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Thule, 2026 (Used with permission)

Next generation cargo box

A user study of Thule's towbar-mounted cargo box
Bachelor thesis within the Design and product development program

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Abstract

This project constitutes a bachelor's thesis conducted at Chalmers University of Technology in collaboration with Thule. The study focuses on the rear-mounted cargo box Arcos XL, a relatively new product within Thule's portfolio.

The aim of the project was to investigate how users interact with Arcos XL to identify opportunities for increased customer value, with a particular focus on enabling single-person mounting, usage, and dismounting. A user study was conducted using both quantitative and qualitative methods to capture user needs and experiences.

The results identified several key challenges, among several; limited clearance between the vehicle and the cargo box, difficulties in verifying correct engagement between the box and the platform, and challenges in aligning the platform during installation. These issues were addressed through a conceptual redesign that includes features such as an extendable platform based on telescopic square hollow sections (SHS), a latch-based attachment system, and an integrated spirit level for improved alignment.

The final concept demonstrates that single-person mounting can be made more feasible through a combination of coordinated design solutions that reduce physical effort and improve usability. The concept is developed at a conceptual level and does not represent a finalized product; however, the proposed solutions are based on realistic and technically feasible design considerations.

TABLE OF CONTENTS

1 Introduction	1
1.1 Background.....	1
1.2 Aim	2
1.3 Objectives	2
1.4 Research questions	2
1.5 Limitations.....	3
2 Theoretical framework	4
2.1 Scenario of use.....	4
2.1.1 Accessible storage.....	4
2.1.2 Key features	4
2.1.3 Ergonomics	5
2.1.4 Efficiency	5
2.2 The Platform	7
2.2.1 Design	7
2.2.2 The Hercules locking system	7
2.2.3 Compatibility	8
2.3 The towbar box.....	8
2.3.1 Shell	9
2.3.2 SlideLock-system.....	10
2.3.3 Attachment points	10
2.4 Relevant regulations	11
2.4.1 Towbar weight limit.....	11
2.4.2 Width.....	11
2.4.3 Visibility in traffic.....	12
2.5 Acronyms and terminology	12
3 Methodology	13

3.1 User study	13
3.1.1 Surveys.....	13
3.1.2 Unstructured interviews	13
3.1.3 Semi-structured interviews	13
3.1.4 Observations	14
3.1.5 User tests	14
3.2 Analysis of retrieved information.....	14
3.2.1 KJ Method.....	15
3.2.2 Ergonomic assessment	15
3.2.3 Function analysis	16
3.2.4 RICE-model	16
3.3 Idea generation	17
3.3.1 Brainstorming	17
3.3.2 Brainwriting	17
3.3.3 PMI	17
3.4 Concept development	18
3.4.1 Morphological matrix	18
3.4.2 Pugh-matrix.....	18
4 Results	19
4.1 User study	19
4.1.1 Participants.....	19
4.1.2 Initial tests	21
4.1.3 Quantitative data collection	21
4.1.4 Visit to Isaberg.....	22
4.1.5 Qualitative User Tests.....	22
4.1.6 Interview with User and Seller	23
4.1.7 Long-term User test	23

4.1.8 Summary of results	24
4.2 Ergonomic assessment.....	25
4.2.1 PEPA.....	25
4.2.2 REBA	28
4.3 Competitor analysis	31
4.3.1 IXTABox	32
4.3.2 Other competitors.....	33
4.4 Analysis of gathered data	34
4.4.1 Structuring of collected data	34
4.4.2 Problem Identification	34
4.4.3 Function analysis	36
4.4.4 RICE-model	38
4.5 Idea generation	40
4.5.1 Initial ideas.....	40
4.5.2 Evaluating ideas	42
4.6 Concept development	42
4.6.1 Concept creation	42
4.6.2 Proof of concept.....	47
4.6.3 Concept selection	58
5 Final concept	60
5.1 Platform	60
5.1.1 Correct positioned platform	60
5.2 Cargo box	62
5.2.1 Mounting the cargo box on to the platform	62
5.2.2 Facilitate usage.....	65
5.3 Single individual mounting	68
5.3.1 Ergonomics	71

6 Discussion	75
6.1 Initial phase.....	75
6.1.1 Quantitative method.....	75
6.1.2 Qualitative methods	76
6.2 Middle phase.....	76
6.2.1 Analysis of the result	77
6.2.2 Concept creation and evaluation.....	77
6.3 Final phase	78
6.3.1 Final concept.....	78
6.3.2 Single-person mounting	79
6.3.3 Ergonomic aspects	80
6.3.4 Further development	82
6.4 Sustainability aspects.....	83
6.4.1 Material impact	83
6.4.2 Climate impact during use	84
6.5 Ethical aspects	85
6.6 Usage of AI.....	87
6.7 Conclusion	87
7 References	89
8 Appendix	91

1 Introduction

Thule is a prominent company within the outdoor-equipment sector, recognized for developing and manufacturing products that support a wide range of outdoor activities. Its portfolio includes vehicle-related transport solutions (e.g., cargo racks and cargo boxes, bicycle carriers, and canoe holders) as well as mobility and travel products such as strollers and backpacks. Established in Sweden in the 1940s, the company expanded its focus during the 1960s towards vehicle-based outdoor equipment, initially with products such as ski carriers, and has since broadened its offering across multiple product categories.

Today, Thule operates on a global scale, with products distributed internationally, while key functions, such as headquarters, research and development (R&D), and major production activities, remain located in Sweden. The company places a strong emphasis on its product strategy on innovation, quality, and sustainability. Its products have received recognition through established design awards, including the Red Dot Design Award and the iF Design Award. In 2024, Thule's R&D team was additionally recognized with the "Design Team of the Year" award.

1.1 Background

Thule is considered the market leader in developing innovative vehicle cargo solutions (Future Market Insights). In early 2023, Thule introduced the Arcos product family within its cargo division: a set of towbar-mounted, hard-shell cargo boxes intended to provide additional external storage at the rear of the vehicle. The Arcos range was positioned as a complement to conventional roof-mounted cargo boxes, particularly in situations where roof racks cannot be installed or where the roof is reserved for other equipment. Key benefits emphasized for the platform include improved accessibility through rear, low-height loading and an aerodynamically contoured, low-profile design intended to minimize drag while maintaining trunk accessibility. At launch, the range comprised the M and L variants. In 2025, the range was expanded with the Arcos XL, presented as the newest addition to the Arcos family and described as offering increased capacity and suitability for long winter-sport equipment such as skis. Across the product family, the primary differentiation between variants is the box size

and the resulting storage capacity, while the overarching use case, supplementary cargo space at the vehicle rear, remains consistent.

Current market reception suggests that Arcos is an appreciated product. Despite increasing market availability, structured knowledge about what creates customer value in towbar-mounted cargo boxes, and which interaction qualities most strongly influence the customer experience, remains under-articulated in accessible design-oriented literature. Against this backdrop, the present thesis aims to examine the factors that contribute to customer value and enhance the customer experience for towbar-mounted cargo boxes, with the long-term objective of informing future product development within this category.

1.2 Aim

The purpose of this thesis is to examine how users interact with Thule's rear mounted cargo box, Arcos, to gain a deeper understanding of user behavior and requirements. The thesis also aims to investigate what is required for a rear-mounted cargo box to be mounted and removed by a single individual. Furthermore, the work will explore and present potential additional features that may provide added value for the user.

1.3 Objectives

The objective of this project is to develop and present a conceptual proposal for how the cargo box can be designed so that a single person can independently mount and remove it from the vehicle. The solution shall also address the transport of the cargo box between the storage solution and the vehicle. The proposed concept will be complemented with illustrative examples and visual renderings.

1.4 Research questions

1. How can the rear-mounted cargo box be designed to allow simple and safe mounting and removal by a single person?
2. How can transport between the storage solution and the vehicle be made more efficient and easier?

3. What new additional features can create added value for the user in daily use and improve the overall user experience?

1.5 Limitations

The scope of this thesis is defined by the following delimitations:

- The study is limited to an analysis of Thule's tow-bar mounted cargo carrier, Arcos.
- The project focuses exclusively on the Arcos XL model, with the assumption that potential features may be transferable to smaller models.
- The scope is restricted to the installation, usage, and dismantling phases of the product.
- As a result, aspects related to storage of the cargo box when not in use are excluded.
- Cost optimization is not considered within the scope of this study.
- A general sustainability analysis is conducted; however, a detailed life-cycle assessment (LCA) is excluded.
- The existing design is not modified with the objective of reducing environmental impact or cost.
- All proposed solutions are presented at a conceptual level.
- Final technical drawings are not included.

In addition, the following components and parameters are excluded from modification and further analysis:

- The Hercules locking system on the platform, including the coupling, latch, and handle.
- The dimensions of the cargo box ($190 \times 76 \times 48$ cm).

2 Theoretical framework

The purpose of this section is to provide the theoretical background that forms the foundation of this report. It presents an overview of the Arcos XL cargo box, including its function and intended use. The section also examines how the use of a rear-mounted cargo box, in comparison to a roof-mounted cargo box, affects a vehicle's driving characteristics and driving range. Finally, the section includes detailed descriptions of the cargo box's constituent components, as well as relevant regulations governing the product and its use.

2.1 Scenario of use

The purpose of the Arcos XL towbar-mounted cargo box is to provide additional storage capacity when the available space in the vehicle's trunk is insufficient. It is mounted on the car's towbar and consists of a two-part product, the platform and the box.

2.1.1 Accessible storage

Traditionally, additional cargo capacity for passenger cars has been achieved through mainly roof-mounted cargo boxes. Although such systems provide functionality comparable to rear-mounted solutions (e.g., increased enclosed storage volume), they are associated with a well-documented usability limitation. Loading and unloading require lifting items above shoulder height, often while reaching across the vehicle roof. This can increase physical effort and reduce perceived convenience, particularly for heavier or bulky goods.

Furthermore, the Arcos is characterized by a low-profile configuration intended to preserve access to the vehicle's original luggage compartment even when the cargo box is installed on the towbar. By limiting vertical and longitudinal obstruction in the rear opening area, the design aims to maintain functional compatibility with the vehicle's standard boot/trunk access. In practical terms, this means that, for many vehicle models, the trunk can typically be opened and used without removing the cargo box, thereby reducing interference with existing vehicle functionality, and improving overall utility.

2.1.2 Key features

One of the Arcos XL's biggest selling points is the width of the box. The 180 cm inner width allows users to put in long items such as skis, something that has not been possible in earlier

versions of the Arcos M and L. This feature targets consumers who previously utilized roof-mounted boxes solely for transporting winter sports equipment.

2.1.3 Ergonomics

According to the Swedish Work Environment Authority, repetitive heavy lifting above shoulder height is associated with a substantially increased risk of musculoskeletal disorders. In its provisions on physical ergonomics, the Authority also presents an assessment model for a symmetrical, two-handed standing lift under ideal conditions, indicating that lifts exceeding 25 kg are inappropriate. Furthermore, in certain circumstances, the recommended limit is reduced to 20 kg.

These considerations are directly relevant to both the mounting and loading phases of cargo-box use. In this regard, the Arcos mitigates a key limitation commonly associated with roof-mounted cargo boxes by relocating handling tasks to a lower working height. As a towbar-mounted solution, mounting and loading can typically be carried out without lifts above hip level, thereby reducing vertical lifting demands. Moreover, the current configuration of the Arcos XL specifies mounting by at least two individuals; under this arrangement, the handling load can be shared such that the per-person demands remain within the recommended lifting limits.

2.1.4 Efficiency

The range is influenced, among other factors, by the vehicle's aerodynamic properties, where increased air resistance can lead to higher energy consumption. This applies to all types of vehicles but is a central challenge for electric vehicle owners who frequently experience so-called range anxiety (Hägglund, 2023) which is the fear of running out of electricity. This is a result of electric vehicles typically having less range than vehicles with a combustion engine and a less developed charge network.

According to Thule, placing a cargo box at the rear of the vehicle significantly reduces aerodynamic drag compared to traditional roof-mounted cargo boxes, which can contribute to improved energy efficiency and an extended driving range for electric vehicles. In a test conducted by Thule, a rear-mounted cargo box was installed on a Volkswagen ID.4, which was then driven approximately 5,400 km under varying weather conditions. The results

indicated that the driving range of the vehicle, when equipped with an Arcos rear-mounted cargo box, increased by approximately 5 % compared to driving without any rear-mounted cargo solution. This corresponds to an increase in driving range of approximately 17 km for the tested vehicle (Thule, n.d.-b) .

When comparing rear-mounted cargo boxes with roof-mounted cargo boxes, the aerodynamic drag differs substantially. According to Hisamuddin et al. (2025), the drag coefficient (C_d) of a vehicle can increase by approximately 40–58 % when equipped with a roof-mounted cargo box, depending on the design of both the vehicle and the cargo box. The drag coefficient (C_d) is a dimensionless quantity in fluid dynamics that represents the resistance an object experiences when moving through a fluid, such as air. It is commonly used to describe the aerodynamic performance of bodies such as vehicles and aircraft, indicating how effectively their shape reduces drag (Simscale, 2023).

According to Simscale (2023), a high C_d value indicates greater resistance, whereas a low C_d value reflects a more aerodynamically efficient design with reduced drag. The drag coefficient depends on several factors, including the drag force acting on the object (D), the density of the fluid (ρ), the velocity of the object relative to the fluid (U), and a characteristic reference area (A) . The drag coefficient is calculated using the following equation:

$$C_d = (2 \times D) \div (\rho \times U^2 \times A) \quad (1)$$

Based on these findings, it becomes evident why positioning the cargo box behind the vehicle is often more advantageous, particularly for electric vehicles. Because electric vehicles are typically designed with more streamlined aerodynamic profiles than conventional cars, the additional drag caused by a roof-mounted cargo box has a comparatively greater impact on efficiency. Previous studies have shown that this increased aerodynamic resistance can reduce an electric vehicle's driving range by up to 20% (Industrifakta, n.d.).

2.2 The Platform

The terms “back box” and “towbar-mounted cargo box” commonly refer to the system consisting of both the platform and the cargo box. The platform is the component mounted onto the vehicle’s towbar and serves as the interface that enables attachment of the cargo box.

2.2.1 Design

The platform is constructed from three Square Hollow Sections (SHS), or square tubes, arranged in an inverted U-shape (see Figure 1). The two parallel sections each feature mounting holes on their upper surfaces to facilitate attachment to the cargo box. Specifically, one set of apertures is designed for the box's pegs to slide into, while the remaining holes serve to secure the box to the platform using screws (See Section 2.2.3). Additionally, the platform incorporates a locking mechanism for vehicle integration. The platform is composed primarily of powder coated steel and ABS plastic, the unit weighs 9 kg and has dimensions of 67 x 69 x 26 cm (W × D × H)(Thule, n.d.-a).



Figure 1: Picture of the Arcos platform (Thule, 2026). Used with permission.

2.2.2 The Hercules locking system

The locking system consists of a coupling designed to encircle the towbar, an adjustable tension mechanism, a handle used to secure the platform to the towbar, and a latch that prevents the handle from disengaging unintentionally. To attach the platform, the latch must first be pressed and the handle lifted, which opens the coupling and allows it to be placed over the towbar’s hitch ball (see Figure 2).

