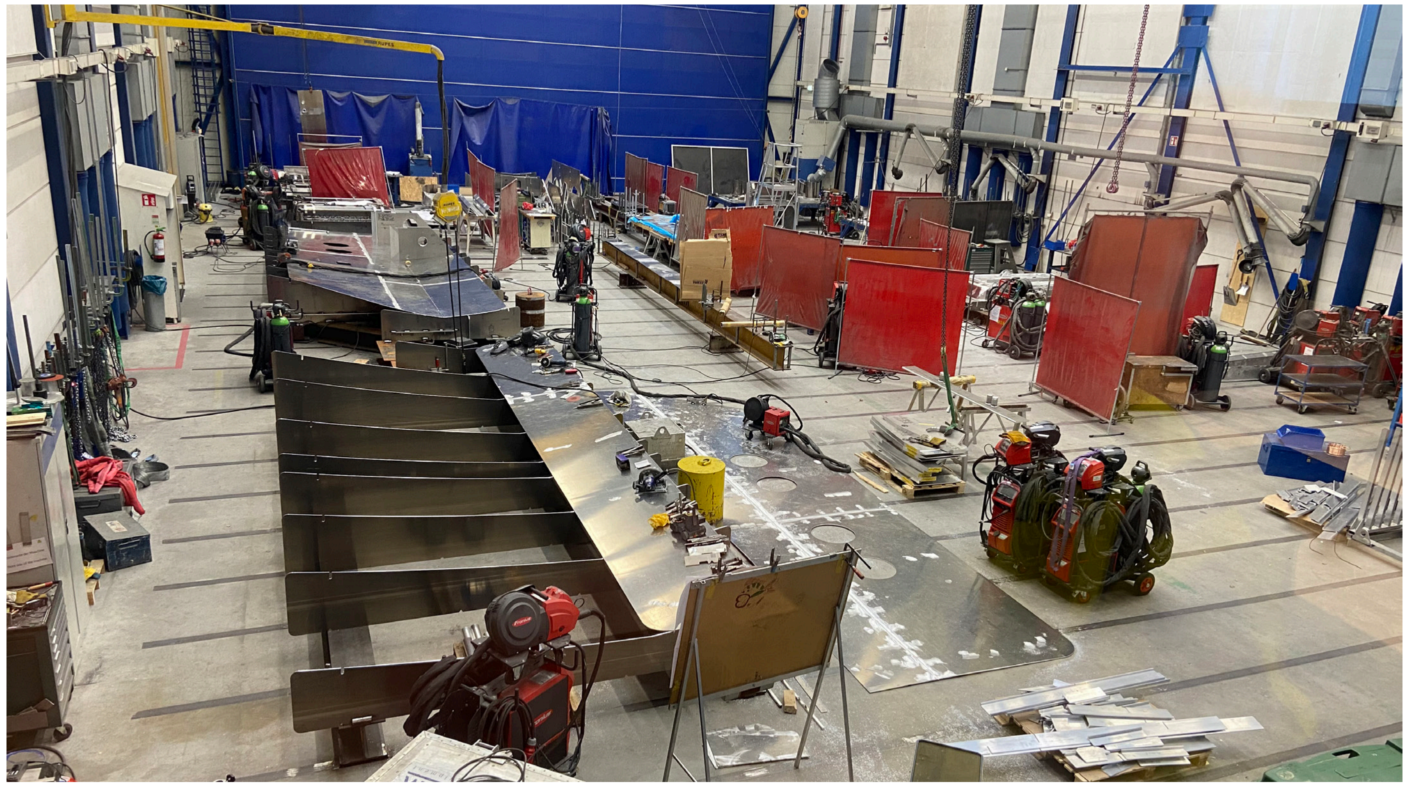


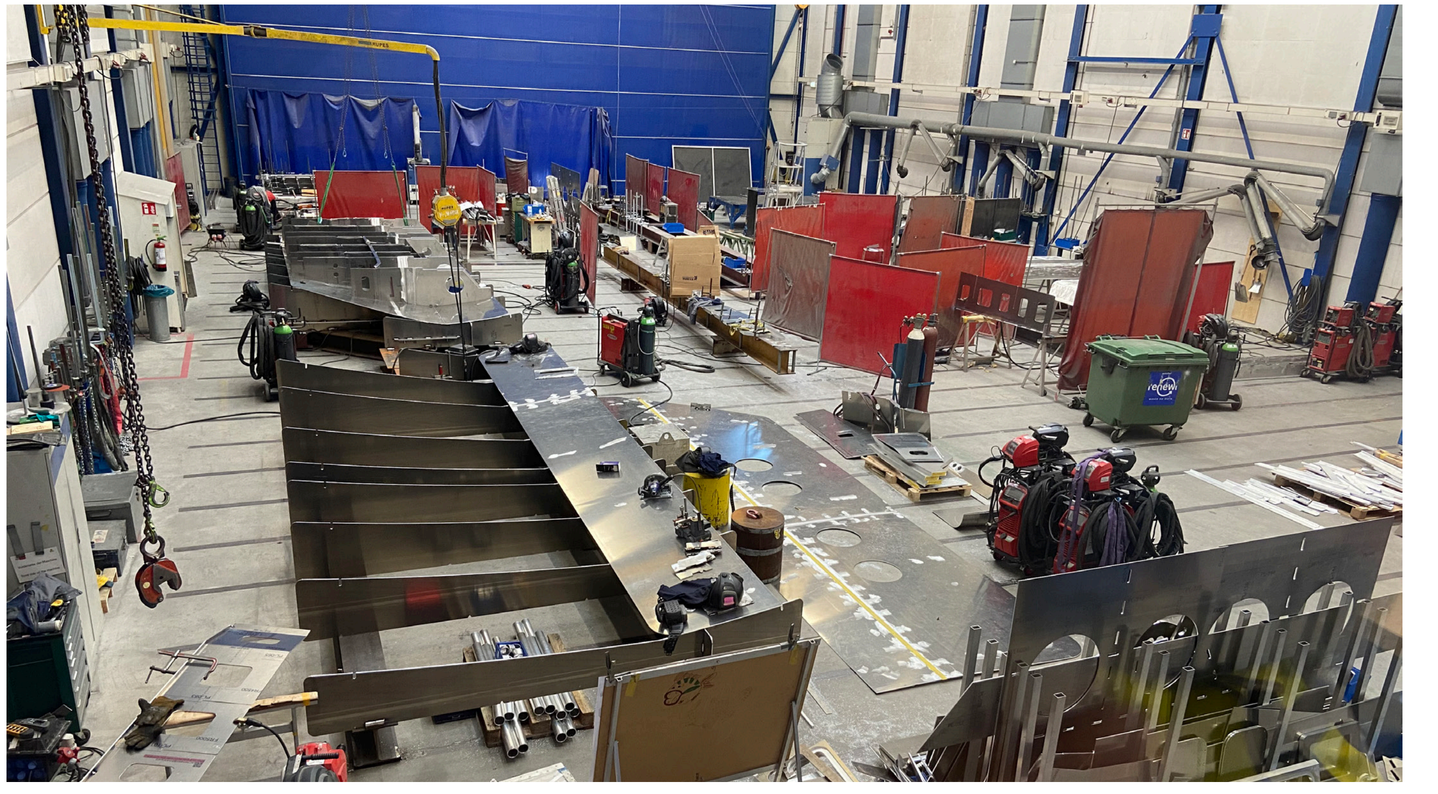


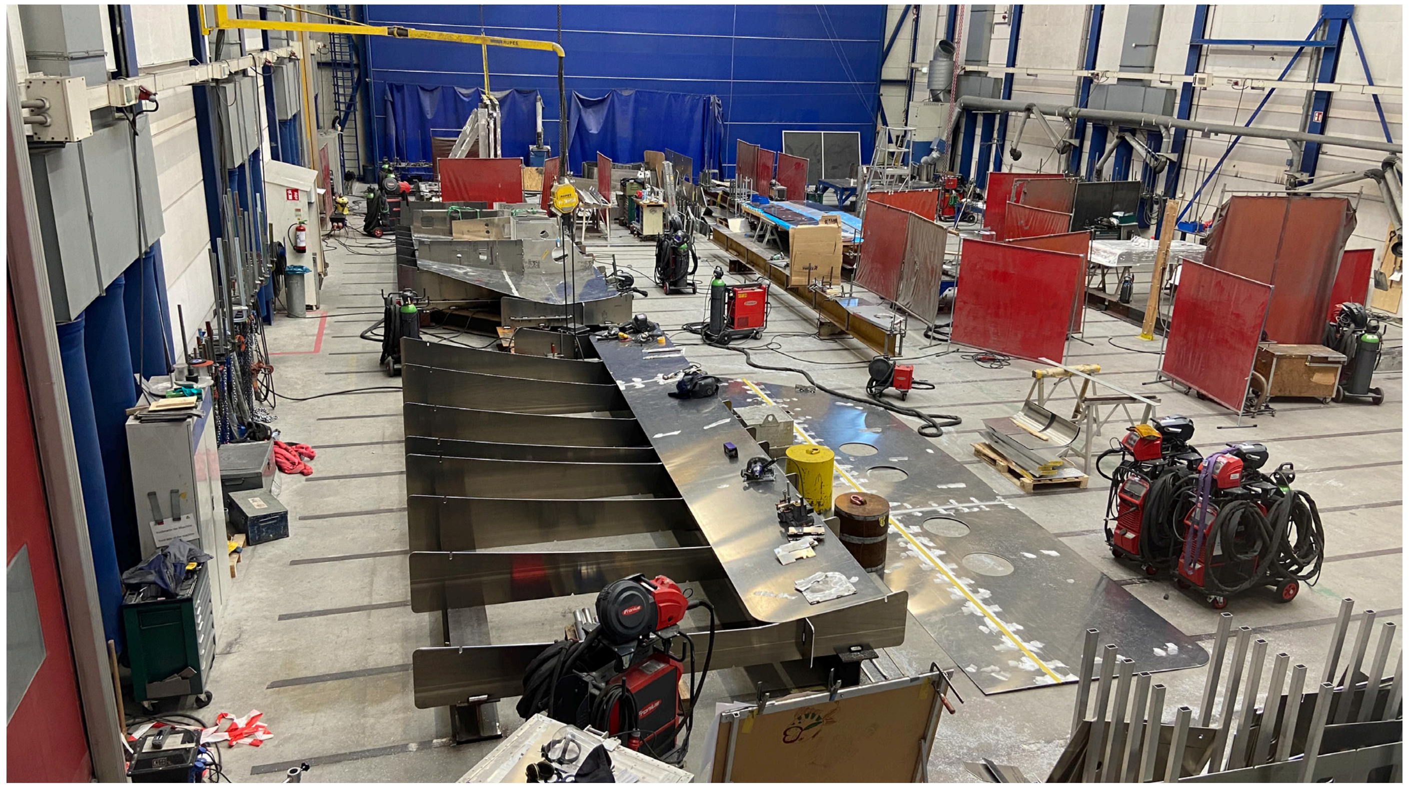