Once the platform is positioned on the hitch ball, the tension mechanism is adjusted to regulate the clamping force. The pressure must be calibrated so that a vertical force of 47 kg

is required to depress the handle again (Thule Arcos XL, n.d.). When the platform is correctly aligned and the appropriate tension has been achieved, the handle can be pushed down to lock the platform in place. This locking mechanism, developed by Thule, is referred to as the *Hercules locking system*. If excessive force is required to lower the handle, the tension must be adjusted using the tension mechanism.

The platform is also equipped with an integrated locking function, allowing it to be secured once it is correctly mounted. This lock uses the same key as the cargo box, ensuring a unified locking system for both components.

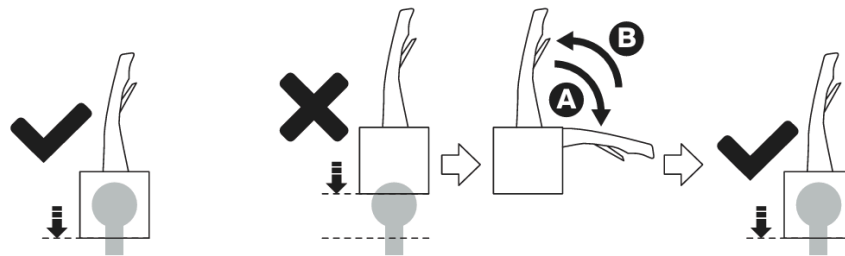


Figure 2: Picture from Arcos XL instruction book that visualizes how to attach the platform to the towbar (Thule, 2026). Used with permission.

2.2.3 Compatibility

The platform is exclusively compatible with the Arcos M, L, and XL models (Thule, n.d.). Operation of a vehicle with the platform mounted, without the cargo box, is prohibited as the platform and the cargo box is certified and approved as one unit and fails to meet regulatory requirements in isolation. Given that the platform and cargo box constitute a single functional unit, the box's locking system is included as a standard component of the platform (Thule, n.d.).

2.3 The towbar box

The cargo box designed for towbar-mounted systems shares numerous characteristics with its roof-mounted counterpart. This chapter focuses exclusively on the box unit (excluding the supporting platform) and presents the relevant background, design features, and functional

characteristics pertinent to the subsequent analysis. The cargo box consists of 4 main parts, the shell, the locking system, the hinges and the attachment points.

2.3.1 Shell

The principal component of the cargo box is the shell, which is manufactured through thermoforming of UV-protected ABS plastic. ABS (Acrylonitrile-Butadiene-Styrene) is a thermoplastic polymer commonly used in consumer and industrial products. The material is characterized by favorable mechanical and physical properties, including high impact resistance, toughness, and good thermal stability. ABS plastic is recyclable; however, recycling can be challenging due to its complex polymer composition and the potential presence of additives and contaminants within the material (Waste Trade, n.d.).

The shell consists of two parts: a base unit and a top cover (see Figure 3 and 4). The two parts are connected by rear-mounted hinges and supported by lateral “lid lifters”, enabling controlled opening of the top cover. When closed, the parts are secured using the Slide-Lock system (see Section 2.3.2). The choice of ABS plastic provides a durable enclosure with resistance to rain, dirt, and road debris.

The external dimensions of the shell are $190 \times 76 \times 48$ cm (W $\times$ D $\times$ H), yielding internal dimensions of $180 \times 55 \times 45$ cm (W $\times$ D $\times$ H). The assembled shell has a mass of 22 kg (including all parts) and accommodates a maximum payload of 50 kg (Thule Arcos XL, n.d.).

The shell is aerodynamically contoured, i.e., designed to reduce air resistance during travel.



Figure 3 & 4: Picture of Arcos XL closed and opened with a ski and a snowboard loaded (Thule, 2026). Used with permission.

2.3.2 SlideLock-system

The Arcos cargo box employs Thule's *SlideLock-system*, a three-point locking mechanism actuated via a slide handle and secured by a key-operated locking cylinder. The arrangement separates the closing action (via the handle) from the final mechanical lock (via the cylinder), thereby providing staged control over closure and security.

The key cylinder is operable only when all three locking points are fully engaged. Lock status is communicated through an integrated visual indicator on the handle: the presence of a red dot signifies incomplete engagement, whereas the absence of the red dot indicates correct engagement and enables locking (see Figure 5). This interlock prevents inadvertent locking under partial closure and reduces the risk of accidental opening during operation.



Figure 5: When the red part shows, all latched are not completely engaged, and the box can therefore not be locked. (Author's own image)

2.3.3 Attachment points

Once the box is positioned on the platform, two distinct steps must be completed to ensure the assembly is secure for use. The underside of the box is equipped with two plastic pegs designed to insert into corresponding apertures on the upper surface of the platform. When these pegs are correctly aligned, two internal mounting holes become accessible. The provided screws are then fastened through these holes to firmly secure the box to the platform.

2.4 Relevant regulations

The design of the Arcos XL is governed by multiple regulatory requirements. These include limits on permissible towbar load, constraints on overall width, and provisions concerning lighting and visibility. The following subsections summaries the principal regulations that informed the product's configuration.

2.4.1 Towbar weight limit

All passenger vehicles specify a maximum permissible vertical load on the towbar, i.e., the vertical force the towbar is designed to withstand. Typical limits range is from 50 to 100 kg, depending on vehicle make and model (Fogelsta, n.d.). Consequently, the combined vertical load from the cargo box system (platform + box + cargo) must remain at or below the vehicle's approved towbar limit.

For the Arcos XL, the platform and box together have a mass of 31 kg. Accordingly, if the vehicle's towbar is approved for 50 kg, the maximum allowable cargo mass is 19 kg ($50 - 31$). If the towbar is approved for 100 kg, the towbar constraint would allow 69 kg ($100 - 31$); however, the box itself is rated for a maximum payload of 50 kg, which therefore governs the allowable cargo to avoid exceeding the product's specification.

2.4.2 Width

In Sweden, the maximum permitted vehicle width is 260 cm, excluding mirrors and certain other components that are not included in statutory width measurements (Sveriges Riksdag, 1998). Furthermore, according to the Traffic Ordinance, the general provision for loads allows lateral projection up to 20 cm beyond the vehicle on each side; however, the Arcos XL is treated as a permanent installation rather than a temporary load, and the lateral projection allowance is therefore not applied in the width assessment (C. Johansson, personal communication, 2026). Consequently, compliance is evaluated by requiring that the vehicle width including the installed Arcos XL remains within the 260 cm statutory limit. Given that the Arcos XL has an overall width of 190 cm, the vehicle must have a body width of at least 190 cm to avoid lateral overhang beyond the vehicle body when the unit is installed.

Comparable width limits and projection rules apply in most EU member states under broadly harmonized road-traffic frameworks, though specific measurement conventions and

allowances may vary slightly by country. As a result, conformity with the Swedish limits will generally align with EU practice, subject to confirmation of country-specific provisions.

2.4.3 Visibility in traffic

Visibility requirements are integral to towbar-mounted cargo boxes. In many countries, particularly within the European Union, rear lamps and the vehicle's license plate must remain clearly visible from behind. If any part of the load obscures these elements, auxiliary rear lighting and a relocated license plate must be fitted to the rearmost point of the assembly.

The Arcos XL addresses these requirements by integrating rear lights and a license-plate mounting bracket. The lighting system is operated through the vehicle's trailer electrical connector, ensuring synchronization with the vehicle's signaling functions. The plate bracket enables installation of a rear-facing license plate on the cargo box.

2.5 Acronyms and terminology

Nudging: A method from behavioral economics used to influence people's decisions by subtly guiding behavior while preserving freedom of choice.

Square Hollow Section (SHS): A type of structural steel profile characterized by a hollow square cross-section, commonly used in load-bearing structures due to its high strength-to-weight ratio and uniform stiffness in both directions.

3 Methodology

The following chapter outlines the methodological approaches referenced in the report. Emphasis is placed on definitional and conceptual descriptions of each method, including its methodological assumptions and standard execution.

3.1 User study

User studies constitute a systematic approach to investigating users' behaviors, needs, and underlying motivations to inform and improve the usability, user experience, and functional performance of products or services (Limetta, n.d.). By employing methods such as interviews, observation, and usability testing, user studies enable the identification of both barriers to effective use and opportunities for design improvement.

3.1.1 Surveys

Surveys constitute a structured data-collection method aimed at obtaining broad insights into user perspectives and self-reported behaviors. The primary purpose is to generate measurable, predominantly quantitative data that can be used to examine patterns in attitudes, preferences, or actions across a larger sample. To ensure comparability across respondents, survey questions are standardized and typically combine closed-ended items (e.g., Likert scales and multiple-choice questions) with a limited number of open-ended prompts to capture additional context.

3.1.2 Unstructured interviews

This interview format is defined by the absence of a fixed, pre-established question guide, which enables flexible sequencing of topics and supports iterative probing through follow-up questions. As a result, the interview process can be adapted in real time to participants' responses, allowing relevant themes to be explored in greater depth as they emerge.

3.1.3 Semi-structured interviews

Semi-structured interviews are a qualitative approach which uses a pre-defined interview guide but allows for flexible, open-ended follow-up questions (Björkman, 2025). As a result, the interview process is steered but can be adapted in real time to participants' responses, allowing relevant themes to be explored in greater depth as they emerge.

3.1.4 Observations

An observational study is characterized by the researcher analyzing a sequence of events without intervening or influencing the situation. This means that the researcher observes phenomena as they naturally occur, without steering the behavior in any particular direction (Forskning, n.d.). Observations can be documented through written field notes, audio recordings, video recordings, or a combination of these methods.

There are several ways of conducting observations, including classifications such as direct or indirect, naturalistic or constructed, and overt or covert. A *direct observation* involves the researcher observing the situation firsthand, without the use of mediating instruments. An observation is considered *naturalistic* if participants behave in their normal environment without being assigned specific tasks, whereas a *constructed observation* occurs when participants are given predefined instructions or tasks by the researcher. Observations may also be classified as *overt* or *covert*, depending on whether the participants are aware that they are being observed (George, 2023).

3.1.5 User tests

User testing is an empirical evaluation method used to examine user-product interaction under conditions that approximate real use. A facilitator (also termed a moderator) guides a participant through a set of predefined tasks involving a product or interface, while systematically observing task performance. Data typically include behavioral measures and verbalized feedback, enabling the identification of usability issues and interaction patterns.

3.2 Analysis of retrieved information

There are several methods that can be used to analyze and prioritize large amounts of data. This section presents one method for organizing and thematizing data. Furthermore, two methods used to analyze and evaluate data from an ergonomic perspective are introduced. In addition, methods for identifying, structuring, and prioritizing functions are described.

3.2.1 KJ Method

The KJ method is a qualitative analysis technique used to organize and synthesize large volumes of unstructured data. The method involves externalizing individual observations, statements, or insights as discrete units, to ensure that each idea is considered independently.

These units are then systematically grouped based on perceived thematic similarities or conceptual relationships. Through an iterative process, related notes are clustered into categories without predefined labels. Once groupings have been established, each category is examined to identify underlying patterns, relationships, and higher-level themes. This process supports the emergence of insights directly from the data rather than through predetermined analytical frameworks.

The KJ method is particularly effective for facilitating shared understanding among researchers. By structuring complex information into coherent thematic groupings, the method aids in problem clarification, sense-making, and the identification of key areas for further analysis (Miro, n.d.-b).

3.2.2 Ergonomic assessment

PEPA, which stands for “Physical Ergonomics Product Assessment”, is a holistic, scenario-based assessment method that evaluates product use across the full sequence of interaction. The procedure involves decomposing the usage scenario into discrete steps and rating seven predefined categories for each step to determine their respective ergonomic impacts. This structure supports a comprehensive appraisal of user-product interaction over time.

REBA, which stands for “Rapid Entire Body Assessment”, is an ergonomic assessment method used for evaluating the risk of a work-related body posture. The method focuses on assessing a single, typically the most demanding or critical, working posture rather than an entire sequence. Postural risk is evaluated by scoring the positions of different body segments, including the neck, trunk, legs, arms, and wrists in combination with load, coupling, and activity factors. The resulting score corresponds to a risk level that indicates the urgency for ergonomic intervention. This posture-based approach enables targeted identification of high-risk postural configurations.

3.2.3 Function analysis

A function analysis is a systematic method used to identify, define, and structure the functions that a product or system must fulfill to meet customer needs. A function analysis typically categorizes these functions into the main function, supporting functions, and additional functions. This classification helps clarify which function constitutes the core value-creating purpose of the product, which functions are essential for enabling the main function to operate as intended, and which functions provide supplementary value beyond the basic functionality.

Functions are commonly formulated using a verb-noun structure to ensure a clear focus on the function itself, independent of specific technical implementations or potential solutions. This abstraction supports objective analysis and facilitates exploration of alternative design approaches (SVID, n.d.).

3.2.4 RICE-model

The RICE model is commonly used by product developers as a decision-support tool to prioritize projects and functions by assessing their potential impact. The model evaluates four key factors: Reach, Impact, Confidence, and Effort. Reach refers to the number of users or customers who will be affected by the project or function within a defined timeframe. Impact measures the expected magnitude of the effect the initiative will have. It is common for teams to use a five-tier scoring system (0.25, 0.5, 1, 2, 3), where 0.25 represents minimal impact and 3 represents a significant impact.

The Confidence factor indicates how certain the evaluators are about their assessments of Reach and Impact. Teams typically assign confidence levels of 50%, 80%, or 100%, with 50% representing low confidence and 100% representing high confidence. Effort refers to the resources required to accomplish the project or function, quantified in terms of time, personnel, and other necessary inputs. Effort is usually measured in person-months, indicating the number of working months a team must dedicate to completing the initiative.

After assigning numerical values to each factor, the final RICE score is calculated by multiplying R, I, and C, and then dividing the result by E. This score helps teams compare and prioritize initiatives in a structured and evidence-based manner (Microsoft, 2024).

3.3 Idea generation

This chapter presents two commonly used methodologies for generating a large number of innovative ideas: brainstorming and brainwriting. In addition, the chapter introduces the PMI method, which is widely used for evaluating ideas and supporting decision-making processes.

3.3.1 Brainstorming

Brainstorming is a creative method commonly used to generate innovative ideas and address complex problems. During this process, team members are encouraged to think freely and propose ideas without restrictions, even if the ideas appear unrealistic or undeveloped. A key principle of brainstorming is that ideas should not be judged or criticized during the creative phase; instead, all contributions should be welcomed and considered with an open mindset (Miro, n.d.-a). There is no single, universally defined approach to conducting a brainstorming session. The method allows for highly flexible implementation in various projects.

3.3.2 Brainwriting

Brainwriting, also known as the 6-3-5 method, is a creativity-stimulating technique used to support groups in generating innovative ideas. The method involves six participants, each of whom generates three ideas within a five-minute interval. These ideas may be documented using brief written descriptions or simple sketches. After each interval, the participants exchange idea sheets, allowing them to build upon and draw inspiration from one another's contributions (Herman, 2024). This iterative process encourages idea development while ensuring equal participation from all group members.

3.3.3 PMI

The PMI method (Plus, Minus, Interesting) is a structured evaluation technique used to support decision-making by promoting a balanced assessment of ideas or concept alternatives. Rather than limiting the appraisal to advantages and disadvantages, PMI additionally captures “interesting” observations, such as secondary effects, uncertainties, assumptions, and potential implications that may warrant further investigation. In practice, each concept is reviewed systematically by documenting positive aspects (Plus), negative aspects (Minus), and notable or ambiguous considerations (Interesting), thereby enabling transparent comparison and supporting reasoned selection in subsequent concept development (The University of Newcastle, n.d.).

3.4 Concept development

This chapter presents two methodologies applied during the concept development phase. One of these, the morphological matrix, is used to systematically explore and combine sub-solutions in order to generate novel and innovative concept combinations. The other methodology, the Pugh-matrix, is employed to compare multiple concepts against a reference concept, thereby identifying the alternatives that best fulfill the defined evaluation criteria.

3.4.1 Morphological matrix

A morphological matrix (also termed a *morphological chart*) is a structured concept-generation method used to explore alternative product concepts by decomposing a system into its key functions (or critical attributes). For each function, multiple solution principles are identified and documented. Concept variants are then generated by systematically combining one alternative per function across the matrix, thereby producing a range of feasible configurations. This approach supports efficient exploration of the design space and enables the rapid creation of multiple concept alternatives in a transparent and repeatable manner.

3.4.2 Pugh-matrix

A Pugh-matrix is a qualitative, criteria-based decision tool used to compare multiple concept alternatives against a defined baseline (reference) concept. Each alternative is assessed criterion by criterion relative to the baseline and assigned a discrete score, typically -1 , 0 , or $+1$, indicating performance worse than, equivalent to, or better than the reference, respectively. The scores are then summed to produce an overall comparative value for each concept. A negative total indicates inferior performance relative to the baseline; a total of zero indicates parity, and a positive total indicates superior performance. The method can be extended by applying weights to criteria (e.g., based on importance), allowing the evaluation to reflect priority differences among requirements while maintaining a transparent comparison structure (Västra Götalandsregionen, n.d.).

4 Results

This section outlines the project execution at an overall level. The work progressed through four sequential phases. First, a user study was conducted to establish an empirical understanding of the usage context and user-product interaction. Second, the collected material was synthesized into a problem identification phase, in which key challenges and opportunity areas were formulated and structured. Third, a function analysis was carried out to clarify the product's core functions and their interrelations, providing a basis for systematic development. Finally, the project advanced to idea generation and concept development, where solution directions were explored and iteratively refined into concept alternatives.

4.1 User study

The user study was designed to gain an in-depth understanding of how users interact with the product in real-world contexts relevant to its intended use. By capturing both observed behaviors and reported experiences, the study ensures that subsequent design decisions are grounded in actual user practice.

The study began with a broad investigation aimed at identifying general patterns and collecting initial data. Based on the insights gained from the early stages, the research focus was gradually narrowed to specific problem areas. The results from the initial methods were subsequently reviewed and served as the foundation for the methods implemented in the later stages.

Methods such as surveys, observational studies, interviews, and various forms of testing were employed to examine the problem from multiple perspectives.

4.1.1 Participants

To identify user needs and behavioral patterns, several forms of user studies were conducted. An overview of the studies and their respective participants are presented in Table 1. The purpose of the initial studies was to identify the preliminary issues raised by participants and, on that basis, determine which additional study formats would be required, and which participant groups should be included. To reach a broader pool of potential users, a field visit was conducted at Isaberg Mountain Resort, and a survey was distributed. Early in the study, it

became evident that relatively few participants had prior experience with the Arcos. Participants were therefore recruited using convenience sampling for the rest of the user study.

Table 1: List of conducted studies and participants.

No.	Place	Type of study	Participant(s)
1	Thule R&D Center	User tests, 2h Direct, constructed observation	2 Authors 2 Supervisors
2	Isaberg Mountain Resort	Unstructured interviews, 6h Covert, naturalistic and direct observations	People at the resort
3	Hestra, Sweden	User test, 2h Direct, constructed and overt observations	Man, 66 years
4	Hillerstorp, Sweden	User test, 1h Direct, constructed and overt observations	Woman, 23 years
5	Hillerstorp, Sweden	User test, 2h Direct, constructed and overt observations	Man, 27 years
6	Hillerstop, Sweden	User test, 2h Direct, constructed and overt observations	Woman, 25 years
7	Thule Store Gothenburg	Semi-structured interviews, 4h	Store personnel
8	Teams	Semi-structured interview, 30 min	Arcos owner Man, 35 years
9	Lindvallen, Sweden	Long-term user test, 5 days	Man, 27 years Man, 26 years Man, 24 years Woman, 24 years

4.1.2 Initial tests

To establish sufficient operational knowledge of the Arcos XL prior to formal data collection, preliminary researcher-led trials were conducted. The objective was to develop adequate familiarity with the product's use to plan and execute the subsequent study competently.

The familiarization phase commenced with a structured introduction delivered by client representatives, covering principal features of the box and its comparative advantages relative to other cargo solutions in the product line. Following this briefing, an initial mounting trial was performed with the Arcos XL, during which the complete mounting sequence was executed using the supplied instructions as the sole aid.

Supplementary trials were undertaken intermittently throughout the project. In one session, all steps of mounting and dismounting were performed both in pairs and individually. These sequences were video-recorded and subsequently reviewed to enable retrospective assessment and refinement of the procedural approach. A screenshot from the mounting sequence in pair can be seen in Figure 6.



Figure 6: Screenshot from one of the videos recorded during the initial tests. (Author's own image)

4.1.3 Quantitative data collection

The initial phase of the project involved data collection from both current and potential users of the Arcos XL. To reach a broad demographic, a survey was conducted in both English and Swedish to collect quantitative data (see Section 3.1.1).

The questions were adapted depending on whether the respondent had experience with a roof-mounted cargo box, a towbar mounted cargo box, or expressed an interest in investing in either solution. The inquiries focused on the rationale behind their current choice of solution and any perceived challenges or limitations associated with it. The survey employed a dynamic structure, utilizing branching logic to present respondents with specific questions based on their prior answers. This approach ensured that the content remained relevant to each participant's individual experience. The survey received a total of 28 responses, the majority of whom had prior experience with roof-mounted cargo boxes. Furthermore, a subset of respondents had experience with both roof-mounted and towbar-mounted solutions; their feedback highlighted the respective advantages and disadvantages of each system. To see all the survey questions and the different answer options, see Appendix 1.

4.1.4 Visit to Isaberg

To further broaden the research and gather qualitative insights, an observational study combined with unstructured interviews was conducted (see Section 3.1.3). The data collection was carried out at Isaberg Mountain Resort in Hestra, Småland, a local ski facility selected to ensure proximity to a primary user group, skiers. A car equipped with a towbar-mounted cargo box was positioned at the end of the main slope as the contextual setting for the interviews. Participants were recruited on a convenience basis (i.e., approached spontaneously) at the site. This methodological approach, paired with the chosen location, facilitated relaxed and informative dialogues, providing participants with the opportunity to interact with the box in its intended environment.

Specific attention was directed toward the users' operational techniques, such as the method for opening the lid and the coordination required to access the vehicle's trunk while the cargo box was mounted. Furthermore, the participants' overall expressions and non-verbal reactions were recorded. The study was carried out over a six-hour period, during which approximately 20 individuals of varying ages were interviewed and observed while interacting with the product.

4.1.5 Qualitative User Tests

To deepen the understanding of how users interact with the Arcos XL, more extensive user tests were conducted. As these tests were performed after the visit to Isaberg, they enabled the

findings from that visit to be validated or critically reassessed. The tests were conducted at different locations; however, all participants used the same vehicle, platform, and cargo box during the tests.

Four individuals of varying ages participated in the user tests. The participant group comprised a male aged 27, two females aged 23 and 24, and a male aged 66. Two of the user tests were recorded while the others were documented with pictures and notes. All participants mounted the platform onto the towbar independently, as well as mounting and dismounting the cargo box. While the core protocol remained consistent across all sessions, certain tasks were tailored to specific test cases. The 66-year-old male participant performed a more extended loading sequence involving three pairs of skis, two pairs of poles, one pair of ski boots, and a large travel bag. This participant also conducted a ten-minute driving cycle, which served to evaluate the impact of the load on the vehicle's handling and driving characteristics.

4.1.6 Interview with User and Seller

The respondents who participated in the semi-structured interviews included one experienced Arcos user and several staff members from the Thule Concept Store in Gothenburg. The Arcos user owned the cargo box in size Large; nevertheless, the insights gathered were considered applicable to the Arcos XL model as well. The interview questions addressed key aspects of use, including usage patterns, the mounting process, the usage phase, and transport and storage considerations. The complete interview guide is provided in Appendix 2.

During the visit to the Thule Concept Store, semi-structured interviews were conducted with the concept manager, store personnel, and an OEM sales representative. The interview questions addressed topics such as commonly experienced problems, customer complaints, and additional user feedback. The complete interview guide is provided in Appendix 3.

4.1.7 Long-term User test

A six-day longitudinal field test was conducted to evaluate the use of a rear-mounted cargo box during a weekend trip to Lindvallen, Sweden. The test focused on a 27-year-old male (hereafter referred to as the *main participant*) and included three additional participants: two males aged 26 and 24, and one female aged 24. Prior to the trial, the main participant received

a project briefing that included findings from earlier tests and was instructed to document observations through field notes throughout the test period.

The cargo box was delivered and mounted on a mid-size SUV. Each participant brought one to two bags of personal belongings; in addition, three participants transported one pair of skis and one pair of ski boots each in separate bags. During the stay, the cargo box was used daily to transport skis between the accommodation and the ski slopes. At the end of the user test, the vehicle and cargo box were reloaded for the return trip to Gothenburg. After arrival, both the trunk and cargo box were unloaded, and the rear-mounted cargo box was subsequently dismantled.

4.1.8 Summary of results

A summary of the data collected through each study method is presented below.

Survey

Of the respondents with experience using roof-mounted boxes, 53% indicated they would consider switching to a towbar-mounted alternative. Among those who were not interested in switching, one respondent notably cited a "smoother solution for accessing the trunk" as a reason for their preference. Overall, respondents familiar with both systems emphasized that towbar-mounted cargo boxes offer superior ease of mounting, as well as improved accessibility during loading and unloading.

Visit to Isaberg Mountain Resort

Several respondents expressed concerns regarding the vehicle's total length when the Arcos XL is mounted. Specifically, they noted potential difficulties with parking and reversing, as well as concerns that the box might be less visible to other drivers in confined spaces.

Furthermore, some participants found the opening mechanism counterintuitive, noting that the lid required prying upward rather than being easily lifted in a single motion.

Qualitative User Tests

Although the user tests were conducted independently, the qualitative data showed high consistency across all participants. A primary concern identified was the restricted clearance between the box and the vehicle, which impeded the unloading of the trunk and the

connection of the signal cable. Furthermore, participants encountered difficulties regarding the alignment of the platform, specifically noting the challenge of positioning it correctly without repetitive adjustments.

Interviews

The Arcos user reported difficulties with aligning the platform and emphasized that the installation process often required two people to complete it correctly. The staff members in Gothenburg did not perceive alignment as a significant issue, as they were accustomed to installing the Arcos XL; however, they acknowledged that it could pose challenges for individuals with less experience. The OEM sales representative noted difficulties both in transporting the Arcos XL from storage to the vehicle and during installation, due to the absence of obvious handles or designated grip surfaces.

Long-term User test

All participants in the long-term user test agreed that the Arcos XL is a well-functioning product that met their expectations. Compared to a roof-mounted cargo box, the solution with which the participants were previously familiar, the Arcos XL was perceived as easier to install. Furthermore, loading and unloading were considered significantly more ergonomic due to the lower mounting position of the cargo box. However, consistent with earlier results, participants noted that the space between the vehicle and the cargo box was relatively limited, which made trunk access and connection of the light-transmitting cable more difficult.

4.2 Ergonomic assessment

The two methods applied to assess ergonomic aspects of the Arcos XL installation process enabled analysis of both the overall mounting sequence and the most physically demanding postures involved. Together, these methods provide a comprehensive evaluation of ergonomic risks associated with the installation procedure.

4.2.1 PEPA

Two different scenarios were analyzed using the PEPA ergonomic assessment method. One scenario involved mounting the cargo box by two individuals, while the other scenario involved single-person mounting of the cargo box. For the first scenario, the intended users

were defined as a middle-aged couple (40-45 years old) with an average body build. For the second scenario, the intended user was defined as a middle-aged male (40-45 years old) with an average body build. The environmental conditions for both scenarios were specified as outdoor use at dusk, with an ambient temperature of -2°C .

The results of the PEPA assessments indicate that the single-person mounting scenario contains a considerably higher number of sequences classified as *H* (see Figure 7), indicating a high load on specific body parts, compared to the two-person mounting scenario (see Figure 8). Furthermore, the analysis showed that the same types of sequences generated the highest physical loads in both scenarios, although the exact scoring differed between them. The sequences associated with the highest scores in both scenarios were transportation of the cargo box between the storage area and the vehicle, lifting the platform onto the towbar, and lifting the cargo box onto the platform. This finding suggests that similar tasks constitute the most physically demanding elements of the mounting process, regardless of whether the task is performed by one or two individuals.

User:	Middle aged man, 40-45 years old, average body built
User-scenario:	Dusk, outdoors, -2 degrees

Installation of towbar mounted cargo box											
Physical Ergonomics Product Assessment (PEPA)	Transport platform from storage to vehicle	Transport cargo box from storage to vehicle	Lift the platform onto the towbar	Align the platform	Tighten and press down the handle	Lift up the box onto the platform	Align the box with corresponding holes	Connect light-transmitting cable	Open cargo box	Tighten screws	Close cargo box
(1) Handling (holding, moving, impulse, catching)	Holding, moving	Holding, moving	Holding, moving	Holding	Impulse	Holding, moving	Moving	Moving	Moving	Moving	Moving
(2) Strength	H	H	H	M	H	H	M	L	L	M	L
(3) Precision	L	L	M	H	L	M	H	H	M	H	M
(4) Endurance	M	M	L	L	L	M	M	M	L	L	L
(5) Grip	H	H	H	M	L	M	M	M	L	L	L
(6a) Neck	L	M	L	M	L	L	M	M	L	L	L
(6b) Shoulders	H	H	H	L	M	H	L	M	L	L	L
(6c) Arm/ Elbow	H	H	M	M	H	H	M	M	M	L	M
(6d) Hand/ wrist	H	H	M	M	M	H	M	M	M	H	M
(6e) Fingers	H	H	M	M	M	H	M	H	H	H	L
(6f) Back	H	H	H	M	M	H	M	M	M	M	M
(6g) Legs/ knees	M	M	H	M	M	H	L	M	L	L	L
(6h) Foot/ ankle	M	M	H	L	L	H	L	L	L	L	L
(7) External circumstances	Possibly tight space	Possibly tight space	-	Dark	-	Not suitable for one person	Difficult to see	Lack of space, difficult to access	-	-	-

Figure 7: PEPA assessment of single-person installation of the Arcos XL.