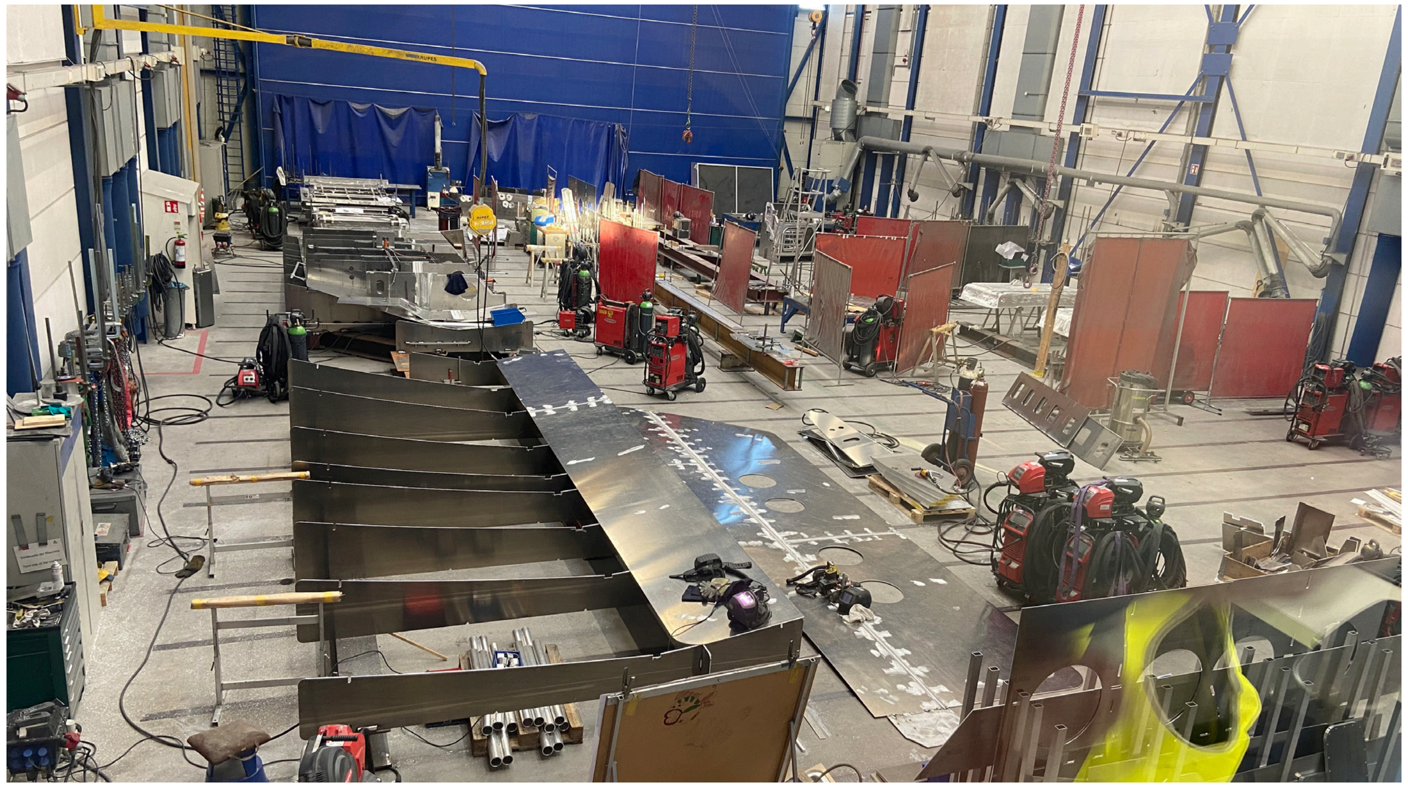
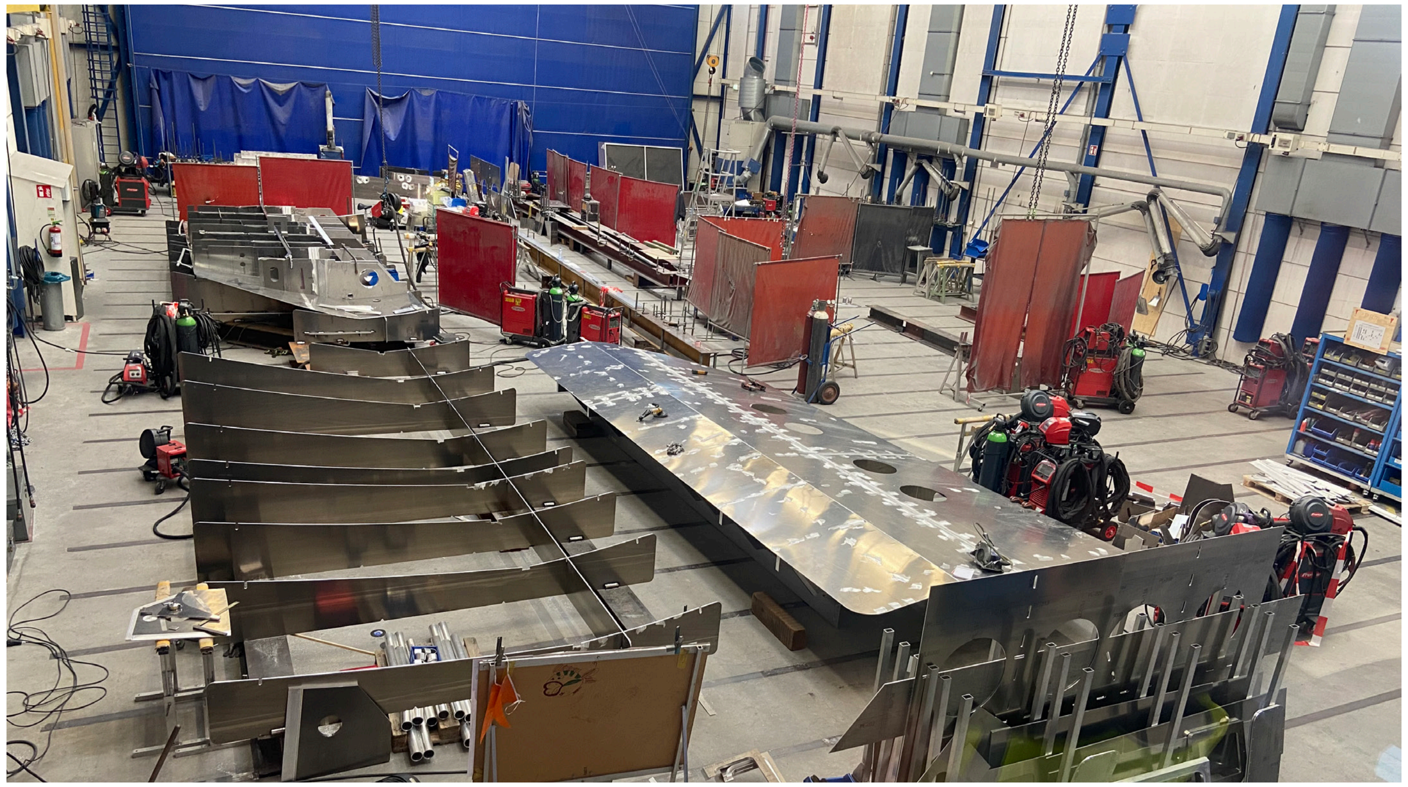
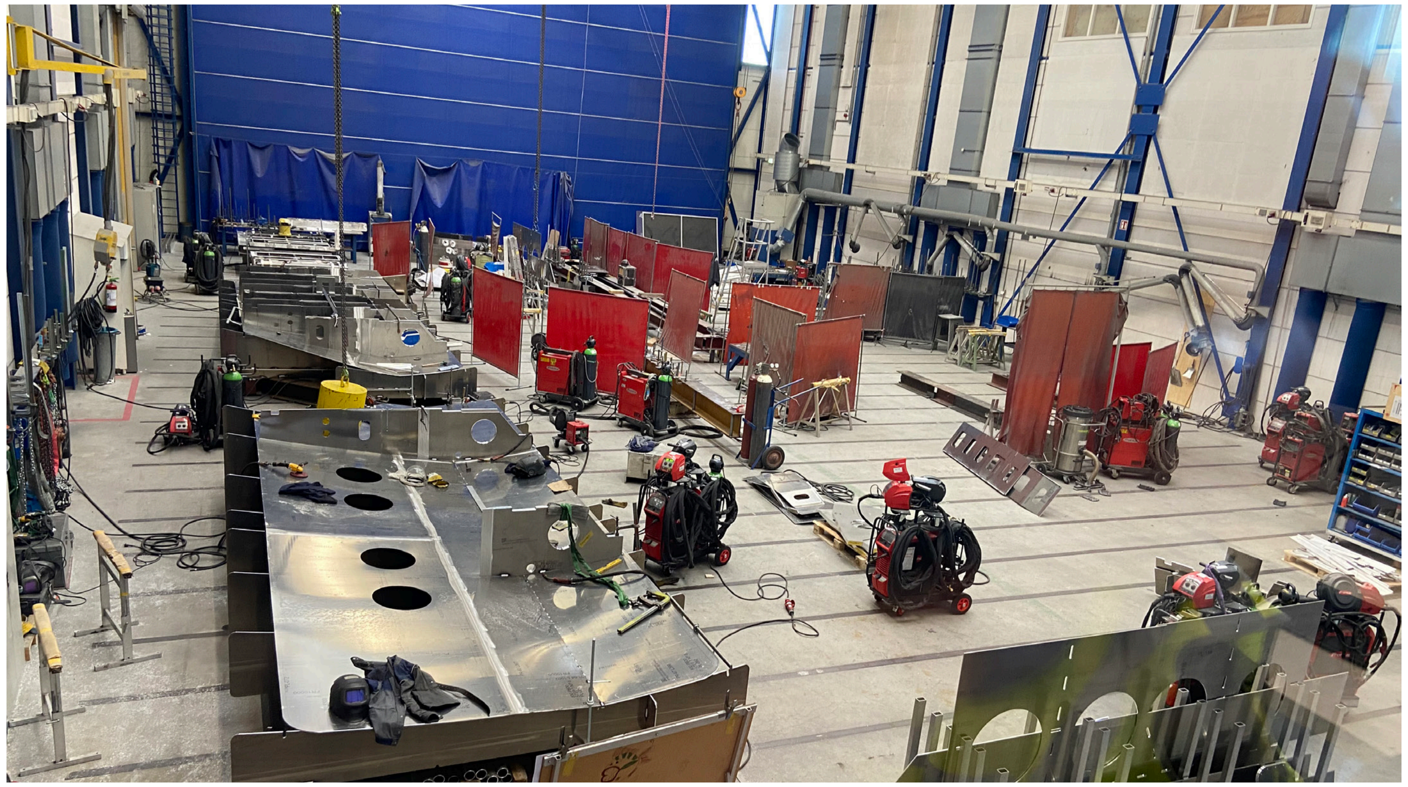
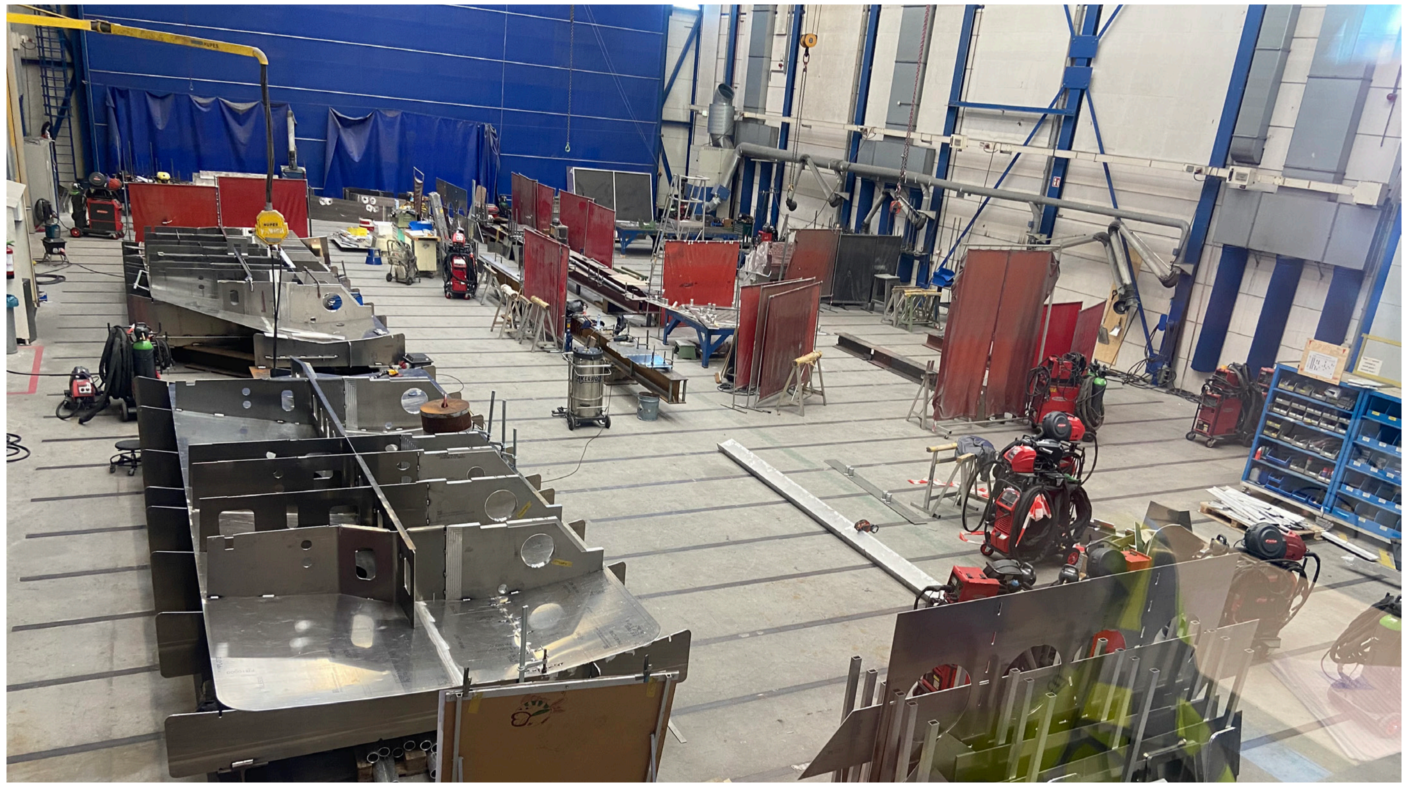