User:	Middle-aged couple, 40-45 years old, average body built
User-scenario:	Dusk, outdoors, -2 degrees

Installation of towbar mounted cargo box											
Physical Ergonomics Product Assessment (PEPA)	Transport platform from storage to vehicle	Transport cargo box from storage to vehicle	Lift the platform onto the towbar	Align the platform	Tighten and press down the handle	Lift up the box onto the platform	Align the box with corresponding holes	Connect light-transmitting cable	Open cargo box	Tighten screws	Close cargo box
(1) Handling (holding, moving, impulse, catching)	Holding, moving	Holding, moving	Holding, moving	Holding	Impulse	Holding, moving	Moving	Moving	Moving	Moving	Moving
(2) Strength	M	M	M	L	H	M	L	L	L	M	L
(3) Precision	L	L	L	H	L	L	H	H	M	H	M
(4) Endurance	L	L	L	L	L	L	L	M	L	L	L
(5) Grip	H	M	H	M	L	M	L	M	L	L	L
(6a) Neck	L	M	L	M	L	L	M	M	L	L	L
(6b) Shoulders	M	M	H	L	M	H	L	M	L	L	L
(6c) Arm/ Elbow	M	M	M	L	H	M	L	M	M	L	M
(6d) Hand/ wrist	M	M	H	M	H	H	M	H	H	H	M
(6e) Fingers	M	H	M	M	L	H	M	H	H	H	L
(6f) Back	M	H	M	M	M	H	M	M	M	M	M
(6g) Legs/ knees	M	M	M	L	L	M	L	M	L	L	L
(6h) Foot/ ankle	M	M	M	L	L	M	L	L	L	L	L
(7) External circumstances	Possibly tight space	Possibly tight space	-	Dark	-	-	Difficult to see	Lack of space, difficult to access	-	-	-

Figure 8: PEPA assessment of two-person installation of the Arcos XL.

4.2.2 REBA

Prior to conducting the REBA ergonomic assessment, the most physically demanding postures were identified. Based on an analysis of video recordings, two distinct postures occurring under different conditions were selected for assessment. One posture was observed during the installation of the cargo box performed by two individuals (see Figure 9). The second posture, used for comparison, was observed during dismounting of the cargo box performed by a single individual (see Figure 9).



Figure 9: The two positions that was assessed with the REBA matrix. (Author's own image)

The first assessment was conducted on one of the two individuals involved in the installation process. By summing the scores from the trunk, neck, and leg assessment together with the arm and wrist assessment, a total REBA score of 10 was obtained (see Figure 10). According to the REBA employee assessment worksheet, a score of 10 corresponds to a high-risk level, indicating that further investigation and implementation of changes are required.

The second assessment, conducted during independent dismounting of the cargo box by a single individual, resulted in a REBA score of 12 (see Figure 11). A score of 12 corresponds to a very high-risk level, indicating that changes should be implemented as a priority.

REBA Employee Assessment Worksheet

Task Name: *- Monitoring*
- 2 personer Date: *3/3-26*

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position
 10-20° 20°+ in extension in extension
 +1 +2 +2
 Neck Score: 2

Step 1a: Adjust...
 If neck is twisted: +1
 If neck is side bending: +1

Step 2: Locate Trunk Position
 0° 0-20° 20-60° 60°+
 +1 +2 +3 +4
 Trunk Score: 4

Step 2a: Adjust...
 If trunk is twisted: +1
 If trunk is side bending: +1

Step 3: Legs
 30-60° >60°
 +1 +2 Add +1 Add +2
 Leg Score: 3

Step 4: Look-up Posture Score in Table A
 Using values from steps 1-3 above,
 Locate score in Table A
 Posture Score A: 7

Step 5: Add Force/Load Score
 If load < 11 lbs.: +0
 If load 11 to 22 lbs.: +1
 If load > 22 lbs.: +2
 Adjust: If shock or rapid build up of force: add +1
 Force / Load Score: 2

Step 6: Score A, Find Row in Table C
 Add values from steps 4 & 5 to obtain Score A.
 Find Row in Table C.
 Score A: 9

Scoring
 1 = Negligible Risk
 2-3 = Low Risk. Change may be needed.
 4-7 = Medium Risk. Further Investigate. Change Soon.
 8-10 = High Risk. Investigate and Implement Change
 11+ = Very High Risk. Implement Change

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:
 20° 20° 20° 20-45° 45-90° 90°+
 +1 +2 +2 +3 +4
 Upper Arm Score: 2

Step 7a: Adjust...
 If shoulder is raised: +1
 If upper arm is abducted: +1
 If arm is supported or person is leaning: -1

Step 8: Locate Lower Arm Position:
 60-100° 100°
 +1 +2
 Lower Arm Score: 2

Step 9: Locate Wrist Position:
 15° 15° 15° 15°
 +1 +2
 Wrist Score: 3

Step 9a: Adjust...
 If wrist is bent from midline or twisted: Add +1

Step 10: Look-up Posture Score in Table B
 Using values from steps 7-9 above, locate score in Table B
 Posture Score B: 4

Step 11: Add Coupling Score
 Well fitting Handle and mid rang power grip, *good*: +0
 Acceptable but not ideal hand hold or coupling
 acceptable with another body part, *fair*: +1
 Hand hold not acceptable but possible, *poor*: +2
 No handles, awkward, unsafe with any body part,
Unacceptable: +3
 Coupling Score: 1

Step 12: Score B, Find Column in Table C
 Add values from steps 10 & 11 to obtain
 Score B. Find column in Table C and match with
 Score A in row from step 6 to obtain Table C Score.
 Score B: 5

Step 13: Activity Score
 +1 1 or more body parts are held for longer than 1 minute (static)
 +1 Repeated small range actions (more than 4x per minute)
 +1 Action causes rapid large range changes in postures or unstable base

Table A													
		Neck											
		1			2			3					
Trunk Posture Score	Legs	1	2	3	4	1	2	3	4	1	2	3	4
	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
5		4	6	7	8	6	7	8	9	7	8	9	9

Table B													
		Lower Arm											
		1			2								
Upper Arm Score	Wrist	1	2	3	1	2	3	1	2	3	1	2	3
	1	1	2	2	1	2	3	1	2	3	1	2	3
	2	1	2	3	2	3	4	2	3	4	2	3	4
	3	3	4	5	4	5	6	4	5	6	5	6	7
	4	4	5	5	5	6	7	5	6	7	6	7	8
	5	6	7	8	7	8	8	8	9	8	9	9	9

Table C														
Score A	Score B													
1	1	1	1	2	3	4	5	6	7	8	9	10	11	12
2	1	1	1	2	3	4	5	6	7	8	9	10	11	12
3	2	3	3	3	4	5	6	7	8	9	10	11	12	12
4	3	4	4	4	5	6	7	8	9	10	11	12	12	12
5	4	4	4	5	6	7	8	9	10	11	12	12	12	12
6	6	6	6	7	8	9	10	10	10	10	10	10	10	10
7	7	7	7	8	9	9	9	10	10	10	11	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11	11	11
9	9	9	9	10	10	10	11	11	11	11	12	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12	12	12
11	11	11	11	12	12	12	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12	12	12

10
+
0
=
10

Table C Score
Activity Score
REBA Score

Original Worksheet Developed by Dr. Alan Hedge. Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-207

Figure 10: REBA assessment of a body posture that occurred during two-person installation of the Arcos XL.

ERGONOMICS PLUS **REBA Employee Assessment Worksheet**

Task Name: *AVMOUNTING AV BOX, 1 PERSON* Date: *23/2-26*

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position
 10-20° +1 20°+ +2 In extension +2
 Neck Score: **3**
 Step 1a: Adjust...
 If neck is twisted: +1
 If neck is side bending: +1

Step 2: Locate Trunk Position
 0° +1 In extension +2 0-20° +3 20-60° +4 60°+
 Trunk Score: **5**
 Step 2a: Adjust...
 If trunk is twisted: +1
 If trunk is side bending: +1

Step 3: Legs
 30-60° +1 Adjust: 30-60° +2 Add +1 Add +2
 Leg Score: **2**

Step 4: Look-up Posture Score in Table A
 Using values from steps 1-3 above, Locate score in Table A
 Posture Score A: **8**

Step 5: Add Force/Load Score
 If load < 11 lbs.: +0
 If load 11 to 22 lbs.: +1
 If load > 22 lbs.: +2
 Adjust: If shock or rapid build up of force: add +1
 Force / Load Score: **3**

Step 6: Score A, Find Row in Table C
 Add values from steps 4 & 5 to obtain Score A.
 Find Row in Table C.
 Score A: **11**

Scoring
 1 = Negligible Risk
 2-3 = Low Risk. Change may be needed.
 4-7 = Medium Risk. Further Investigate. Change Soon.
 8-10 = High Risk. Investigate and Implement Change
 11+ = Very High Risk. Implement Change

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:
 20° +1 20° +2 In extension +2 20° +3 20-45° +4 45-90° +3 90°+
 Upper Arm Score: **3**
 Step 7a: Adjust...
 If shoulder is raised: +1
 If upper arm is abducted: +1
 If arm is supported or person is leaning: -1

Step 8: Locate Lower Arm Position:
 60-100° +1 0-60° +2
 Lower Arm Score: **2**

Step 9: Locate Wrist Position:
 15° +1 15° +2 15°
 Wrist Score: **1**
 Step 9a: Adjust...
 If wrist is bent from midline or twisted: Add +1

Step 10: Look-up Posture Score in Table B
 Using values from steps 7-9 above, locate score in Table B
 Posture Score B: **4**

Step 11: Add Coupling Score
 Well fitting Handle and mid rang power grip, good: +0
 Acceptable but not ideal hand hold or coupling acceptable with another body part, fair: +1
 Hand hold not acceptable but possible, poor: +2
 No handles, awkward, unsafe with any body part, Unacceptable: +3
 Coupling Score: **2**

Step 12: Score B, Find Column in Table C
 Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.
 Score B: **6**

Step 13: Activity Score
 +1 1 or more body parts are held for longer than 1 minute (static)
 +1 Repeated small range actions (more than 4x per minute)
 +1 Action causes rapid large range changes in postures or unstable base

	Neck											
	1				2				3			
Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture	1	1	2	3	4	1	2	3	4	3	3	5
Score	2	2	3	4	5	3	4	5	6	4	5	6
	3	2	4	5	6	4	5	6	7	5	6	7
	4	3	5	6	7	5	6	7	8	6	7	8
	5	4	6	7	8	6	7	8	9	7	8	9

	Lower Arm					
	1			2		
Wrist	1	2	3	1	2	3
Upper Arm	1	1	2	1	2	3
Score	2	1	2	3	2	3
	3	3	4	5	4	5
	4	4	5	5	5	6
	5	6	7	7	8	8
	6	7	8	8	9	9

Score A	Score B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	11	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score: **12** + Activity Score: **0** = REBA Score: **12**

Original Worksheet Developed by Dr. Alan Hedge. Based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000): 201-205

Figure 11: REBA assessment of a body posture that occurred during single-person mounting of the Arcos XL.

4.3 Competitor analysis

To identify Thules position on the market and identify market gaps ahead of idea generation, a competitor analysis has been conducted (see Table 2). Five competitors have been identified via Google Searches using the term such as “towbar mounter cargo carrier”. All competitor products which have been chosen utilizes either a towbar mount fixed to the box or a platform made specifically for the box. Boxes made for mounting on, for example bicycle racks were opted out.

Table 2: Comparison of the Arcos XL with competitors.

	Unit	Thule Arcos XL	IXTABox Pro compact	IXTABox Pro standard	IXTABox Pro large	MFT Backbox	Dezo Expedition	Peruzzo GP Evolve	Hapro Boxer L He
Price, incl. ev. platform	SEK	17898	29990	29990	29990	14990	9098	11995	8799
Outer dimension	Cm	190x76x48	175x55x45	190x55x45	205x55x45	154x53x74	163x72x57	130x63x60	163x74x57
Inner width	Cm	180	175	190	205	150/187	-	-	156,6
Volume	L	450	360	390	420	300	410	340	420
Weight (incl. ev. platform)	Kg	22+9	30	31	32	20+10	15+16	-	18,5
Load capacity	Kg	50	70	69	68	57	60	45	41,5
Tilttable	-						x		

4.3.1 IXTABox

The IXTABox is offered in two models, Classic and Pro, each available in multiple sizes with optional add-ons. Both models share a common form-factor and are manufactured primarily from aluminum and stainless steel. Unlike the Arcos XL's modular architecture, the IXTABox integrates a fixed towbar mount directly into the box assembly.

The Classic model is available in widths of 175 cm and 190 cm; the Pro model is available in 175 cm, 190 cm, and 205 cm widths. All variants share the same depth (55 cm) and height (45 cm). The Classic provides a cargo volume of 360 L (175 cm) or 390 L (190 cm), whereas the Pro offers 360 L, 390 L, or 420 L corresponding to the three widths. All IXTABox configurations are rated for a maximum load of 100 kg including the box, resulting in a net payload of approximately 68-70 kg, depending on model mass.

In terms of external size, the IXTABox Classic and Pro are broadly comparable to the Arcos XL (width 190 cm), as both models are available in this width. A notable advantage of the IXTABox Pro is the 205 cm width option, which can accommodate very long skis; however, this configuration presupposes a vehicle wide enough to support the installation, which is relatively uncommon. Even with the widest 205 cm Pro variant, the Arcos XL offers approximately 30 L greater cargo volume.

The Pro model supports up to ten optional add-ons. Illustrative upgrades include side-mounted handles, alternative surface finishes, internal dividers and rail systems, integrated lighting, and a 12 V power outlet. At present, no dedicated accessory ecosystem is offered

specifically for the Arcos XL; however, a limited set of accessories is shared with its sister product line of roof-mounted boxes.

The Classic model is priced at 19,990 SEK irrespective of width; the Pro model is priced at 29,990 SEK on the same basis. Consequently, the IXTABox occupies a higher-price segment; by comparison, the Arcos XL with its platform is approximately 2,000 SEK less expensive than the Classic and 12,000 SEK less expensive than the Pro. A fully configured IXTABox Pro with all add-ons is priced at 42,395 SEK.

4.3.2 Other competitors

Several competing towbar-mounted cargo boxes were reviewed, including the MFT BackBox, Dezo Expedition, Peruzzo GP Evolve, and Hapro Boxer L Hexagon. Although all four products provide rear-mounted storage solutions, none offers the same capability profile as the Arcos XL. The principal differentiator is overall width. Among the reviewed competitors, the widest model measures 163 cm, which positions it between the Arcos M and L variants (141 cm and 171 cm, respectively). Consequently, these alternatives generally do not accommodate elongated items, most notably skis, which constitute a key unique selling point (USP) of the Arcos XL. An exception is the MFT BackBox, which can be fitted with an extension that increases the internal width to approximately 187 cm, partially mitigating this limitation.

With respect to mass and capacity, the reviewed products are broadly comparable. Total system weight (including the mounting platform) ranges from 18 to 31 kg. Storage volume spans 300-420 L, compared with the Arcos XL's stated volume of 450 L. Maximum payload ratings range from 41 to 60 kg, which is in line with the Arcos XL's load capacity. The primary advantage of the reviewed competitors lies in their price positioning. The lowest-priced option is the Dezo Expedition at 9,098 SEK, while the most expensive of the group is priced at 14,990 SEK; all are less expensive than the Arcos XL when the required platform is included.

4.4 Analysis of gathered data

To organize and synthesize the empirical material obtained from the user study and the competitor analysis, the KJ method was applied. This synthesis resulted in the identification of a set of key problems and improvement opportunities, which were subsequently translated into functional statements. These functions served as the foundation for continued concept development.

4.4.1 Structuring of collected data

All collected data was fed into a Miro-board, utilizing the KJ method to categorize and structure all data (see section 3.2.1). Seven primary categories which all data from the user study was divided into were identified:

1. The platform
2. Mounting and dismantle of box
3. Usage phase
4. Storage
5. Desired additional features
6. Disadvantages with roof-box
7. Other data

In each category, all data relating to the relevant theme were consolidated and sorted, irrespective of the data-collection method from which they originated. Categories 5, 6, and 7 above were deemed outside the scope of the present project and are therefore not discussed further. Category 5 contained functional suggestions proposed by participants during the study; these inputs were excluded to avoid unduly constraining or biasing subsequent ideation activities. Category 6 comprised statements primarily concerning roof-mounted cargo boxes; any observations considered transferable to the present context were reclassified under the most appropriate category. Category 7 served as a residual grouping for data that could not be meaningfully categorized and were assessed as not applicable to the project. To see the entire KJ analysis, see Appendix 4.

4.4.2 Problem Identification

Based on the results from the user study, which were synthesized through a KJ analysis, specific problems were identified within the various categories. From the full dataset, a selection of recurring issues was extracted, focusing on those mentioned repeatedly by

participants. These identified problems were then compiled into a table, organized according to the same categories used in the KJ analysis, and accompanied by brief explanatory descriptions (see Table 3).

Two of the identified problems were directly related to the platform. These issues indicated that the platform was difficult to position correctly on the towbar and that it was challenging to grip during handling.

A total of eight problems were associated with the mounting and dismounting of the cargo box. These included difficulties related to handling loose components, inadequate seating of the light-transmitting cable and its connector in the holder, and challenges when connecting the cable to the towbar. Additional problems concerned transportation of the cargo box and uncertainty during the mounting process regarding whether the box was correctly engaged with the platform.

Problems identified during the usage phase primarily concerned the limited space between the vehicle and the cargo box, which made access to the trunk difficult. Participants also reported challenges related to parking and reversing with the cargo box mounted, as well as difficulties when opening and closing the lid. Furthermore, issues were raised regarding perceived stability, including concerns about the risk of overloading the cargo box and forgetting to properly secure the load.

Finally, problems related to the storage of loose components and the storage of the cargo box itself were identified. Users experienced difficulties keeping track of loose parts and expressed concern about the risk of components being lost. In addition, users highlighted challenges related to storing the cargo box when not in use, due to its high weight and large dimensions.

Table 3: Problem identification list.

Problem area	Identified problems
Platform	Difficult to align straight
	Difficult to grip
Mounting and dismounting	Cumbersome to handle loose screws (parts)
	The cable is poorly seated in the holder
	Difficult to notice when it is correctly engaged in the rails; no audible or visual feedback
	Difficult to transport (from storage to vehicle)
	User gets dirty (not enough space between the vehicle and the box)
	Difficult to connect the taillight connector to the vehicle (short cable / limited space)
	The holder is on the opposite side compared to the vehicle connector
	Difficult to mount alone
Usage phase	Difficult to open and close the tailgate and load luggage with the box mounted (limited space between box and vehicle)
	Difficult to judge how far the box extends behind the vehicle
	Difficult to open the lid of the box; requires lifting upwards
	Difficult (cumbersome) to fully close the lid and enable locking
	Risk of overloading
	Other drivers have difficulty seeing the box from the side in low-light conditions
	Difficult to remember to secure the load (easy to forget)
	Perceived as somewhat unstable / wobbly (side-to-side, especially when mounted)
Storage compartment	No place to store screws, washers, Allen keys, or tie-down straps when not in use
Storage (box)	The unit is large and difficult to store when not in use
	"Requires a hoist in the garage"
	"Must be stored outdoors under a tarp"

4.4.3 Function analysis

The initial function analysis identified the product's main function, supporting functions, and additional functions (see Table 4). This type of function list was developed primarily to clarify the overall purpose of the product, determine which function creates value for the customer, and identify the function that generates revenue for Thule. It was essential that the main function was correctly defined, as this function cannot be altered without fundamentally changing the product's purpose.

The supporting functions comprise all functions that enable the main function to perform as intended. Although these functions do not create direct value for the customer, they are necessary for the product to function properly. In contrast, the additional functions are not essential for basic functionality but contribute added value for the customer. This project primarily focuses on these additional functions and explores how they can be further developed to increase customer value.

Table 4: Function analysis that presents the main function and the support functions.

Area	Function	Type of function	Comment
Cargo box	Allow storage space	MF	Contains a volume of 450 L and a geometric footprint of 190 x 76 x 48
Platform	Provide mounting points	SF	The platform shall allow mounting between the vehicle and the box
	Mount on towbar	SF	The platform shall be able to be mounted onto a towbar
	Secure to towbar	SF	The platform shall be able to be firmly secure to a towbar
	Lock in place	SF	The platform shall be lockable to prevent removal from the towbar at unwanted times
	Allow box mounting	SF	The platform shall enable mounting of the box on the platform
Cargo box	Open box	SF	The box shall be able to be opened using the current locking system and hinge
	Enable attachment	SF	The box shall be easy to attach to the platform
	Lock in place	SF	The box shall be lockable to the platform
	Allow closing	SF	The lid shall be able to be closed and locked with the three point locking system
	Connect cable	SF	The cable on the box shall be connectable to the vehicle to allow transmission of light signals
	Lock box	SF	The box shall be lockable using the current locking system
	Enable load securing	SF	The box shall have attachment points to secure the load using straps

Once all identified problems had been compiled into a problem identification list (see Table 2), the subsequent function analysis was based on these newly identified problems. The function analysis in Table 5 does not correspond to main and support functions presented in Table 4. Each problem was translated into a corresponding function, which was then organized according to the same categories used in the KJ analysis and the problem identification list (see Table 3). Each function was formulated using a verb-noun structure, followed by its classification (necessary, desirable, conceivable, or undesirable) and accompanied by a brief explanatory comment describing the function in more detail.

Table 5: Function analysis that corresponds to the identified problems.

Area	Function	Classification	Comment	R	I	C	E	Score
Platform	Communicate positioning	D	Indicate when the platform is correctly aligned on the tow hitch	7	2	0.8	3	3.73
	Provide grip	C	Facilitate gripping of the platform	3	0.5	0.8	3	0.40
Mounting/dismounting	Secure cable	D	Make it harder for the cable to come loose from the current holder on the box	3	1	0.8	1	2.40
	Communicate engagement	D	Audibly or visually communicate when the box has engaged in the rails	8	2	1.0	6	2.67
	Increase clearance	C	Increase space between the box and the vehicle	7	2	1	7	2.00
	Facilitate movement	D	Facilitate moving the box from storage to the vehicle	6	2	1	3	4.00
	Connect cable	D	Facilitate connection of the cable to the towbar	5	0.5	0.8	1	2.00
	Simplify positioning (cable)	C	Avoid opposite-side placement of cable holder and tow-bar connector	1	0.25	1	1	0.25
	Enable single-person mounting	D	Do not depend on a second person during mounting and dismounting	8	3	1	10	2.40
	Minimize components	D	Minimize loose parts such as screws, washers, Allen key	5	1	0.8	2	2.00
Usage phase	Increase clearance	C	Increase space between box and vehicle for better access to the trunk	7	2	1	7	2.00
	Facilitate parking	C	Audibly or visually communicate to the driver where the box is located during parking	6	3	1	10	1.80
	Prevent twisting	C	Increase torsional stiffness in the lid	4	2	0.8	8	0.80
	Minimize hand grips	C	Simplify closing of the lid by requiring fewer "presses" on the box	2	1	0.8	6	0.27
	Communicate load capacity	C	Minimize risk of overloading	2	0.25	1	3	0.17
	Emphasize extension	C	Make the box easier to see from the side in low-light conditions	2	0.5	1	1	1.00
	Encourage load securing	C	Encourage and remind the user to secure the load	1	0.25	1	1	0.25
	Provide stability	D	Stabilize the box side-to-side	3	0.5	0.8	6	0.20
Storage compartment	Simplify storage	D	Simplify storage of screws, washers, and Allen key	5	1	1	2	2.50
Storage (box)	Simplify storage	D	Enable easy storage of the box	4	2	1	9	0.89
								31.72

4.4.4 RICE-model

To prioritize the functions identified in the initial functional analysis, the RICE-model was applied. The model was used in a manner similar to the description provided in Section 3.2.3, with minor adjustments tailored to this study. For the Reach factor, each function was evaluated based on the number of participants who had mentioned the corresponding issue during the user study, thereby indicating its relative reach. These assessments were conducted using a scale from 1 to 10, where a score of 1 indicates that the issue was mentioned by only one participant, and a score of 10 indicates that it was reported by all participants.

The Impact and Confidence factors were applied in accordance with the procedures described in Section 3.2.3. However, Effort was not evaluated using person-months, as typically recommended. Instead, each function was assessed on a scale from 1 to 10 based on the anticipated difficulty and the number of resources required to develop a solution that adequately addresses the function.

After applying the RICE-model, several functions were identified as having a higher potential impact than others if addressed (see Table 5). The evaluators determined that functions receiving a score above the average value would constitute the focus of this project going forward. The total combined score for all functions was 31.72, which results in an average score of 1.59 when divided across the 20 evaluated functions. Based on this threshold, nine functions were excluded, leaving 11 functions to be prioritized in the continued development work.

Among these 11 functions, one corresponds to the problem of facilitating parking through audio or visual communication to inform the driver of the cargo box's position during parking maneuvers. Thule is currently developing an internal solution for this function, which is expected to be released in the near future. Due to confidentiality requirements and patent considerations, this function will therefore not be included in the scope of this project.

Another function excluded from the project scope was "enable single-person mounting". This decision was made because the function is closely interrelated with several of the functions that were retained for further development. Consequently, this functionality is expected to be achieved indirectly as the included functions are further developed and refined.

After these exclusions and the merging of two functions into one, a total of eight functions remained for continued development, see Table 6.

Table 6: Functional analysis after reducing functions.

Area	Function	Comment
Platform	Communicate positioning	Indicate when the platform is correctly aligned on the tow hitch
Mounting/dismounting	Secure cable	Make it harder for the cable to come loose from the current holder on the box
	Communicate engagement	Audibly or visually communicate when the box has engaged in the rails
	Facilitate movement	Facilitate moving the box from storage to the vehicle
	Connect cable	Facilitate connection of the cable to the towbar
	Minimize components	Minimize loose parts such as screws, washers, Allen key
Usage phase	Increase clearance	Increase space between box and vehicle for better access to the trunk
Storage compartment	Simplify storage	Simplify storage of screws, washers, and Allen key

4.5 Idea generation

After the functions had been prioritized using the RICE-model, the next phase of idea generation was initiated. The purpose of this phase was to generate a broad range of solution concepts for each prioritized function. In the initial stage of idea generation, no consideration was given to whether proposed solutions for different functions conflicted with one another.

4.5.1 Initial ideas

To generate a wide range of innovative ideas, both brainstorming and the 6-3-5 method (See section 3.3.1 and 3.3.2) were employed. These methods enabled the participants to think individually, engage in discussions, and further develop ideas by building upon one another's contributions. During the idea-generation process, all ideas were documented using quick sketches accompanied by brief explanatory keywords. This approach facilitated effective discussions of each proposed solution, ensuring mutual understanding between the participants. Following the discussions, the ideas were refined based on shared feedback, resulting in clearer and more coherent sketches. At the end of the initial idea-generation phase, between two and seven concept ideas had been developed for each function. All ideas can be seen in Figure 12 with a complementary sketch or picture.

Some solutions, for example the fine adjustment mode, are intended to function as additions to the existing Hercules locking mechanism. These additions are not intended to alter the original function of the mechanism, as this has been defined as a limitation of the project.

Communicate positioning	2D spirit level	Angle hook	Ground reference setup	Fine-adjustment mode	Foldable support legs	Markings	
Secure cable	More robust construction	Tool clamp	Bottle holder	Cable clamp	Elastic strap		
Communicate engagement	Transparent plastic	Click system	Reversed sliding motion	More visible groovers	Front-side markings		
Facilitate movement	Wheels on short side	Canoe cart	Skidplates	Trolley	Hand truck	Wheels on platform	Handles
Connect cable	Coiled cable	Extended cable	Vacuum-cleaner-style cable	Cable routed through platform			
Minimize components	Fixed screws	Latch	Click system	Pre-assembled on platform	Clamp		
Increase clearance	Tilting function	Adjustable offset					
Simplify storage	Inside pocket	Tray with holes	Elastic strap				

Figure 12: All proposed solutions to each function with illustrations. (Author's own image)

4.5.2 Evaluating ideas

To evaluate the generated ideas and reduce the number of solution concepts, a PMI (Plus, Minus, Interesting) matrix was applied. Within the matrix, each solution was assessed based on its positive, negative, and interesting aspects. This qualitative evaluation enabled the different criteria to be weighed against one another and served as the basis for validating the ranking of the solutions (see Appendix 5).

Based on the resulting rankings, several solution concepts were eliminated. The initial approach was to reduce the number of solutions for each function by approximately half. For instance, if a function was associated with six solution concepts, three were retained after the elimination process. In cases where an odd number of solutions existed, for example seven, more solutions were retained than eliminated. However, this strategy was revised in certain cases, such as when a function only had two associated solutions or when a particular solution required further testing before a final decision could be made.

4.6 Concept development

The following section presents the concept development process and outlines the composition of each proposed concept, including the sub-solutions on which they are based. In order to enable a systematic comparison between the concepts, several of the sub-solutions were evaluated through practical testing as part of a proof-of-concept approach. The insights gained from these evaluations supported an informed and objective assessment of each concept, ultimately leading to the selection of the final concept.

4.6.1 Concept creation

In order to generate concept alternatives, the remaining ideas were compiled into a morphological matrix (see Section 3.4.1). Based on this matrix, four distinct concepts were developed by combining alternative solution principles for each function (see Figure 13). The concepts were intentionally configured to represent different performance profiles and design emphases. Accordingly, the combination process prioritized coherent and mutually compatible solution sets rather than exhaustively generating all possible permutations. During concept creation it was realized some functions were contradictory to each other, and therefore not used. For example, the plastic screw holder is not needed if screws are replaced

with for example latches. The resulting concepts are briefly described in the subsequent sections.

Morphological Matrix - Next Generation CargoBox

Sub-Functions	Sub-Solutions			
Communicate positioning	2D Spirit Level	Angle hook	Fine-adjustment mode	
Secure cable	Tool clamp	Bottle holder	Elastic strap	
Communicate engagement	Click system	More visible groovers	Front-side markings	
Facilitate movement	Wheels on short side	Canoe cart	Skidplates	Handles
Connect cable	Coiled cable	Extended cable	Vacuum-cleaner-style cable	
Minimize components	Fixed screws	Latch	Click system	
Increase clearance	Tilting	Adjustable offset		
Simplify storage	Inside pocket	Tray with holes		

Figure 13: Morphological table with lines indicating different concepts. (Author's own image)

Concept A

Concept A, illustrated by the red line in Figure 13, incorporates a two-dimensional spirit level integrated into the platform. This component provides visual feedback on the platform's rotational alignment around the X- and Y-axis, based on the X-axis aligned horizontally with the car's direction of travel. The spirit level does not take rotation around the Z-axis into consideration.