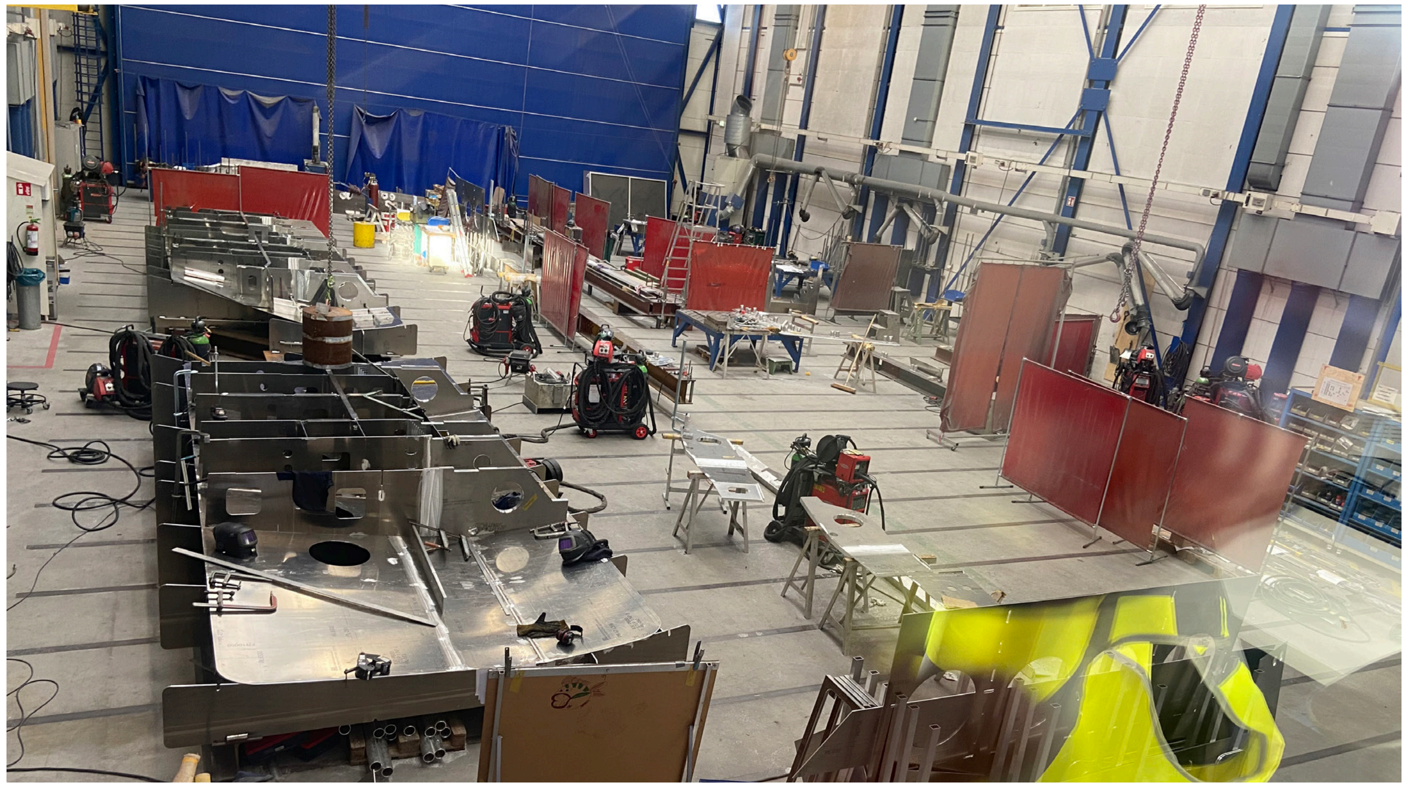
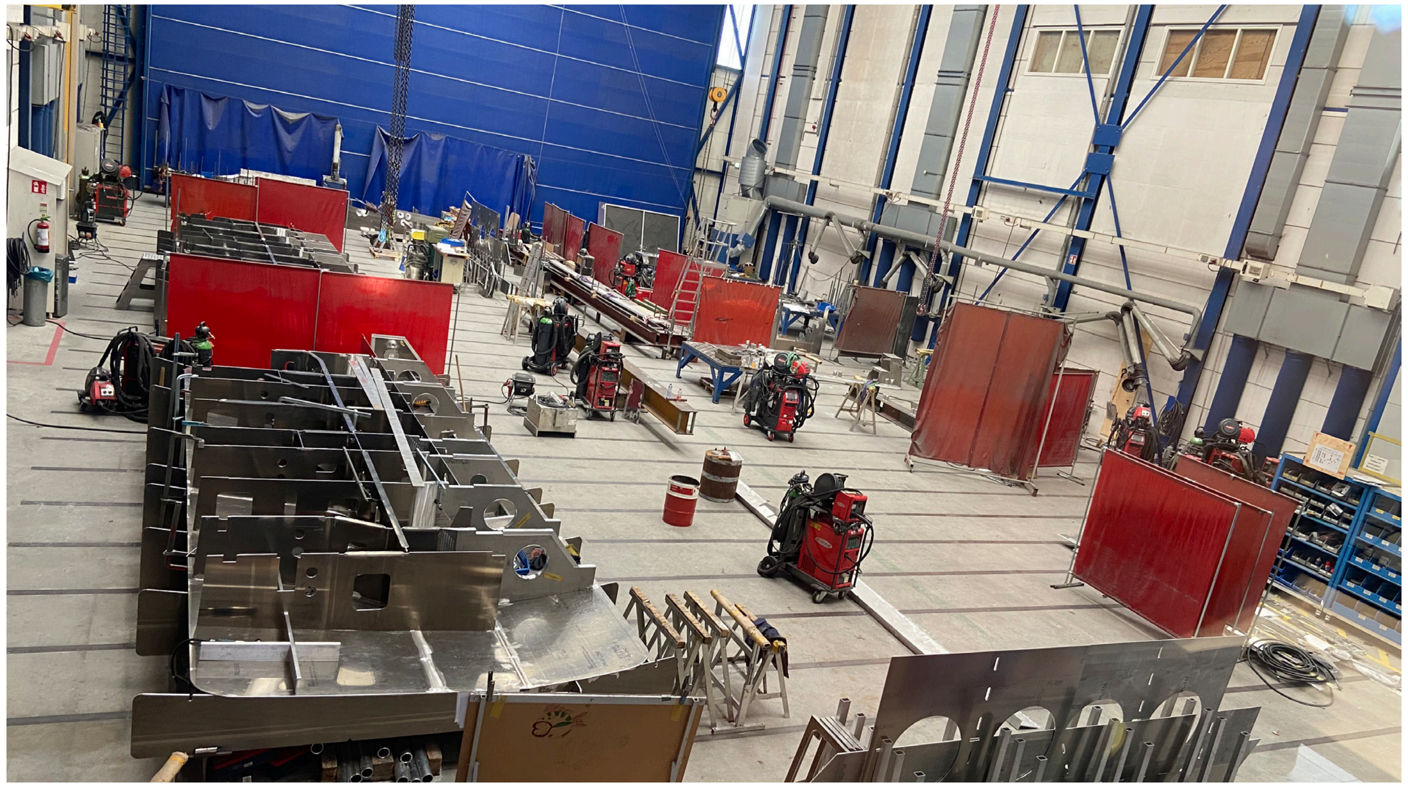
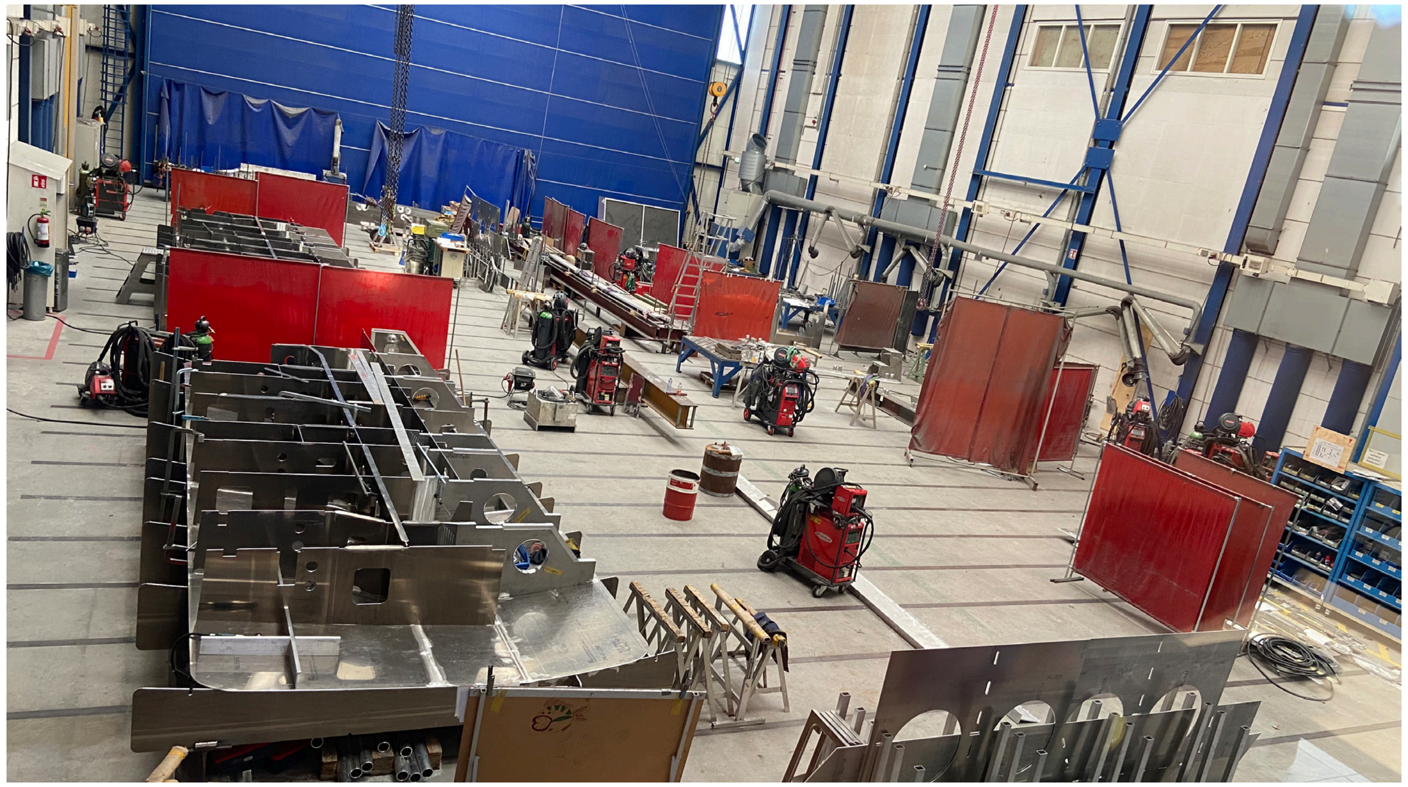
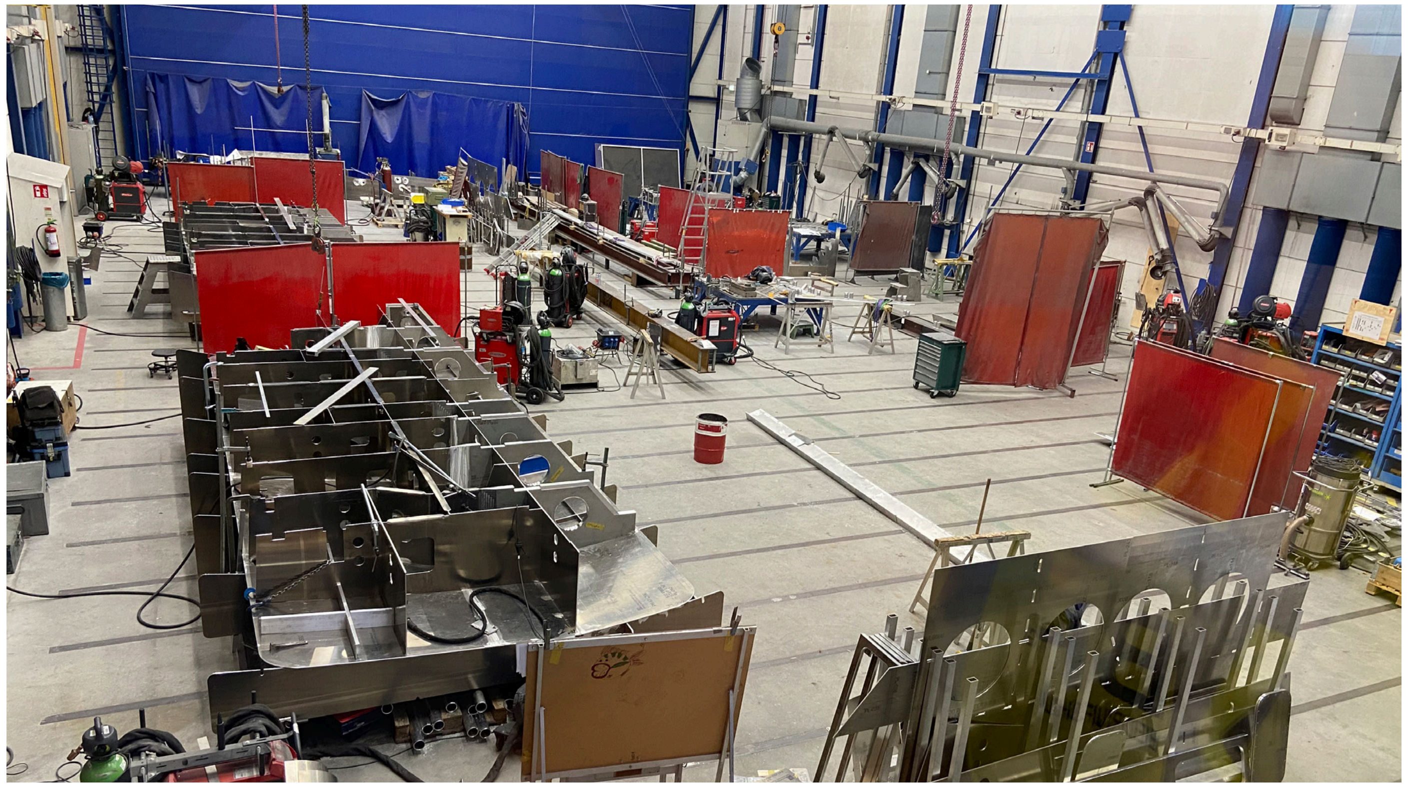


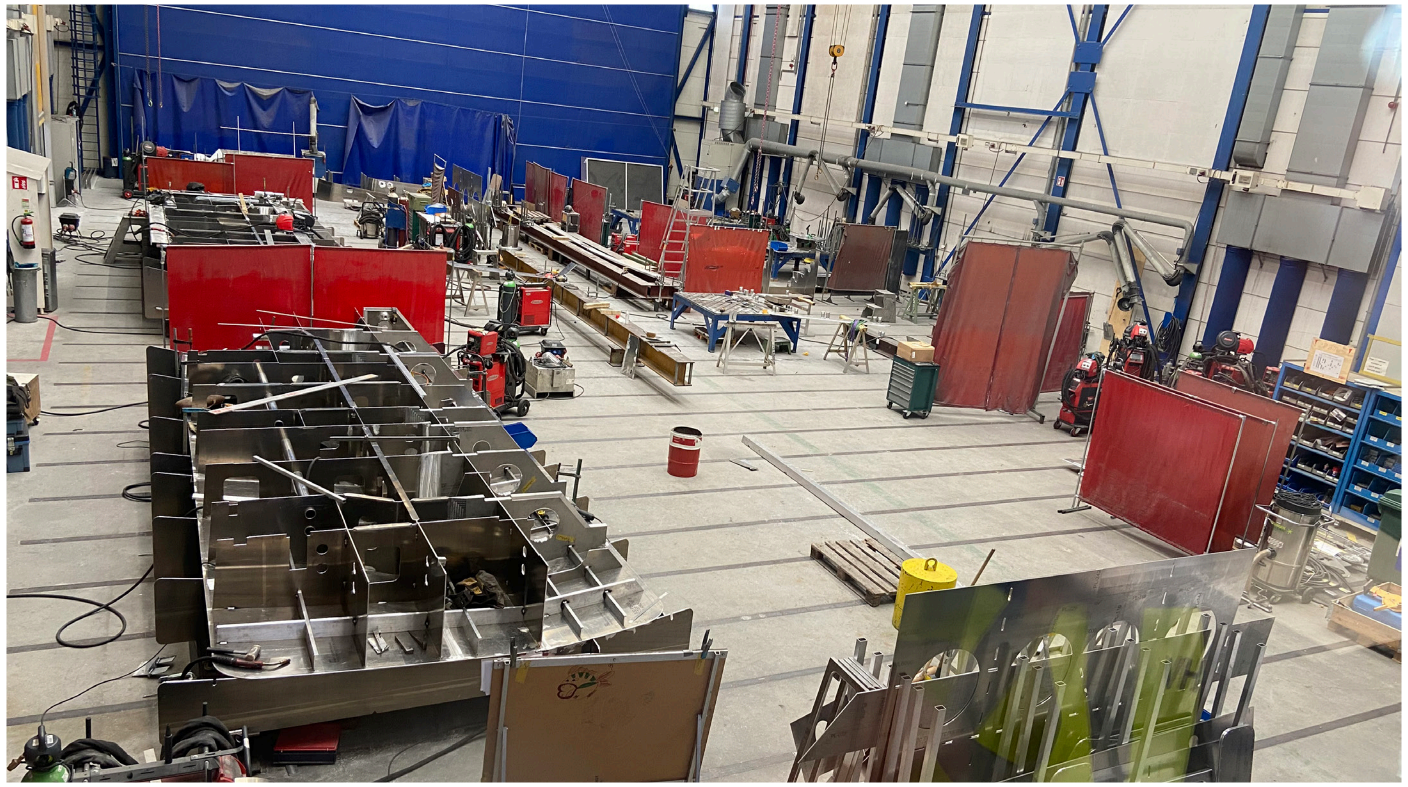
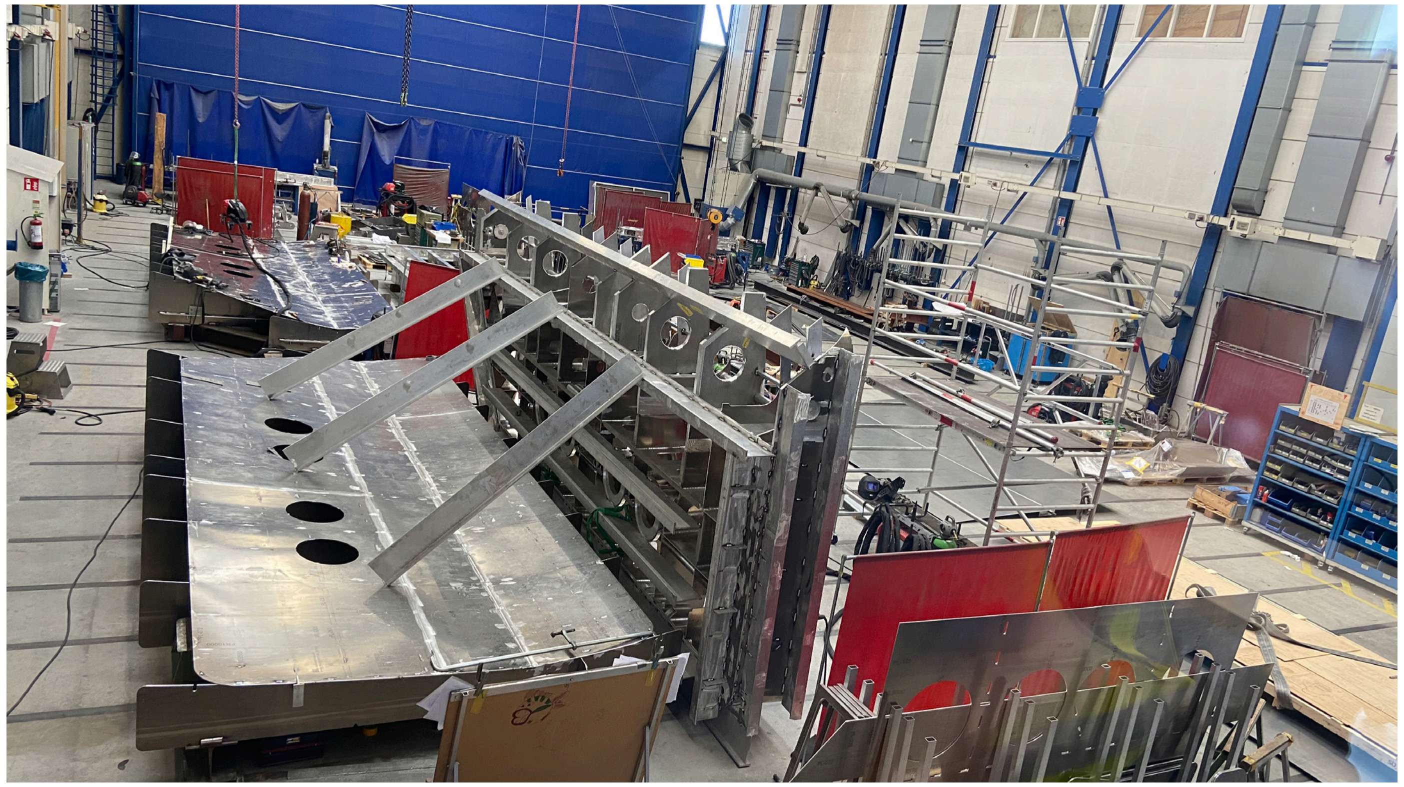