To prevent the power cord and plug from loosening when the cargo box is mounted onto the platform, the current fastening solution has been replaced with a tool clamp. The clamp is U-shaped and manufactured from a flexible plastic material, allowing it to securely grip the plug and provide improved stability. To further facilitate installation of the cargo box, the underside has been designed with more prominent and visually distinguishable grooves. The purpose of this feature is to assist the user in aligning the grooves with the corresponding attachment points on the platform. In combination with the addition of two wheels on one side of the cargo box, this design significantly simplifies the installation process. Rather than lifting the heavy cargo box, the user can roll it into position, align the grooves with the platform, and gently lower the box into place. Once correctly positioned, the cargo box can be secured using fixed pins instead of loose screws and washers, further reducing installation effort.

To increase the clearance between the cargo box and the vehicle, the platform has been redesigned to allow horizontal displacement of approximately 20 cm away from the car. This feature improves access to the vehicle's trunk and facilitates loading and unloading. Additionally, it simplifies connection of the electrical cable used to transmit lighting signals to the vehicle. For this reason, the conventional straight cable has been replaced by a spiral cable, which provides extended reach when the cargo box is in its displaced position while retracting when the box is returned to its original position.

To further enhance customer value, the interior of the cargo box includes a flexible storage pocket. This pocket is intended to store the instruction manual, and the securing straps used to fasten the load. To increase versatility, the pocket is designed to be removable, allowing it to be attached or detached as needed.

Concept B

Concept B, illustrated by the blue line in Figure 13, incorporates two foldable angle brackets mounted on the platform. These brackets fold upward from the platform and are designed to make contact with the rear of the vehicle. This feature assists the user in positioning the platform correctly in relation to rotation around X- and Y-axis as well as the Z-axis.

To prevent the power cord and plug from loosening when the cargo box is mounted onto the platform, the existing fastening solution has been replaced with an alternative holder resembling a bottle cage. To further facilitate installation, the cargo box is equipped with a low-friction reinforcement made of plastic along one underside edge. This allows the user to slide the cargo box along the ground rather than lifting it, thereby enabling the box to be dragged into position. As the box is guided toward the platform, the user can then easily lift and place it into its final position. Once positioned on the platform, the cargo box is secured using a click-locking mechanism. This system provides auditory feedback to confirm correct installation and eliminates the need for loose screws and washers, thereby simplifying the mounting process.

To increase the available space between the cargo box and the vehicle, the platform has been designed to incorporate a tilting function. When tilted upward, this function improves access to the vehicle's trunk and facilitates loading and unloading. Additionally, the tilted position provides increased space for connecting the electrical cable used to transmit lighting signals to the cargo box. Since the original cable length is insufficient in this configuration, it has been replaced with a longer cable housed within a spring-loaded container. This mechanism allows the user to extend only the required length of cable, which automatically retracts when the cargo box is returned to its intended position, comparable to the cord-management system of a vacuum cleaner.

As in Concept A, the interior of the cargo box is equipped with a flexible storage pocket intended to store both the securing straps and the instruction manual.

Concept C

Concept C, illustrated by the green line in Figure 13, is in several aspects similar to Concept A. The concept incorporates the same two-dimensional spirit level integrated into the platform, the same tool clamp designed to secure the electrical plug, and the same visually enhanced and more prominent grooves on the underside of the cargo box to assist alignment during installation.

One feature that distinguishes Concept C from Concept A is the approach taken to facilitate mobility of the cargo box during handling and installation. Whereas Concept A integrates wheels permanently on one side of the box, Concept C addresses the same challenge through a detachable add-on solution. This add-on resembles a canoe transport cart and can be attached when needed and removed when no longer in use. The cart enables easier transportation of the cargo box and assists in mounting it onto the platform by allowing the box to be pulled into position from the side.

Once correctly positioned on the platform, the cargo box is secured using fixed screws that are accessible from the interior of the box. Similar to Concept A, Concept C features a redesigned platform that allows horizontal displacement, thereby increasing the clearance between the vehicle and the cargo box when desired. This feature also facilitates connection of the light-transmitting cable. The concept is equipped with the same cable-management mechanism as Concept B, allowing the user to extend the required length of cable from a holder, which automatically retracts when the cargo box is returned to its intended position.

As in Concepts A and B, the interior of the cargo box is equipped with a flexible storage pocket designed to store the instruction manual and securing straps.

Concept D

Concept D, illustrated by the yellow line in Figure 13, introduces an additional operating mode to the Hercules locking system: a fine-tuning mode. This mode is intended to allow the platform to be positioned on the towbar and lightly tightened while still permitting minor positional adjustments. Maintaining limited adjustability at this stage enables more precise alignment prior to final tightening.

To facilitate handling during transport from storage to the platform and to support the mounting sequence, two rubberized handles are integrated at the rear of the box, directly beneath the lid. These handles improve grip and reduce the effort required when lifting. To support accurate placement on the platform, visual alignment markings are applied adjacent to the rear grooves below the handles. These markings remain visible during lifting, thereby providing guidance for initial positioning. For fixation between the box and the platform, Concept D employs a click-in locking interface, eliminating the need for loose fasteners such as separate screws.

The electrical connection for the rear lighting is modified through the introduction of a longer cable. This change enables connection of the trailer plug before the box is lifted onto the platform, improving access to the towbar connector when the box is not yet installed and reducing constraints during mounting.

In addition, Concept D incorporates the same tilting function as Concept B, allowing increased clearance between the box and the vehicle when installed. The concept also includes a flexible storage pocket, consistent with the other concepts, intended for storing the instruction manual and securing straps.

4.6.2 Proof of concept

Once the different concepts had been developed, the sub-solutions included in each concept needed to be evaluated in order to enable a fair and informed comparison. Several of the sub-solutions could be tested using a full-scale physical product, while others were evaluated theoretically or through simplified mock-up models. These tests aimed to assess the feasibility and functionality of the proposed solutions prior to concept selection.

Communicating positioning

Three different solutions were evaluated for communicating the positioning of the platform: a two-dimensional spirit level, an angle hook, and a fine-adjustment approach.

The two-dimensional spirit level was tested by placing a miniature spirit level on top of the coupling that surrounds the tow hitch. However, the intended placement did not provide a sufficiently flat surface, which prevented the spirit level from functioning as intended. To

enable proper operation, the spirit level had to be positioned on an extension of the platform. This required removal of the plastic surrounding the coupling and the construction of a small extension using a modified square hollow section (SHS) shaped as an angle bracket. The two-dimensional spirit level was then integrated into the SHS and positioned on a flat surface on one side of the coupling, which resulted in the spirit level functioning as intended (see Figure 14).



Figure 14: Spirit level mounted on the platform. (Author's own image)

The angle-hook solution was evaluated using a quick mock-up. This test did not yield the intended outcome, as the platform handle consistently obstructed the functionality of the hook (see Figure 15). Consequently, further development and testing would be required for this solution to be viable.



Figure 15: Mock-up of angle hook. (Author's own image)

The fine-adjustment approach was evaluated theoretically using the full-scale product. It was observed that partially lowering the handle produced a similar effect to a fine-adjustment mode. While this approach could achieve the desired positioning accuracy, the user would not be able to release the handle and leave the system in a fine-adjustment state, as the handle would return to its open position when released.

Secure cable

Three different solutions were evaluated for securing the electrical cable on the cargo box when not in use: a tool clamp, a bottle-holder-inspired solution, and an elastic strap.

The tool-clamp solution was tested by removing the existing cable holder and replacing it, see Figure 16. The clamp used in the test was a commercially available component purchased from Hylte Jakt och Lantmän and was not specifically designed for this application. The clamp could secure the contact used to transmit lighting signals. Despite this limitation, the clamp provided a sufficiently strong grip and successfully held the contact in place. The test also demonstrated that the cable and contact could be secured using only one hand, which was identified as a practical advantage.



Figure 16: Tool clamp. (Author's own image)

The second solution, inspired by a bottle holder, was more challenging to test, as no existing component fully met the intended functional requirements. Consequently, this solution was evaluated theoretically and through a simple mock-up model. The underlying concept was that the holder would be designed so that the contact could rest upon it. However, the

evaluation indicated that the contact was held relatively loosely, making it susceptible to dislodgement when the cargo box was subjected to vibrations or minor impacts.

The third and final solution evaluated was an elastic strap. This solution was tested by replacing the existing cable holder with a simple elastic strap. The test showed that the strap was unable to secure the cable and contact sufficiently, resulting in the cable falling toward the ground. Furthermore, this solution required the user to use both hands during operation, which was considered inflexible and inconvenient from a usability perspective.

Communicate engagement

Three different solutions were evaluated to facilitate communication of correct engagement between the cargo box and the platform: an audible click system, more visually prominent grooves, and simple color markings on the front side of the cargo box.

The first solution, an audible click system, and the second solution, visually enhanced grooves, were difficult to evaluate using the physical product. Consequently, these solutions were assessed theoretically through visualization. The audible click system was evaluated by manually moving the cargo box back and forth and simulating the sound that would occur when the box engages with its attachment points. The visually enhanced grooves were evaluated by visualizing alternative designs, such as replacing the existing grooves with externally mounted U-profiles (see Figure 17). Individually, these solutions were not expected to result in a significant improvement. However, when combined, they were assessed to provide clearer feedback to the user, as both auditory and visual cues would indicate when the cargo box is correctly positioned.



*Figure 17: U-profiles were test-mounted on the underside of the box.
(Author's own image)*

The final solution evaluated for communicating engagement involved the use of simple color markings on the front side of the cargo box (see Figure 18). This solution was tested by applying small colored markings around the grooves on the front face of the box. While these markings were not intended to physically assist the installation process, the underlying concept was to increase user awareness through cognitive nudging. However, the evaluation showed that the markings were difficult to see during installation, rendering them ineffective and failing to provide the intended support.

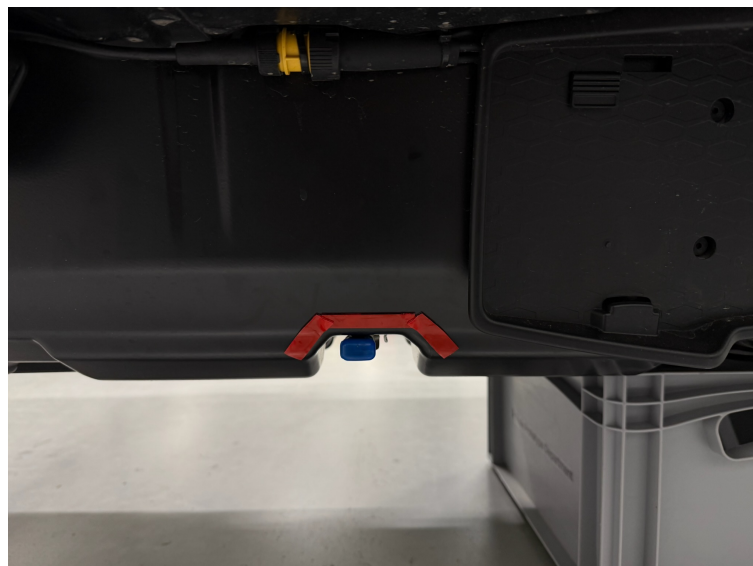


Figure 18: Marking were tested through applying red tape were the grooves are placed. (Author's own image)

Facilitate movement

Four different solutions were evaluated to facilitate the movement of the cargo box: wheels mounted on one side of the box, a canoe cart, skid plates, and simple handles.

The solution involving wheels mounted on one side of the cargo box was tested by applying a set of wheels originally designed for another towbar-mounted cargo box from Thule (see Figure 19). Although the design was not fully compatible with the Arcos XL, it functioned sufficiently well to allow evaluation of the concept. The results were positive, as the wheels significantly reduced the effort required to transport and maneuver the cargo box.



Figure 19: Wheels attached to the side of the box. (Author's own image)

The canoe cart solution was evaluated using a small, wheeled cart placed beneath one side of the cargo box to simulate the intended functionality (see Figure 20). The test demonstrated that the solution was effective in facilitating movement. However, the evaluation also revealed a limitation in that the cart constituted a separate component, making the solution less flexible and potentially less convenient for the user.



Figure 20: A low-profile trolley was placed under one side of the box simulating a canoe cart. (Author's own image)

The skid-plate solution was tested by attaching a low-friction material to one underside of the cargo box. This allowed the box to be pushed along the ground, although it required more force compared to the wheel-based solutions. Furthermore, observations indicated that the material used for the skid plates would likely experience rapid wear over time, raising concerns regarding durability.

The final solution evaluated for facilitating movement involved the use of simple handles. This solution was tested by tightening straps around the cargo box to simulate integrated handles (see Figure 21). While this approach improved grip and made the cargo box easier to maneuver, the overall load remained heavy and still required the user to lean the box toward the body during handling.



Figure 21: Picture from handle mock-up. (Author's own image)

Connect cable

Three different solutions were evaluated to facilitate connection of the electrical cable: a coiled cable, an extended cable, and a vacuum-cleaner-style retractable cable.

The coiled cable solution was tested by removing the original cable and replacing it with a coiled alternative (see Figure 22). The original cable measured approximately 75 cm, whereas the coiled cable measured approximately 50 cm in its retracted state and up to 1.5 m when fully extended. This configuration allowed the cable to be connected to the vehicle before the cargo box was mounted, providing increased space and improved accessibility during connection. Once the cargo box was mounted, the coiled cable automatically retracted to its minimum length.



Figure 22: Picture of the coiled cable.
(Author's own image)

Another evaluated solution involved extending the original cable by approximately 30 cm. This modification functioned as intended, as it enabled the cable to be connected prior to mounting the cargo box onto the platform. However, once the box was installed, excess cable remained loose and hung between the vehicle and the cargo box, which was identified as a drawback of this solution.

The final solution evaluated was a vacuum-cleaner-style retractable cable system, in which the cable can be extended to the required length and automatically retracted when no longer needed. This solution proved difficult to test in practice and was therefore primarily assessed through visualization using a loose cable and a cable housing. Observations indicated that the concept could function effectively; however, further development and more extensive testing would be required. An additional advantage of this solution is that it eliminates the need for a

dedicated contact holder, which addresses one of the functional challenges identified in this project.

Minimize components

Three different solutions were evaluated to reduce the number of loose components, such as screws and washers: fixed screws, latches, and a click-locking system.

The first solution, fixed screws, was evaluated by visualizing a fixed version of the existing loose screws used to secure the cargo box. This approach proved effective in reducing small components that are easy to misplace. However, positioning the fixed screws on the inside of the box made it difficult to visually align the screw holes with the corresponding holes in the platform. As a result, attaching the cargo box to the platform became significantly more challenging.

The second solution evaluated was the use of latches. Due to the complexity of the mechanism, this solution was assessed through visualization on the physical product rather than through a functional mock-up. Observations indicated that a latch-based system could provide a simple and intuitive method for attaching the cargo box to the platform. However, implementation of this solution would require substantial design modifications to the underside of the cargo box, which was identified as a limitation.

The third and final solution evaluated was a click-locking system, intended to allow the cargo box to be attached to the platform by simply clicking it into place. This solution proved difficult to assess, as repeated attempts to visualize a feasible implementation indicated that the system would be complex to construct. Consequently, no further testing of this solution was conducted.