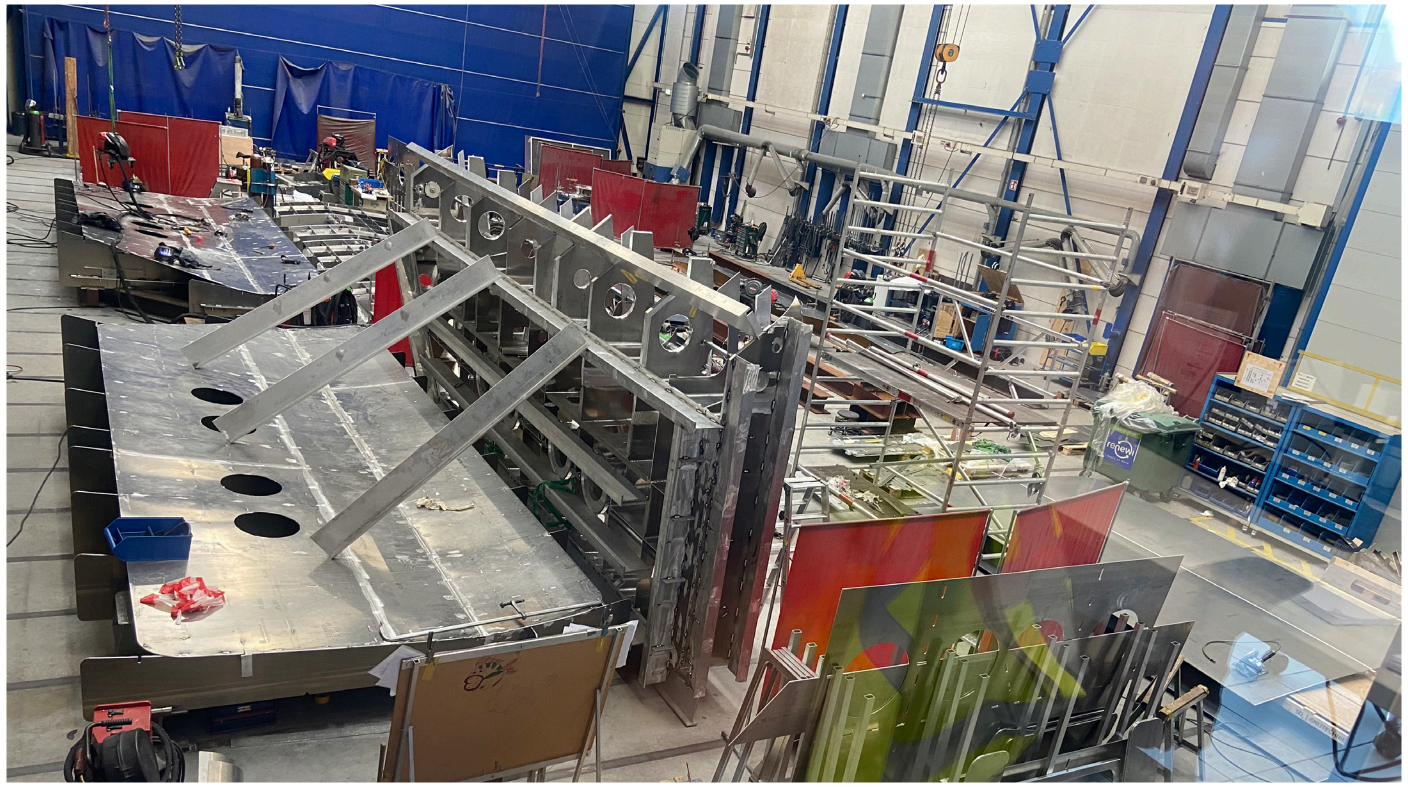


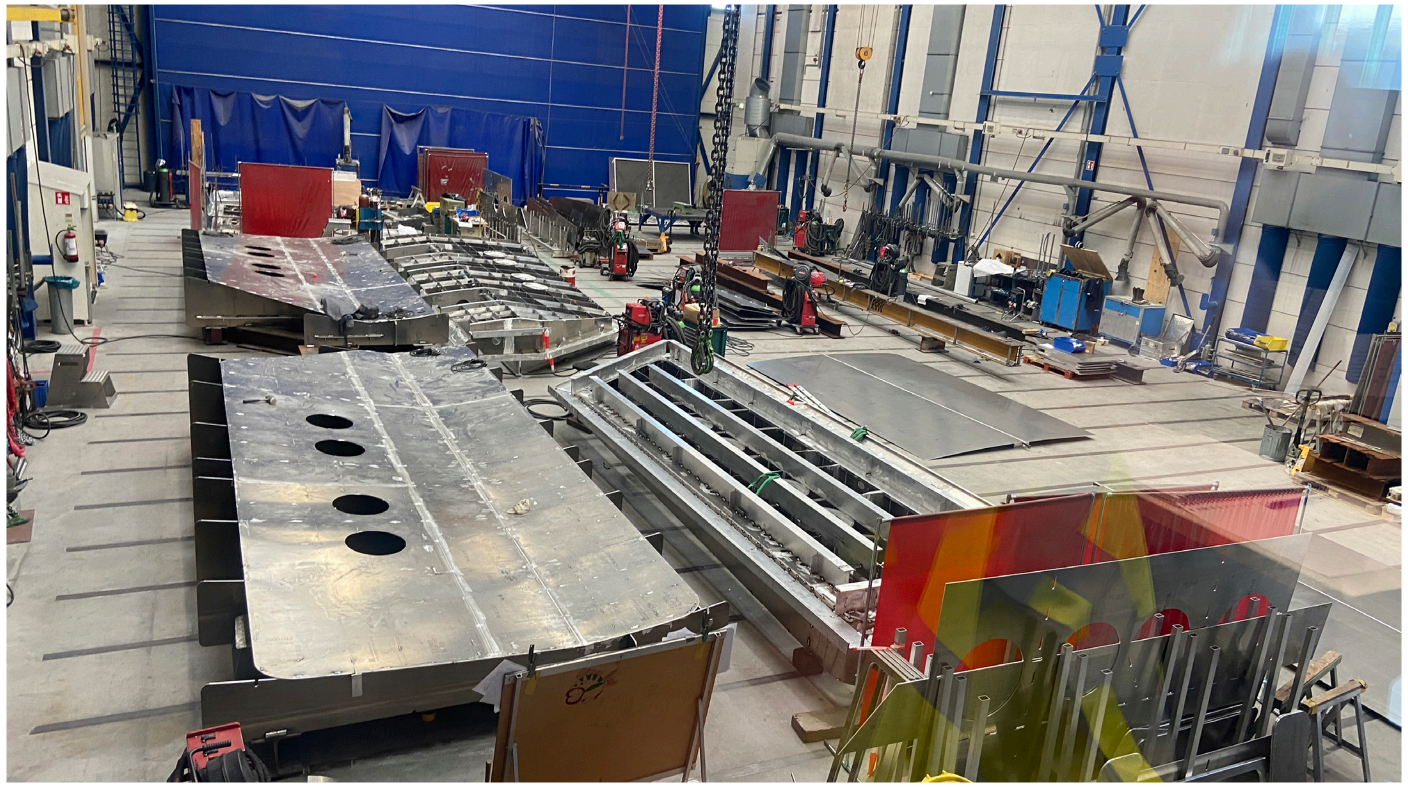


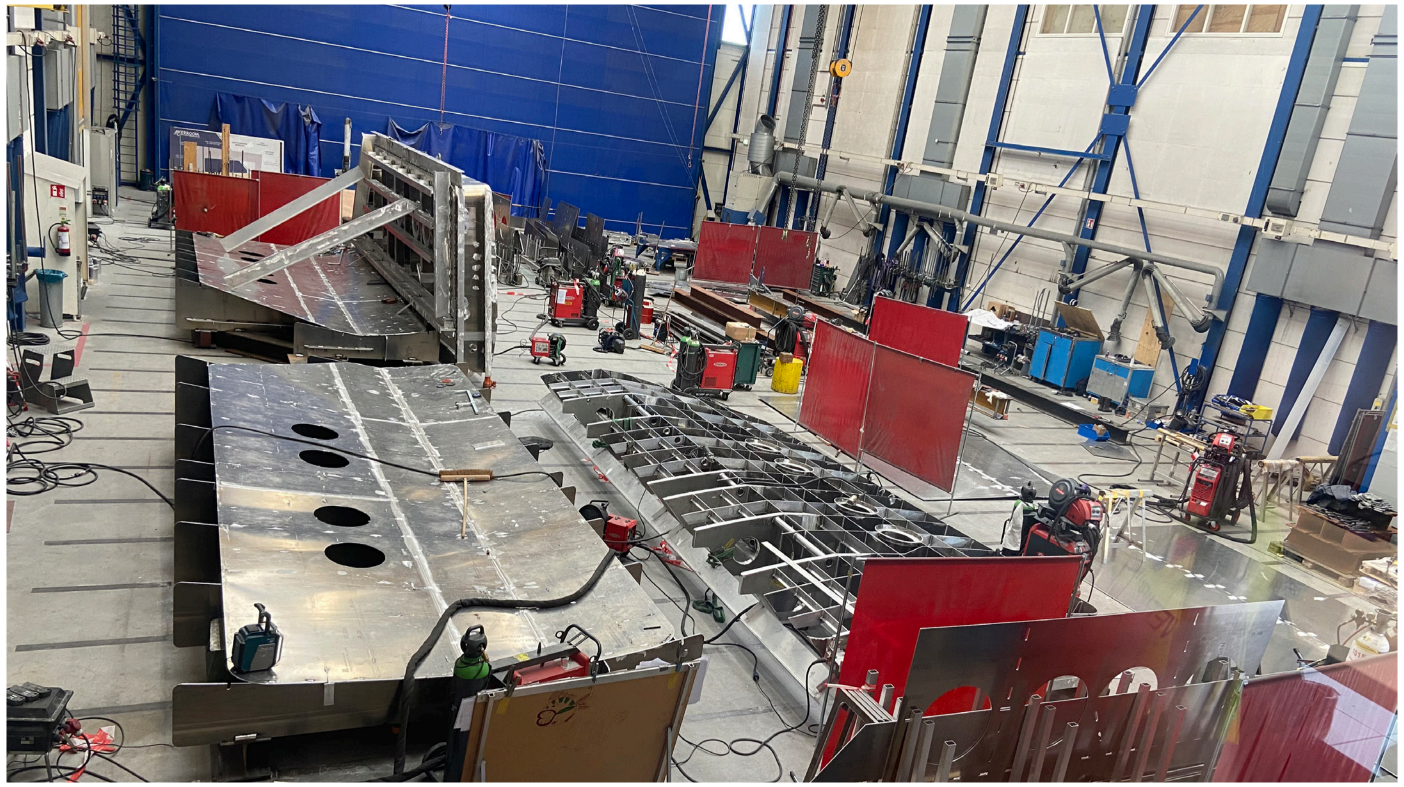





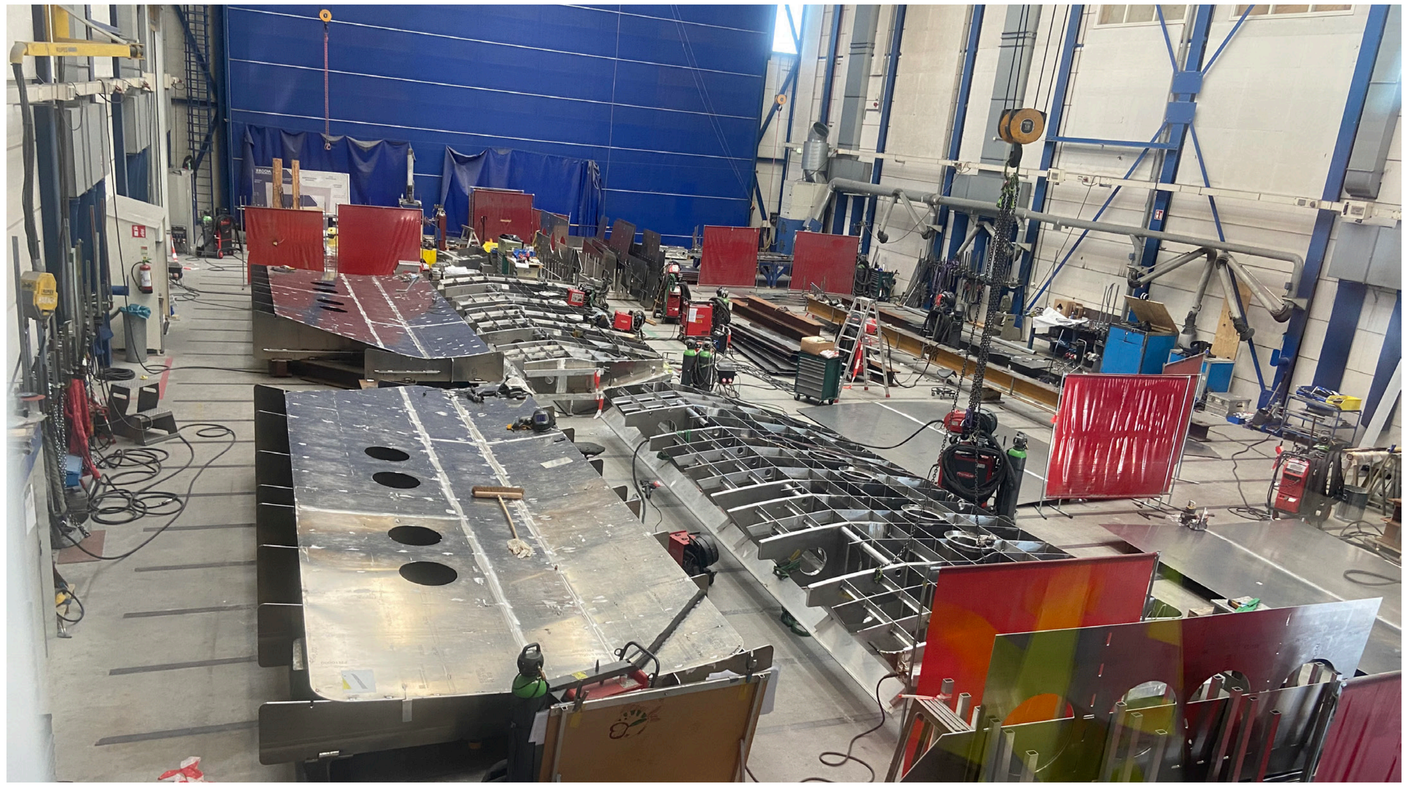





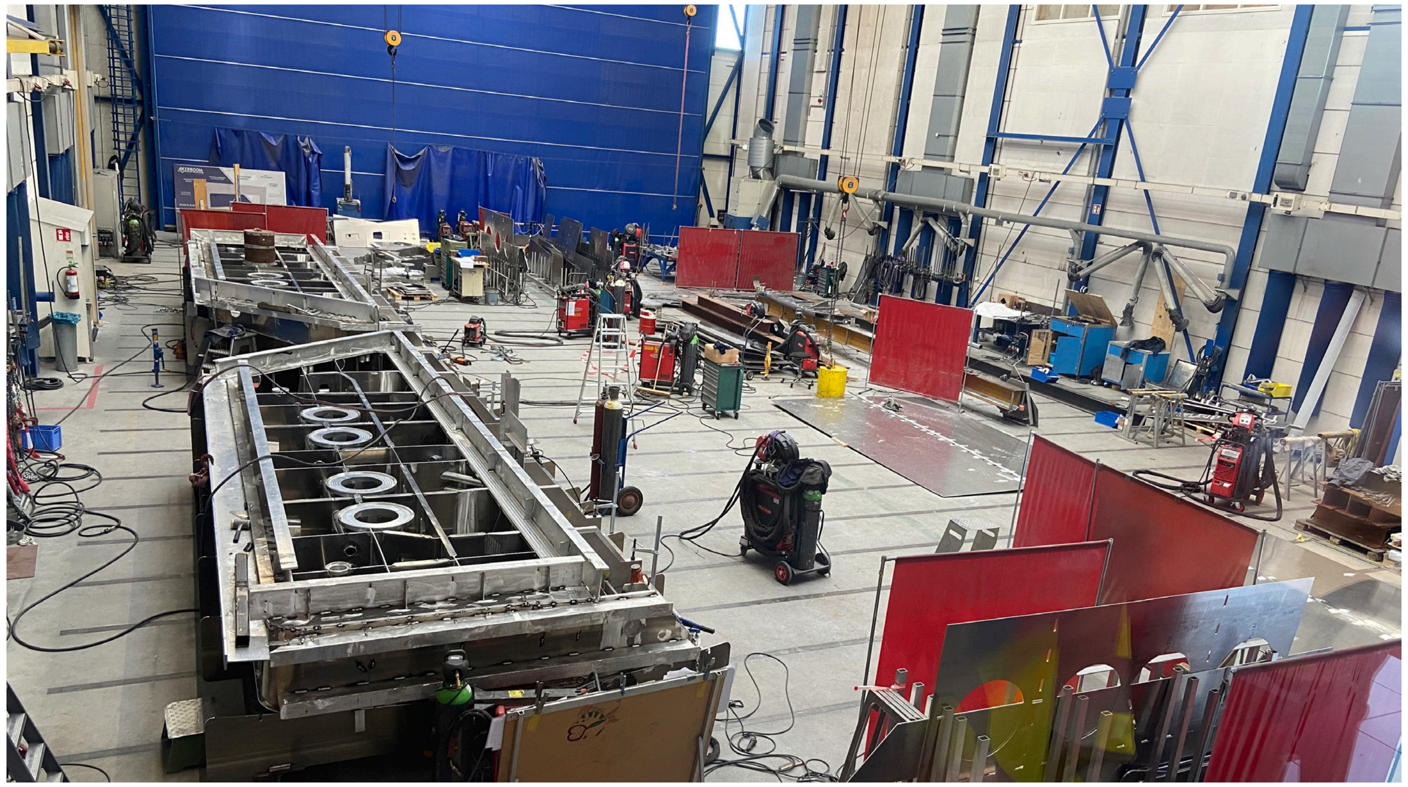



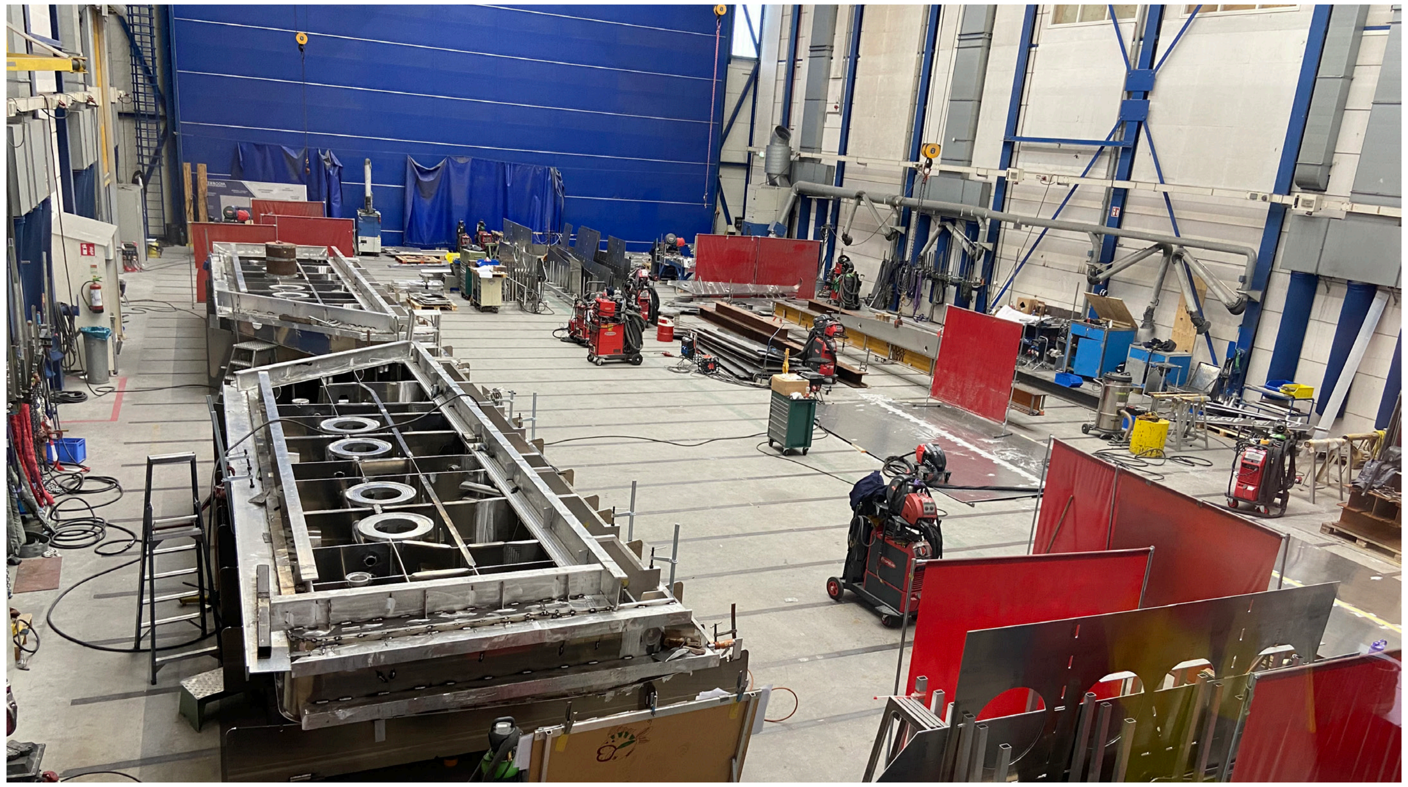


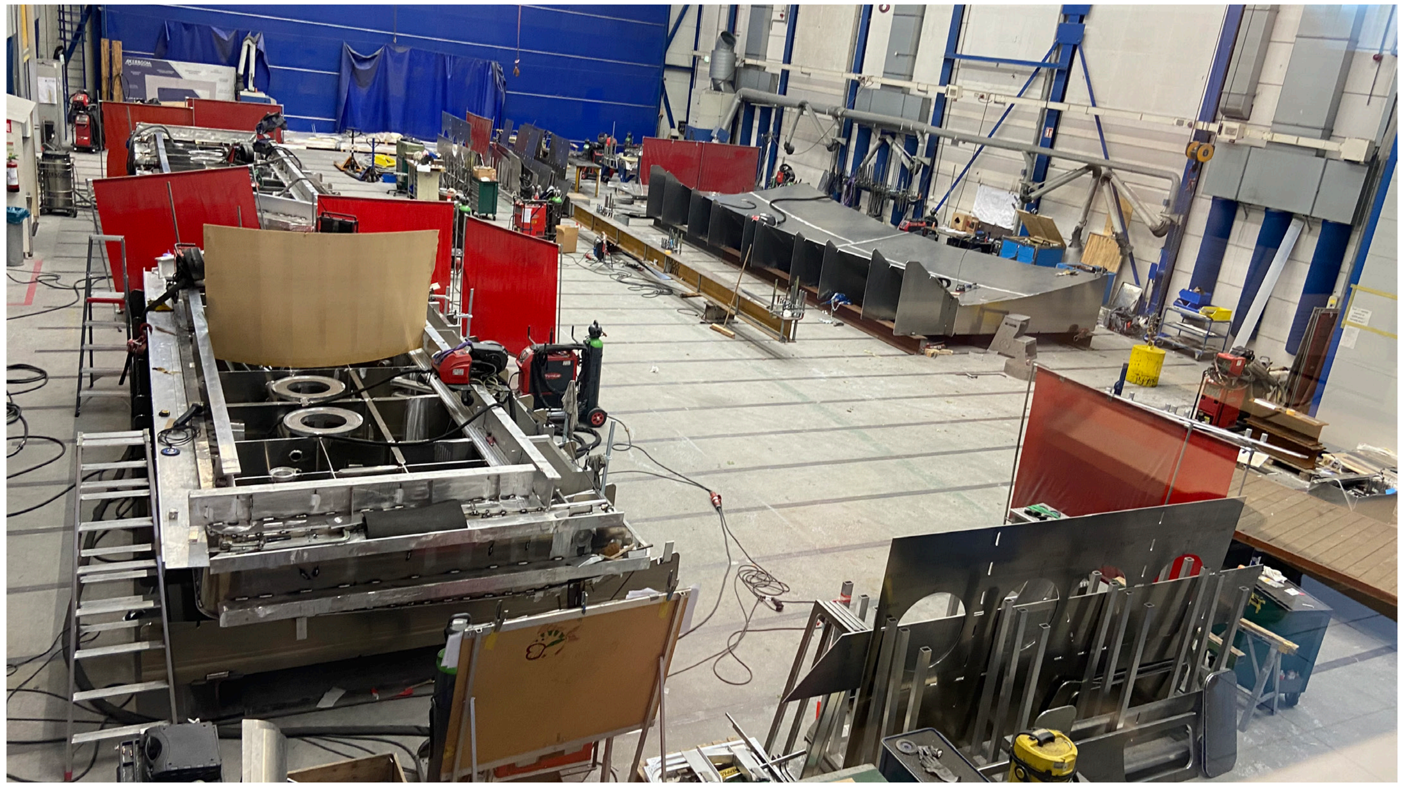


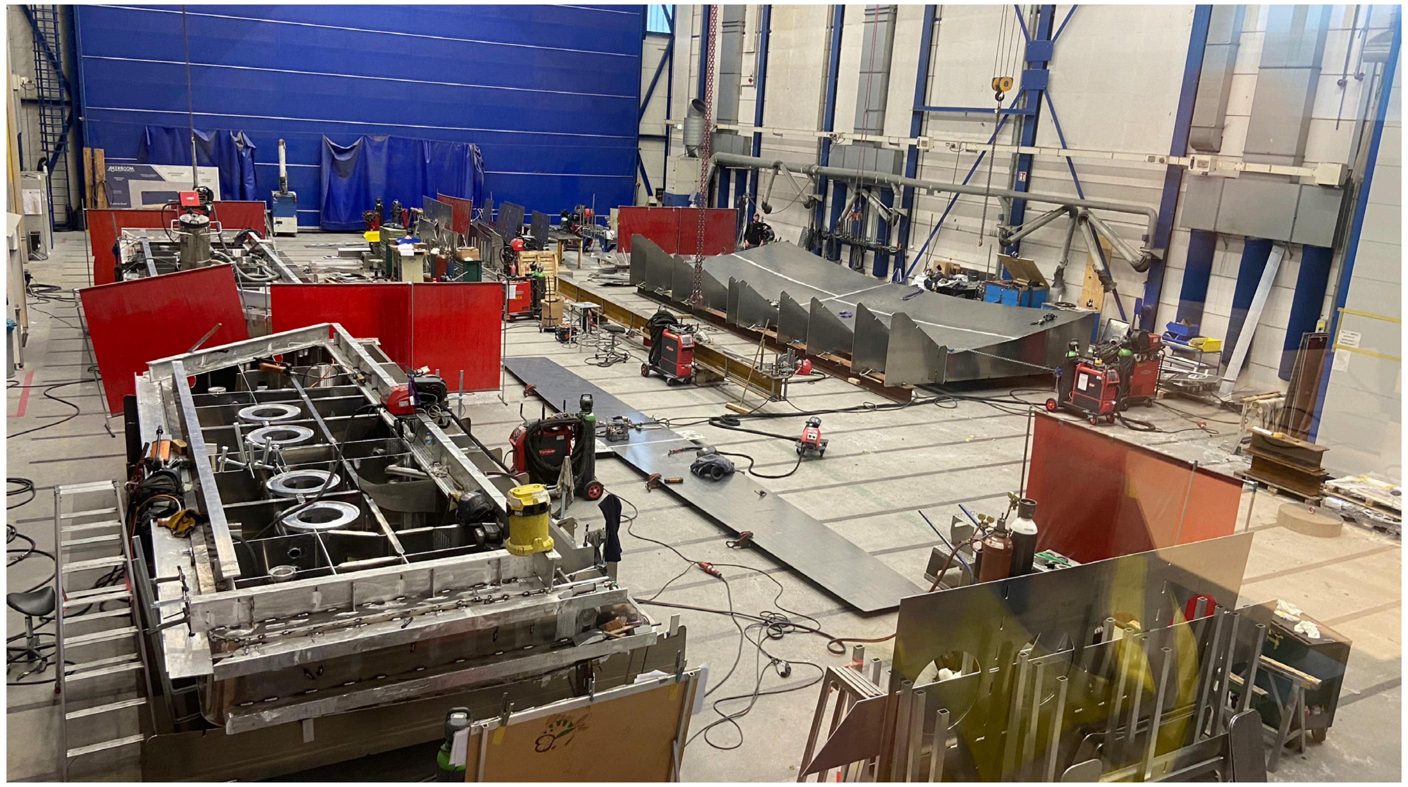






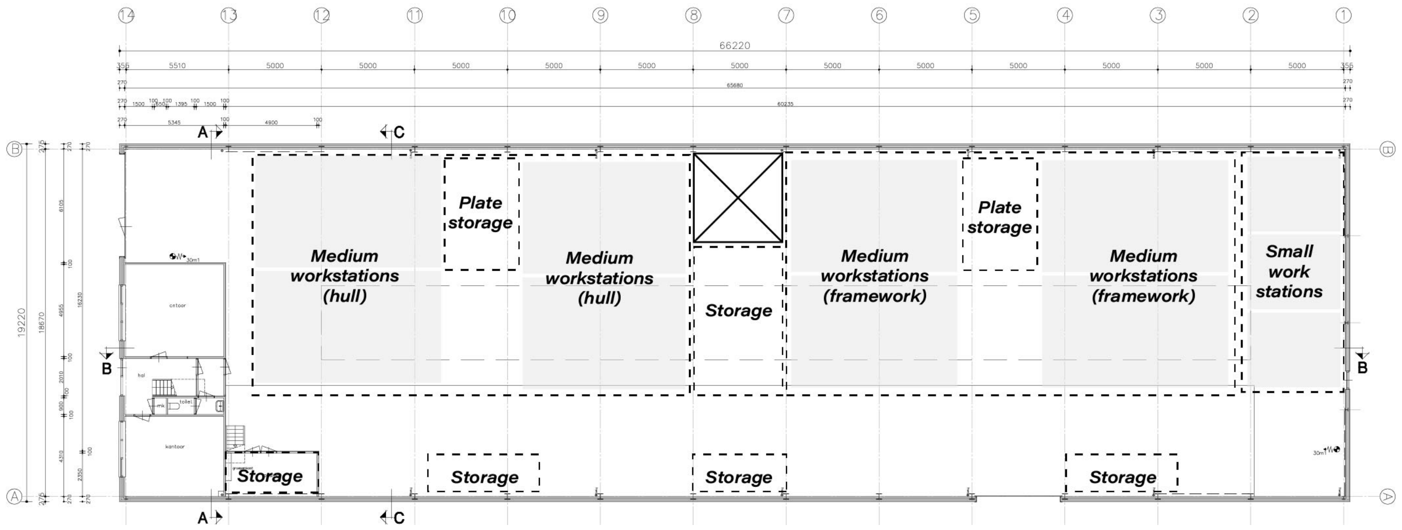




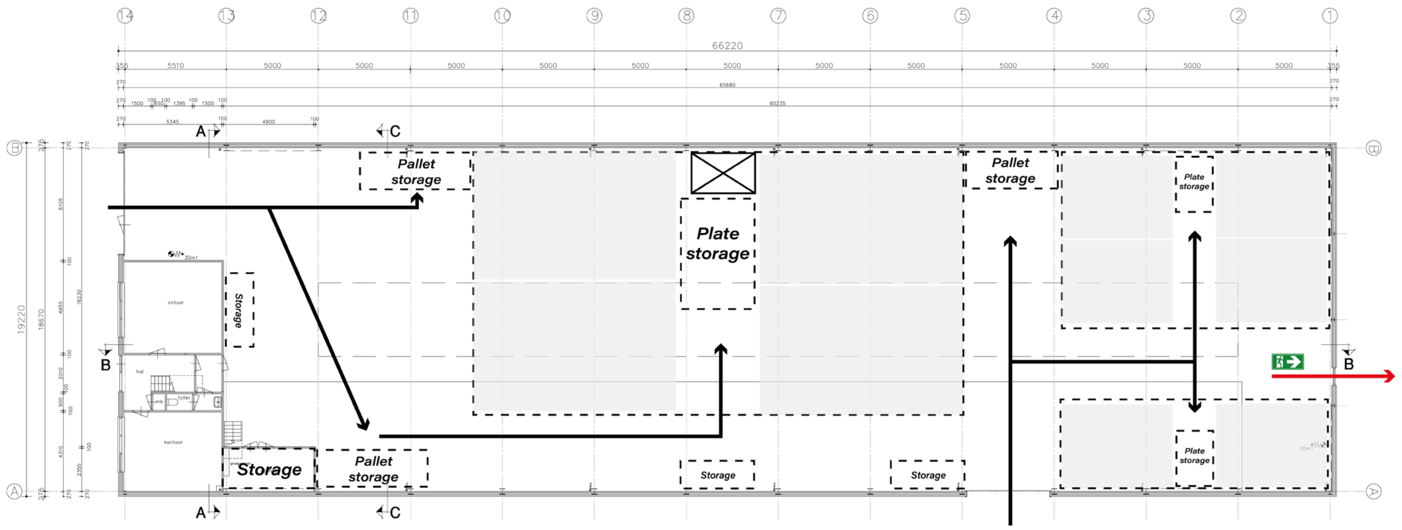


Appendix Q

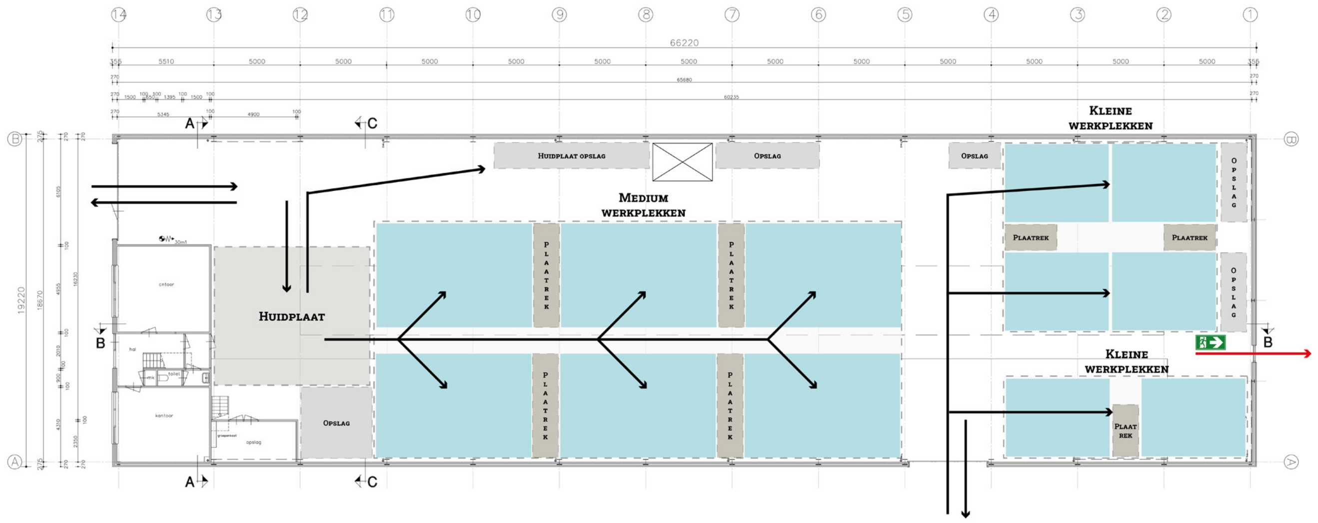
Iterations on the Katwijk's hall lay-out



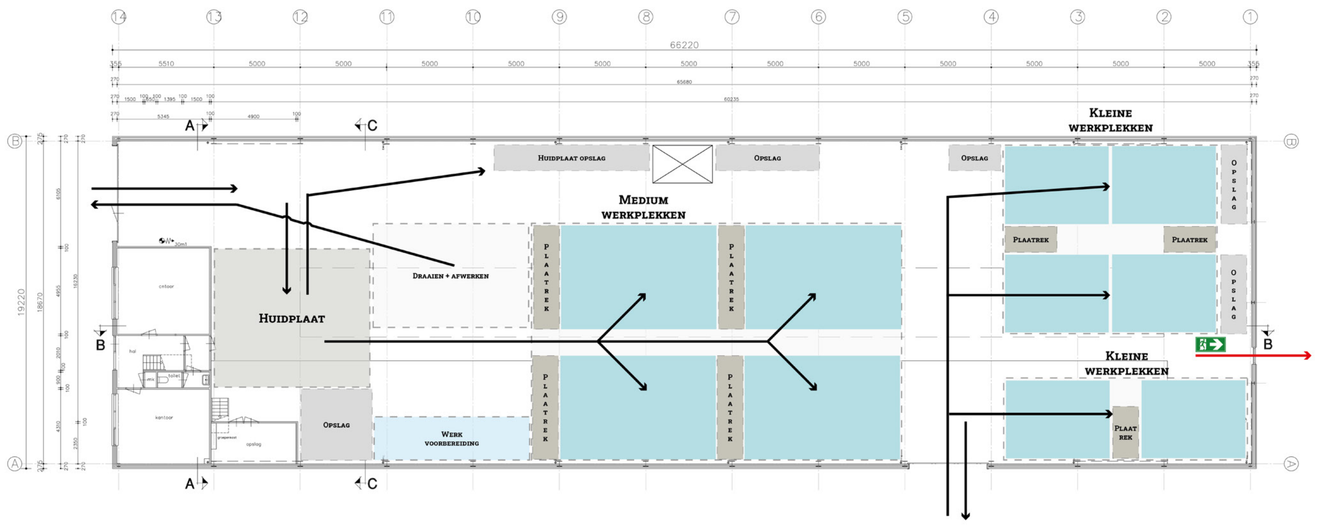
The first lay-out aimed to maximize the number of workstations within the hall while still allocating some space for storage. In this setup, the smaller workstations were placed toward the back (left side of the map), and the remaining floor area was filled with medium-sized workstations. However, this layout failed to reserve adequate space for a loading bay, and the overall flow of goods was not considered. Additionally, one of the small workstations blocked an emergency exit at the rear of the hall, posing a safety concern.



The second layout addressed these shortcomings by taking the flow of goods and truck loading/unloading space into account. Although this resulted in a reduction in the total number of workstations, it allowed for a more functional and compliant layout. The goods flow was also optimized by splitting it into two distinct streams: one serving the medium workstations and one for the smaller ones.



In the third iteration, the medium-sized workstations were repositioned to the right side (bottom of the map) of the hall to optimize the flow of goods across the left side (top of the map). This adjustment improved the overall logistics and material movement within the space. Additionally, a dedicated workstation for **hull plate** welding was introduced to streamline that specific process. To further enhance organization, each workstation was equipped with its own vertical plate storage, reducing unnecessary movement and improving material accessibility.



In the final layout, two medium-sized workstations were removed to free up space for setting and finalizing the assembled **items**. At the same time, a third workstation was added specifically for welding and preparing additional components, ensuring a more balanced and specialized distribution of tasks across the hall.

Appendix R

Justification for the fixture for the structure

To determine the most suitable fixture for the workstations, a comparative evaluation was conducted. This included assessing the concepts proposed during the ideation phase as well as exploring alternative solutions.

Initially, the fixtures developed in the ideation phase were reviewed and assessed using a set of predefined criteria. These include estimated costs, modularity, ease of use, and space efficiency.

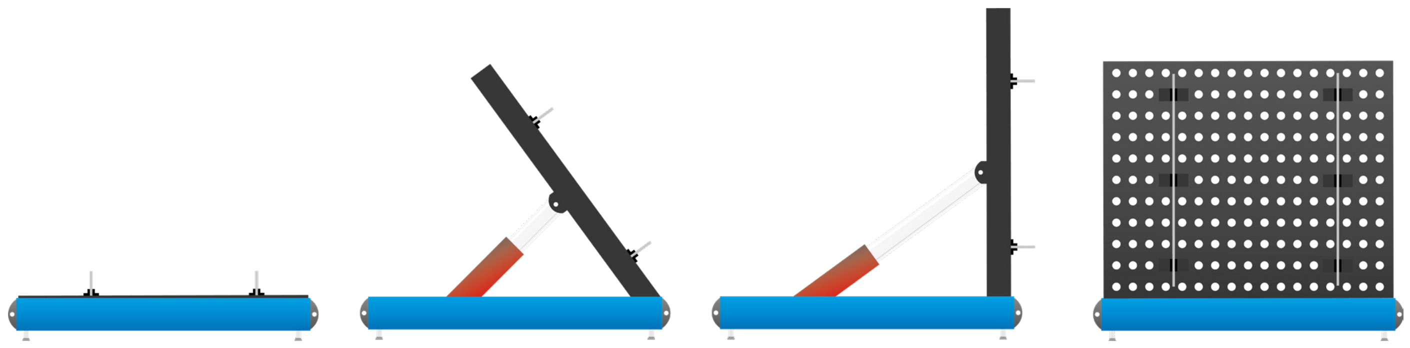
As an alternative, a standard welding table was also considered. Like the earlier concepts, a welding table provides muliple clamping options and sufficient stifness to prevent warping during welding. Additionally, it is a more cost-effective solution and can be used independently of floor type. To further enhance usability, the table can be fitted with height-adjustable legs and caster wheels to improve ergonomics and allow for repositioning within the workspace.

However, a standard table does not allow for rotation of the **item**, meaning the current method, where the **structure** is lifted upright using overhead cranes and supported by T-profile beams, would still be required. While this approach is less efficient, the added value of a rotating fixture does not justify its significantly higher cost within the scope of this project.

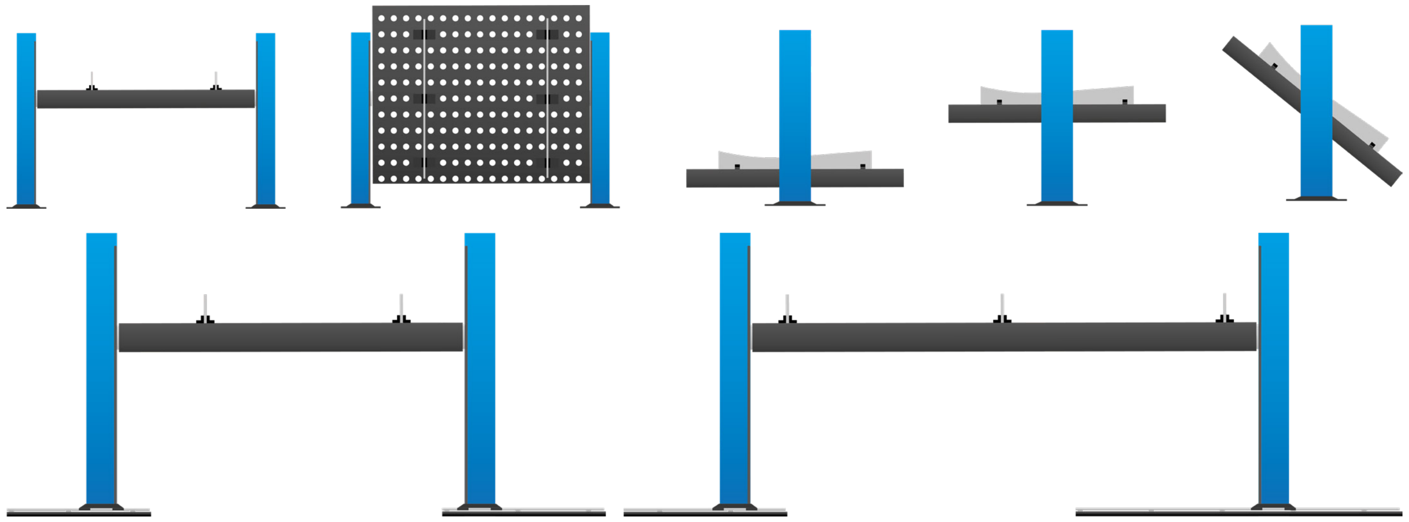
Therefore, it was concluded that a regular, height-adjustable welding table offers the best balance between functionality, cost, and implementation feasibility, and is the most suitable fixture for welding the **items** within the boundaries of this project.

Criteria	Weight	Idea one	Idea two	Idea three	Alternate idea
Cost efficiency	40%	5	2	7	9
Modularity	30%	2	6	4	8
Ease of use	20%	8	6	9	9
Space efficiency	10%	9	5	9	9
Total		5.1	4.3	6.7	**8.7**