Increase clearance

Two different solutions were evaluated to increase the clearance between the vehicle and the cargo box: a tilting function and an adjustable offset function.

The tilting function was evaluated without the use of additional components or materials. Instead, the assessment was conducted by visualizing the cargo box in both its intended

mounted position and its tilted position (see Figure 23). The evaluation indicated that tilting the box would increase the clearance between the vehicle and the cargo box, thereby facilitating access to the trunk and simplifying connection of the light-transmitting cable. However, the box was found to be relatively heavy to tilt even when unloaded, leading to the conclusion that tilting would be difficult when the box is fully loaded. Furthermore, when the box is tilted while carrying a load, unsecured items could shift or fall, potentially causing damage to the luggage.



Figure 23: The tilt function was evaluated by simply tilting the box on the platform. (Author's own image)

The second solution evaluated was the adjustable offset function. This solution was tested by attaching two drawer slides between the underside of the cargo box and the platform. The drawer slides were equipped with locking mechanisms, allowing the box to be secured both in its intended position and in an offset position that increased the clearance between the vehicle and the cargo box by approximately 20 cm (see Figure 24). The slides could be extended even further, although locking functionality was not available in those additional positions. The evaluation confirmed that the cargo box could be smoothly translated along the drawer slides both when unloaded and when fully loaded.



Figure 24: One part of the slide was mounted to the platform and the other to the underside of the box. (Author's own image)

Simplify storage

One solution was evaluated to simplify storage of loose components: an interior-mounted pocket.

The solution was evaluated by sewing a fabric pocket designed to accommodate loose screws, washers, an Allen key, as well as the instruction manual and securing straps (see Figure 25). The pocket was attached to the interior of the cargo box using Velcro, allowing it to be easily attached and removed when desired. If the function *to minimize components* is successfully achieved, the need to store screws, washers, and an Allen key would be eliminated. However, the pocket would still be required for storing the instruction manual and securing straps, indicating that this solution retains relevance regardless of component minimization.



Figure 25: Pocket to store loose components. (Author's own image)

4.6.3 Concept selection

After four different concepts had been developed and their respective sub-solutions evaluated through proof-of-concept testing, a Pugh-matrix was used to support the concept selection process (see Table 7).

In the Pugh-matrix, the concepts were systematically compared against one another using a set of predefined evaluation criteria. These criteria were derived from the function analysis and subsequently reformulated as requirements. Once the requirements had been established, Concept B (indicated by the blue line in the morphological matrix), was selected as the reference concept. The remaining concepts were then evaluated relative to the reference concept by assessing whether they fulfilled each requirement better than, equal to, or worse than the reference concept. Scoring was based mostly on experience during proof of concept. Functions not tried by mock-ups (see Section 4.6.2) were evaluated theoretically.

Table 7: Pugh-matrix.

Chalmers	Pugh-matrix:			
Next Generation Cargo Box	Created: 2026-04-20			Page 1
	Modified:			
Criteria	Concept			
	A	B	C	D
Visual feedback when the platform is level in X and Y direction	0	R	0	-1
Movement in Y-direction when mounted	1	E	1	0
Minimize loose components	0	F	0	0
Storage of loose components	1	E	1	0
Audible/visual feedback that the box is correctly positioned on the platform	0	R	0	-1
Smoothest handling of the electrical connector	1	E	0	-1
Movement by a single person	1	N	0	-1
Mounting by a single person	0	C	0	-1
		E		
$\Sigma +$	4	0	2	0
$\Sigma 0$	4	0	6	3
$\Sigma -$	0	0	0	5
Net value	4	0	2	-5
Ranking	1	3	2	4
Further development	Yes	No	No	No

After aggregating the evaluation scores, the completed Pugh-matrix indicated that Concepts A and C fulfilled the requirements to a greater extent than the reference concept, whereas Concept D performed worse than the reference concept. Furthermore, the results showed that Concept A fulfilled the requirements more effectively than Concept C. Based on these results, Concept A was selected for further development.

5 Final concept

This section presents the final concept of the modified Arcos XL together with its corresponding platform. All newly introduced features are described in detail and supported by visual renderings and figures, such as Figure 26. Complementary renders of the CAD-model can be found in Appendix 6.

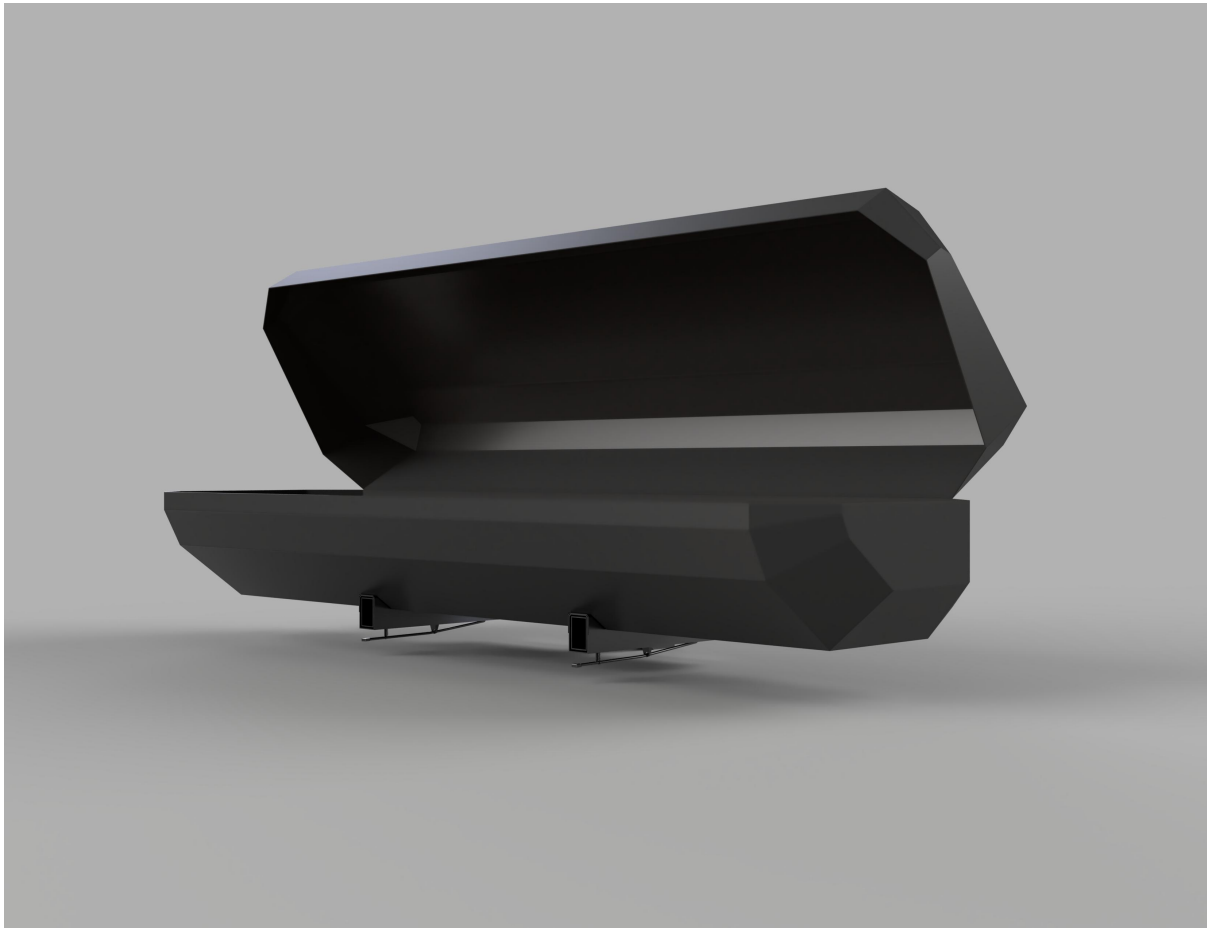


Figure 26: Render of the final concept. (Author's own image)

5.1 Platform

To improve usability during installation, the platform has been subject to minor design modifications aimed at facilitating correct positioning and simplifying the installation process.

5.1.1 Correct positioned platform

To provide the user with clear feedback regarding whether the platform is correctly aligned, a miniature spirit level has been integrated on one side of the coupling that surrounds the tow

hitch (see Figure 27). This spirit level indicates correct rotational alignment around the X- and Y-axis, while rotation around Z-axis is adjusted manually by the user.

The miniature spirit level is mounted within an aluminum, powder-coated angle bracket positioned on the side opposite the tensioning handle (see Figure 27). This placement allows the user to maintain visual access to the spirit level throughout the entire installation process, from initial positioning of the platform to final tightening of the handle. The angle bracket, together with the spirit level, is attached to the platform using screws and is mounted on top of the protective plastic that surrounds the metal coupling enclosing the tow hitch.



Figure 27: Placement of spirit level. (Author's own image)

The angle bracket is manufactured from aluminum due to its low weight and corrosion-resistant properties. It is powder-coated in black to match the rest of the platform and to provide an additional protective layer (note: not visualized on the prototype).

Although the integrated spirit level simplifies correct positioning of the platform without requiring additional adjustments, certain conditions must be considered for it to function effectively. Specifically, the user must account for the slope of the surface on which the vehicle is parked during installation. As the spirit level operates based on gravity, its accuracy is reduced if the vehicle is positioned on uneven ground or an incline, in which case the indication may not reflect the true alignment of the platform relative to the vehicle.

5.2 Cargo box

The Arcos XL cargo box has previously been characterized by its weight and limited maneuverability, which have posed challenges during handling and installation. This section presents the newly developed features aimed at facilitating maneuvering, mounting, usage, and dismounting of the cargo box.

5.2.1 Mounting the cargo box on to the platform

The process of mounting the cargo box onto the platform has previously been challenging due to the box's weight and limited maneuverability. To address this issue, several design features have been introduced to facilitate and simplify the mounting procedure.

The first feature introduced to facilitate both transportation and mounting of the cargo box is the integration of wheels on the underside of the box. Specifically, a pair of wheels have been mounted on the right-hand underside of the cargo box when viewed from the front (see Figure 28). These wheels enable the user to transport the cargo box more easily between the storage area and the vehicle, as well as to maneuver it during the mounting process.



Figure 28: Placement of plastic wheels on the right-hand side of the box which allows the box to be rolled rather than lifted. (Author's own image)

The wheels are not mounted directly onto the cargo box. Instead, they are integrated into a dedicated ABS plastic component that follows the contours of the box and is shaped to fit this specific location. This component is injection-molded and designed to match the geometry of the box underside. The wheels themselves are made from a durable polypropylene (PP) selected for its wear resistance. The ABS plastic component, together with the wheels, is secured to the cargo box using four screws.

To further support correct alignment and provide clear feedback when the box is correctly positioned, galvanized steel U-profiles are integrated on the underside of the box (see Figure 29). These U-profiles improve positional guidance and enhance tactile and/or audible confirmation upon correct seating. The profiles are zinc-coated to provide corrosion protection and to ensure long-term durability.

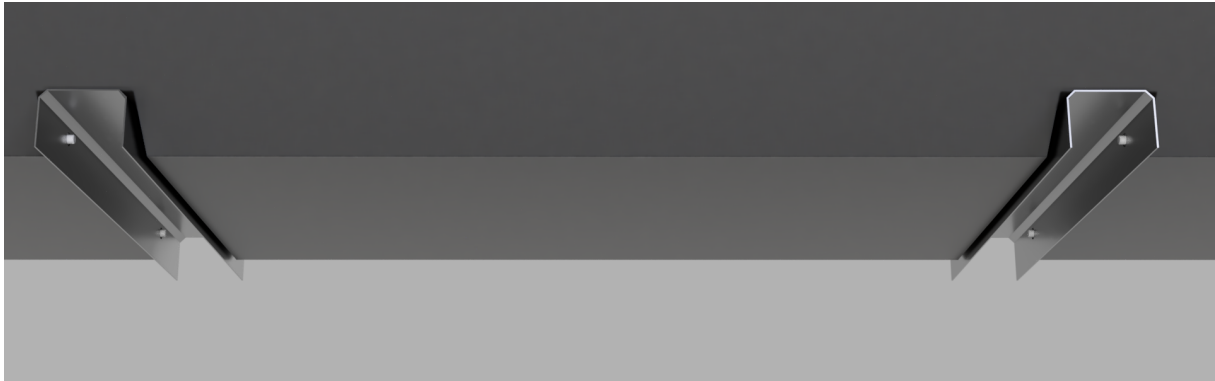


Figure 29: Visualization of U-profiles placed on the underside of the box from CAD-model. (Author's own image)

Once the cargo box is correctly positioned on the platform, it is secured using four latches. These latches are accessible from the interior of the cargo box (see Figure 30). During installation, the user pulls out the latches and may need to move the cargo box slightly back and forth along the grooves until the spring-loaded latches align with and engage in their corresponding holes. When all latches have engaged, the cargo box is securely attached to the platform.

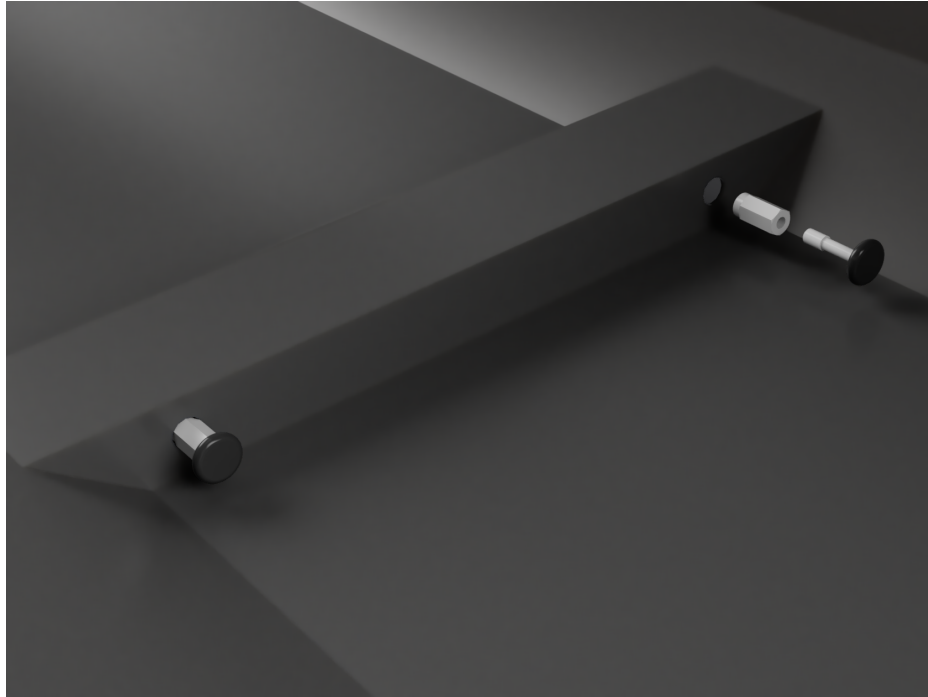


Figure 30: Illustration of the placement of spring-loaded latches which can be accessed from the inside of the box. Left one in correct position, right one in exploded view showing constituent components. (Author's own image)

To further enhance and facilitate the mounting process, the light-transmitting cable has been equipped with a redesigned holder (see figure 31). The new holder is based on a tool-clamp principle, allowing the connector to be snapped into place using only one hand. The clamp is manufactured from injection-molded plastic and is positioned in the same location as the previous holder, on the rear side of the cargo box. This tool clamp securely retains both the cable and the connector, ensuring a firm grip and preventing the cable from coming loose due to minor impacts or vibrations that may occur during the mounting process.