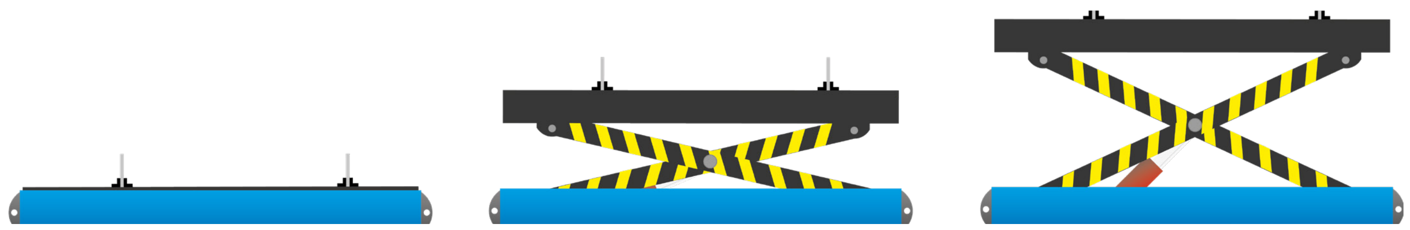
Idea one: Tiltable fixture



Idea two: Fixed height-adjustable and rotating-fixture



Idea three: Lifting fixture



Alternate idea: Welding table

Appendix S

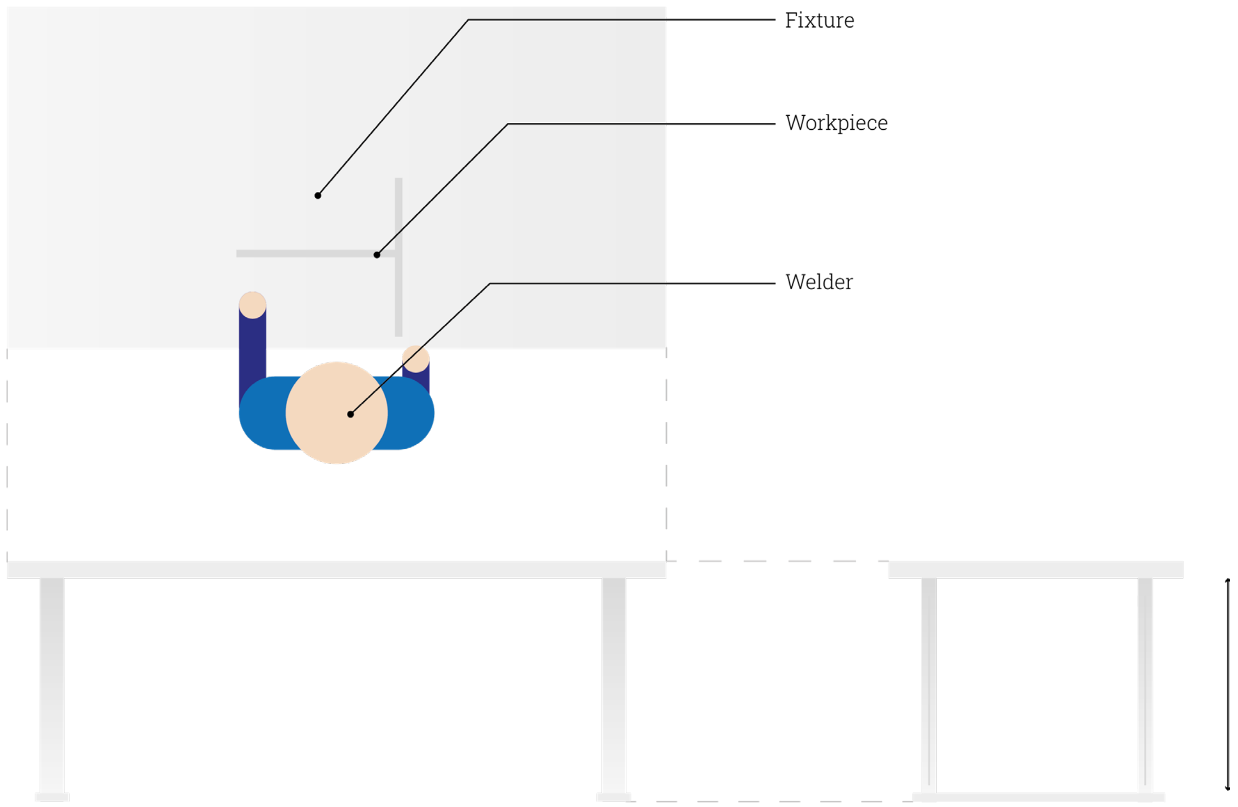
User test setup & results (translated to english)

For the user test, welders at Akerboom are asked to perform a series of welding tasks on a height-adjustable fixture, which holds a 2 × 1 meter aluminum plate (see the figure below). Smaller plates, simulating **girders**, can be welded onto this base plate. The legs of the fixture consist of two trestles which can be set to any desirable height. The welders can set the fixture to their desired height (ranging between when performing the tasks. This mock-up fixture simulates the fixture proposed for the concept.

The welders are instructed to weld in three standard positions: PB and PF. To simulate varying working conditions, they are also asked to weld at different locations on the fixture, including both the sides and the center.

Photographs are taken during the welding process to facilitate later evaluation of the ergonomics and to record adjustments made with the fixture during the tasks. After completing the tasks, the welders are asked the following set of questions to assess the perceived value and desirability of using a height-adjustable fixture:

- Did the fixture improve your physical comfort and working posture during welding tasks?
- Was adjusting the height intuitive?
- Did the fixture help you perform the welds more efficiently or accurately?
- Would you want to use a height-adjustable fixture in your regular work? Why or why not?



Participant one

Did the fixture improve your physical comfort and working posture during welding tasks?

Yes, I could definitely stand up straighter. Normally I hunch over, since I am a taller guy. This fixture let me keep my back straighter, which helped.

Was adjusting the height intuitive?

Adjusting the height was easy enough, didn't have to think much about it, but an extra pair of hands would be useful.

Did the fixture help you perform the welds more efficiently or accurately?

I think I worked a bit faster in the PA position, mostly because I wasn't adjusting myself, but the quality stayed the same.

Would you want to use a height-adjustable fixture in your regular work? Why or why not?

Yes, I'd use this. Saves my back and shoulders, especially after a long shift. However, the heigh-adjustability mechanism needs to be simple and able to hold the heavy items.

Participant two

Did the fixture improve your physical comfort and working posture during welding tasks?

It was nice to bring the table up for the horizontal welds.

Was adjusting the height intuitive?

Honestly, the adjustment is a but clumsy. I had to wrestle it into the right height.

Did the fixture help you perform the welds more efficiently or accurately?

I felt like I had more control, especially in the PF position. I wasn't constantly shifting my stance.

Would you want to use a height-adjustable fixture in your regular work? Why or why not?

With a sturdier and faster mechanism, I'd definitely be in favour of using a table like this. The concept is solid, just needs refinement.

Participant three

Did the fixture improve your physical comfort and working posture during welding tasks?

I usually just deal with whatever setup there is, but this felt better on my shoulders.

Was adjusting the height intuitive?

It was straightforward. The mechanism worked without much effort.

Did the fixture help you perform the welds more efficiently or accurately?

Didn't change much for the weld quality, but I felt less tension in my arms.

Would you want to use a height-adjustable fixture in your regular work? Why or why not?

I'd consider using it if it's reliable and doesn't slow me down. My body's not what it used to be.

Participant four

Did the fixture improve your physical comfort and working posture during welding tasks?

Yeah, less strain on my shoulders.

Was adjusting the height intuitive?

Adjusting the height was a bit of a fight, not something I'd want to do repeatedly in a busy shift.

Did the fixture help you perform the welds more efficiently or accurately?

I wouldn't say more accurate, but for longer periods of time I could hold a steady position better without getting tired.

Would you want to use a height-adjustable fixture in your regular work? Why or why not?

Yeah, I'd use it, but not with the current mechanism, it takes too much time to re-adjust. But anything that keeps me from having a bad back is profitable.

Appendix T

Full test score of the Ergoscore tool

Ergonomische risico's

Selecteer
- Tillen (>3kg)
- Trekken en duwen
- Repetitief werken (>10x/min)
- Staand werken (<2m)
- Geknield werken
- Zittend werken
- Extreme houdingen (rug/schouders)
- Vermoeiend werk (>4u wandelen)

Tillen

Tijd (frequentie)
<1x/3min | <160x/dag

Intensiteit (max. gewicht)
15-25kg

Houding rug
Licht gebogen EN gedraaid

Houding schouders (positie handen)
Boven ellebogen | Op halve armlengte

Omstandigheden (ruimte, grip)
Gewoon | >90x90cm | haakgreep

Risicoscore tillen
75

Trekken en duwen

Tijd
<10m/keer | <400m/dag

Intensiteit (gewicht + transpallet)
<400kg

Houding - rug en schouders
Licht gebogen of gedraaid

Omstandigheden - wielen, ondergrond
Optimaal | vloer vlak/hard | goede staat wielen | verticale handgreep

Risicoscore trekken en duwen
25

Repetitief werken

Duur (% taakduur)
25-50% | 2-4u/dag

Intensiteit (# handbewegingen / minuut)
>15x/min

Houding (polsen en schouders)
Licht gebogen EN gedraaid

Omstandigheden (verlichting, trilling, tempo)
Beperkt | <500Lux | voelbare trilling | tempo met buffer

Risicoscore repetitief werken
70

Staand werken

Duur (ter plaatse staan)
50-75% | >4u/dag

Intensiteit (aan één stuk door ter plaatse staan)
>1u

Houding (rug en nek)
Licht gebogen EN licht gedraaid

Omstandigheden (ondergrond, trilling, temperatuur, ruimte)
Gewoon | vlakke ondergrond | geen trilling | >90x90cm

Risicoscore staand werken
85

Geknield werken

Tijd (duur of frequentie)
<15min/dag | <1x/2min

Intensiteit (duur aan één stuk door op knieën)
>5min

Houding (rug)
Licht gebogen of gedraaid

Omstandigheden (vloer - ruimte)
Slecht | lokale druk op knie | <90x90cm

Risicoscore geknield werken
75

Zittend werken

Duur (% tijd zitten)
<25% | <2u/dag

Intensiteit (aantal uur zitten zonder onderbreking)
<2uur

Houding (rug en nek)
Licht gebogen EN gedraaid

Omstandigheden (zetel, kussen, ondergrond)
Gewoon | stoel verstelbaar | dun kussen | kleine oneffenheden

Risicoscore zittend werken
50

Extreme houdingen

Tijd (frequentie)
>1x/2min | >5% | >30min/dag

Intensiteit (kracht)
Redelijk | >5kg

Houding (rug/schouder)
Eén gewricht met torsie

Omstandigheden (omgeving, ruimte, grip)
Gewoon | haakgreep | >90x90cm | niet-voelbare trilling

Risicoscore ongunstige houdingen
80

Vermoeiend werken

Duur (%tijd op de voeten)
>4u/dag | 50-75%

Intensiteit (zwaarte werk)
Middelmatig | werken met handen en armen | 5-15kg

Houding (rug/armen)
Matig | Licht gebogen

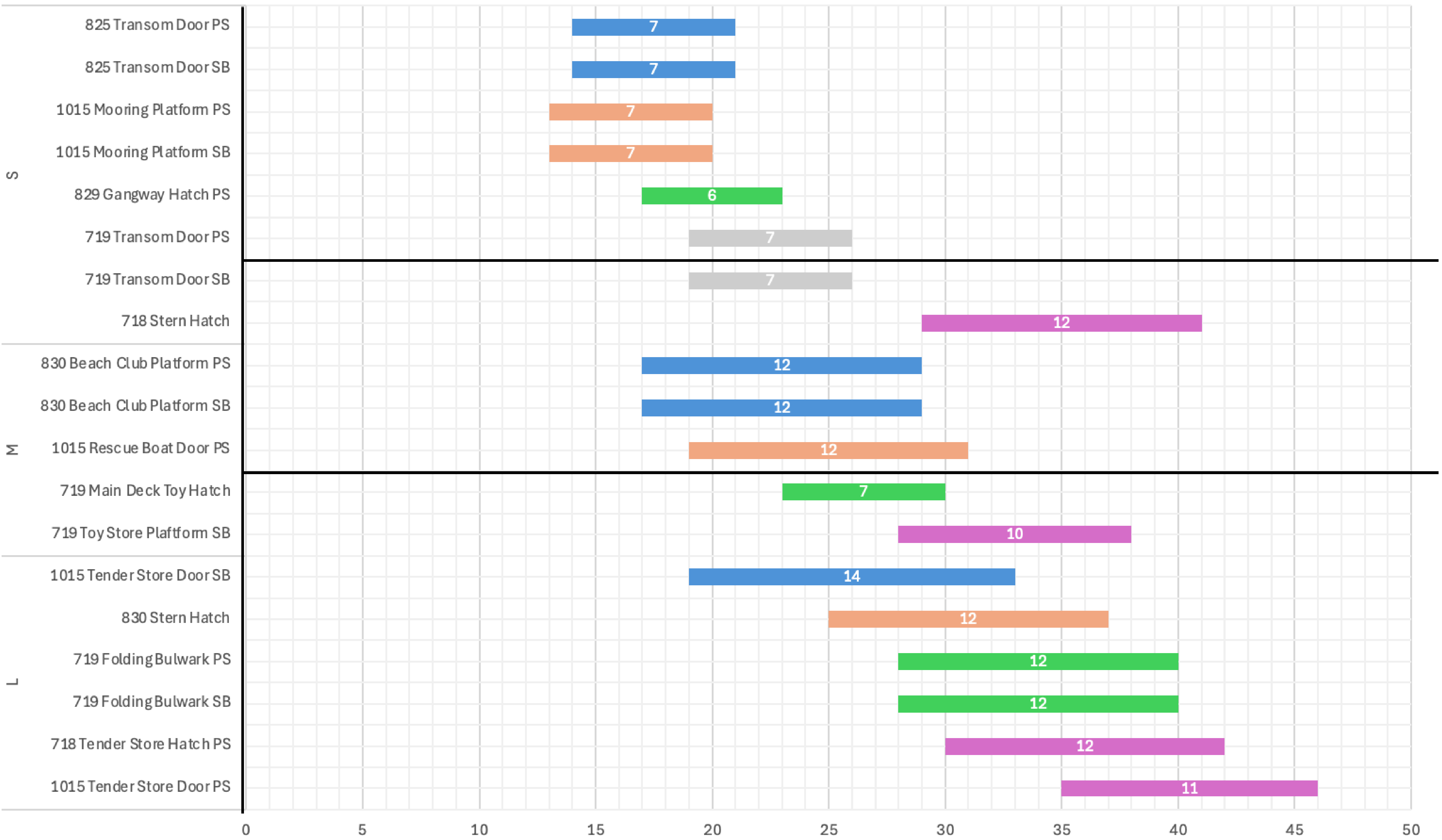
Omstandigheden (normale temperatuur)
Gewoon | 18-22°C

Herstel (zittende pauze van 15')
Elke 3u pauze | 2x/dag

Risicoscore vermoeiend werken
41.25

Appendix U

Original planning



Designed, researched, and written in the heart of Akerboom's production halls — this report combines practical design thinking with the raw realities of aluminium, welding, and modularity.

It's not just about manufacturing. It's about people, processes, and finding the space for change within an industry that balances craftsmanship with constant deadlines.

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