Figure 31: A tool clamp has replaced the cable holder. (Author's own image)

5.2.2 Facilitate usage

To facilitate loading and unloading of the vehicle's trunk, as well as connection of the light-transmitting cable to the towbar, a function enabling increased clearance between the vehicle and the cargo box has been integrated into the final concept.

The fork-like elements that extend from the platform have been redesigned. Instead of a single square hollow section (SHS), the platform now incorporates multiple telescoping SHS profiles that slide within one another, allowing the platform (and thereby the cargo box) to be extended away from the vehicle to increase clearance. The inner SHS profile, which is welded into the platform frame, has dimensions of 60×40 mm, while the outer SHS profile measures 70×50 mm. To prevent excessive friction and ensure smooth movement between the steel profiles, polyoxymethylene (POM) inserts have been placed between the profiles. POM is a low-friction engineering plastic, which facilitates controlled sliding between the components. On the inner SHS profile, POM sheets measuring 30×20 mm are positioned at the ends, while corresponding POM inserts of the same dimensions are placed on the inner surfaces of the outer SHS profile. The construction of the sliding mechanism was tested with a physical mock-up using two SHS which can be seen in Figure 32.

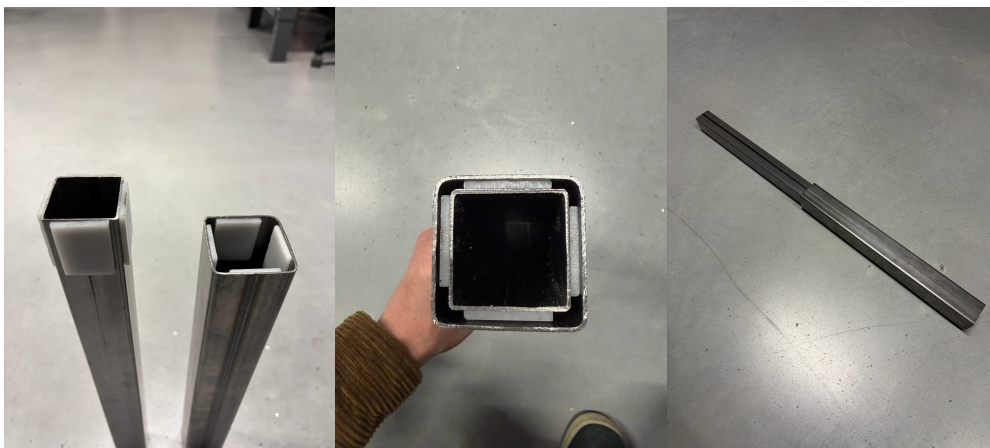
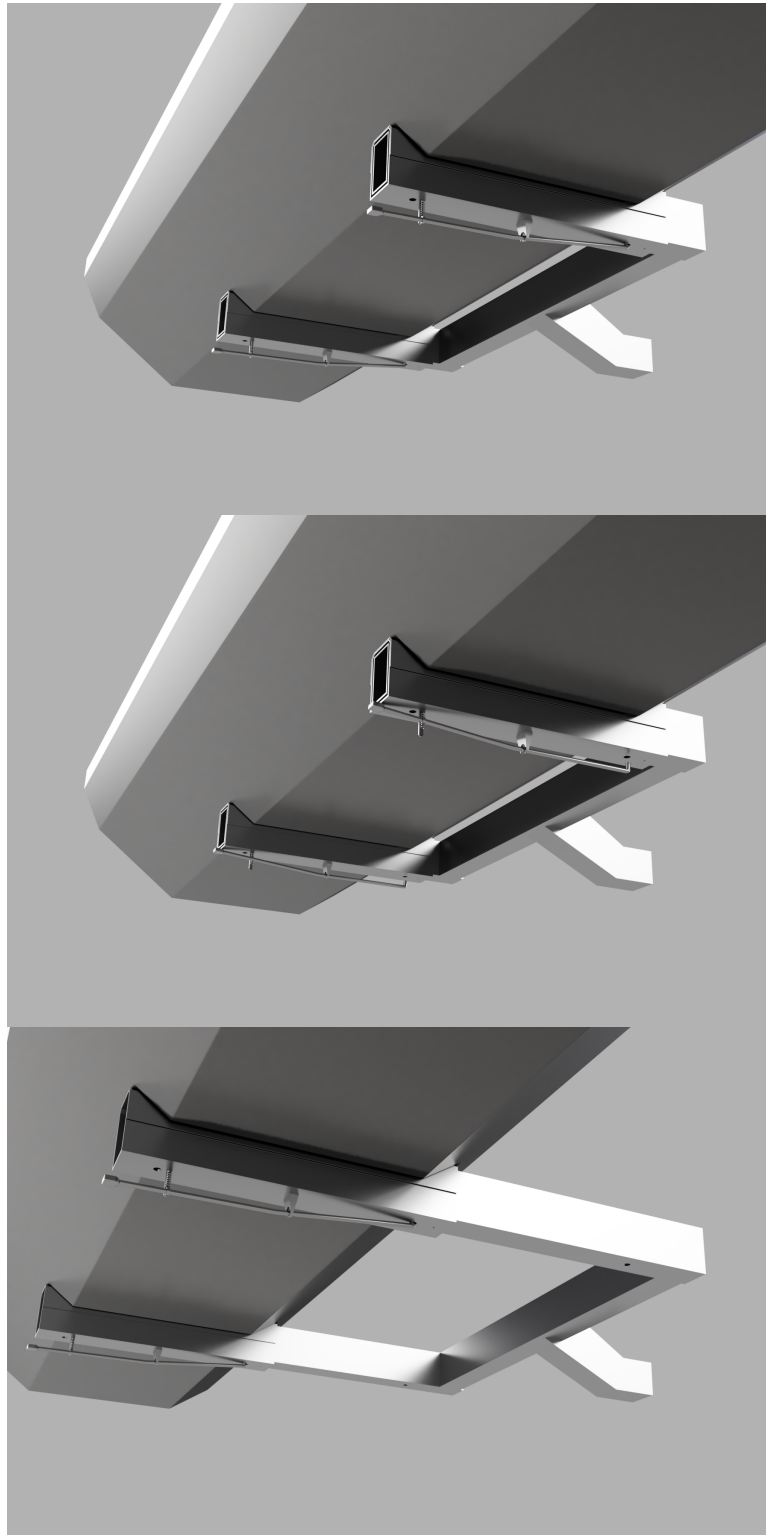


Figure 32: The slide mechanic was tested through a physical mock-up using two square tubes with glued on pieces of POM-plastic. (Author's own image)

To ensure functionality during vehicle operation, the telescoping SHS profiles must be securely locked both in the intended position and in the extended position. For this purpose, a latch-based locking system has been integrated (see Figure 33). The latches are accessible from the front side of the platform, positioned beneath the outer SHS profile. When the user

lifts the latch handles, they disengage spring-loaded pins from their corresponding holes, allowing the platform to be moved away from the vehicle. Upon releasing the handles and pushing the cargo box away from the vehicle, the latches automatically engage into a second set of holes located 280 mm from the initial position. This results in an increase in clearance of 280 mm between the vehicle and the cargo box (see Figure 34). To retract the box, the user again lifts the handles, slides the cargo box back to its original position, and allows the latches to re-engage in the corresponding holes.



*Figure 33: Render of proposed latch-system to lock the platform in two different positions.
1st position: Latches locked in retracted position.
2nd position: Latches disengaged.
3rd position: Latches locked in extended position.
(Author's own image)*



Figure 34: Illustration of the increased space between the car and the box facilitated by the new slide function, with a person standing in between as reference. (Author's own image)

In addition to facilitating access to the trunk, the increased clearance provides additional space for connecting the light-transmitting cable. To accommodate the varying distance between the vehicle and the cargo box, the original cable has been replaced with a coiled cable. The coiled cable can extend up to 1.5 m, allowing connection while the cargo box is in the extended position. When the box is returned to its intended position, the cable retracts automatically and adjusts its length accordingly. This ensures that no excess cable remains hanging between the vehicle and the cargo box, while still providing sufficient reach when extended clearance is required.

The final feature introduced to facilitate the usage phase is an interior storage pocket designed to accommodate both the instruction manual and the securing straps. The pocket is manufactured from a water-resistant material, ensuring that the contents remain dry even if wet luggage is loaded into the cargo box. The pocket is closed with a zipper and is attached to the interior of the box using Velcro, allowing it to be easily removed if required.

5.3 Single individual mounting

Single-person mounting was identified as one of the most important functions to address. Although this function was later removed as an explicit item in the function analysis, based on the assumption that it would be implicitly achieved through the resolution of other functions. All newly developed features (see Sections 5.2.1 and 5.2.2) have been designed with the

intention that a single user should be able to maneuver, mount, use, and dismount the cargo box independently.

The integrated spirit level on the platform enables a single user to correctly position the platform onto the towbar without assistance. Instead of tightening the handle and repeatedly stepping away from the platform to visually assess its alignment, correct positioning can be achieved immediately. As seen in Figure 35, the spirit level can be clearly seen from the user's position. Although the platform is relatively heavy (9 kg), somewhat unbalanced and requires the user to adopt a posture involving a curved back, the purpose of the spirit level is to make the installation process both easier and more efficient. This reduces the duration for which the user must maintain physically demanding postures.



Figure 35: The spirit level can be easily seen from the user's perspective. (Author's own image)

The wheels integrated into the cargo box further support single-person handling by facilitating both transportation and mounting. Rather than lifting the 22 kg cargo box, the user can roll it from the storage area directly to the vehicle, significantly reducing the required physical effort. Once at the platform, the user can roll the box into position and gently lower it onto the platform (see Figure 36). Previously, this step involved a heavy and ergonomically unfavorable lift, which was eliminated through the introduction of the wheels mounted on one side of the box.



Figure 36: Series of pictures illustrating how the wheels allow the user to lay the box on the platform instead of lifting it. (Author's own image)

After aligning the platform with the grooves on the underside of the cargo box, the user can open the lid to access the latch system used to secure the box to the platform. The user pulls out the two latches on one side and moves the box slightly back and forth until the spring-loaded latches align with their corresponding holes in the platform. The same procedure is then repeated on the opposite side. Once all four latches have engaged with their respective holes, the cargo box is securely mounted, and the lid can be closed.

With the cargo box attached to the platform, the user can lift the latches located on the front side of the platform, beneath the cargo box, to increase the clearance between the vehicle and the box. This extended position simplifies connection of the light-transmitting cable. The user can easily release the connector from the redesigned, more stable holder, and extend the cable to the socket located near the towbar. While the cargo box is in the extended position, the vehicle's trunk can also be loaded without obstruction. After loading the trunk, the user can retract the cargo box to its intended position using the same latch mechanism. The cargo box can then be loaded, and the contents secured using the securing straps stored in the interior pocket.

When dismounting the cargo box, the latches are disengaged while the unit is shifted slightly away from the vehicle to prevent re-engagement with the corresponding holes. The box can then be tilted laterally towards the wheels until it clears the platform interface. Once released from the platform, the box may be rolled away for subsequent storage.

5.3.1 Ergonomics

The same ergonomic assessment methods that were previously used to evaluate single-person and multiple-person mounting of the original product were applied to assess single-person mounting of the final concept. This enabled a direct comparison of ergonomic risks between the original design and the proposed solution.

PEPA

To evaluate the ergonomic performance of the final concept using the PEPA matrix, the same scenario definition as in the previous assessment was applied. As in the initial PEPA analysis, the intended user was defined as a middle-aged man (40-45 years old) with an average body build. The environmental conditions were also kept consistent with the previous analysis, assuming outdoor use at dusk with an ambient temperature of -2 °C.

The results of the PEPA assessment indicate that the final concept requires the user to perform a greater number of individual steps before the cargo box is fully installed. However, several sequences that previously received high scores were assigned lower scores in the assessment of the final concept. This suggests that although the overall process includes more distinct sequences, the physical load and required effort for each sequence have been reduced. Some sequences remain unchanged and still require relatively high effort. The sequences with the highest load classifications (*H*) were identified as transporting the platform and lifting it onto the towbar (see Figure 37).

User:	Middle aged man, 40-45 years old, average body built
User-scenario:	Dusk, outdoors, -2 degrees

Installation of towbar mounted cargo box													
Physical Ergonomics Product Assessment (PEPA)	Transport platform from storage to vehicle	Roll cargo box from storage to vehicle	Lift the platform onto the towbar	Align the platform	Tighten and press down the handle	Lower the cargo box onto the platform	Open Cargo Box	Pull out latches	Find corresponding holes	Close cargo box	Extend platform	Connect light transmitting cable	Retract platform
(1) Handling (holding, moving, impulse, catching)	Holding, moving	Holding, moving	Holding, moving	Holding	Impulse	Holding, moving	Moving	Moving	Moving	Moving	Moving	Moving	Moving
(2) Strength	H	L	H	M	H	L	L	L	L	L	M	L	M
(3) Precision	L	L	M	M	L	H	M	L	H	M	L	H	L
(4) Endurance	M	L	L	L	L	M	L	L	M	L	L	L	L
(5) Grip	H	M	H	M	L	M	L	L	L	L	M	L	M
(6a) Neck	L	L	L	M	L	M	L	L	M	L	L	L	L
(6b) Shoulders	H	M	H	L	M	M	L	L	L	L	L	L	L
(6c) Arm/ Elbow	H	M	M	M	H	M	M	L	M	M	L	M	L
(6d) Hand/ wrist	H	M	H	M	H	M	M	L	L	M	L	M	L
(6e) Fingers	H	M	M	M	M	M	H	L	L	L	M	M	M
(6f) Back	H	L	H	M	M	M	M	M	M	M	M	M	M
(6g) Legs/ knees	M	L	H	M	M	L	L	L	L	L	M	M	M
(6h) Foot/ ankle	M	L	H	L	L	L	L	L	L	L	M	M	M
(7) External circumstances	Possibly tight space	Possibly tight space	-	Dark	-	-	-	-	-	-	-	-	-

Figure 37: PEPA assessment of single-person installation of the final concept.

REBA

The most physically demanding posture selected for evaluation using the REBA assessment was observed during the mounting process of the cargo box (see Figure 38). In Score A, which includes assessment of the neck, trunk, and legs, the posture received a score of 4. In Score B, which includes evaluation of the arms, wrists, and coupling, the posture received a score of 7.

These values resulted in a total REBA score of 7 in Table C, indicating a *medium risk* level. According to the REBA assessment guidelines, a medium-risk score suggests that the task

should be further investigated and that changes should be implemented in the near future. A detailed breakdown of the assessment and individual scoring categories is provided in Figure 39.



Figure 38: Picture of most demanding posture during mounting of final concept. (Author's own image)

ERGONOMICS PLUS

REBA Employee Assessment Worksheet

Task Name: - Mounting
- 1 person
- NY product

Date: 13/5-26

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

 Step 1a: Adjust...
 If neck is twisted: +1
 If neck is side bending: +1
Neck Score: 3

Step 2: Locate Trunk Position

 Step 2a: Adjust...
 If trunk is twisted: +1
 If trunk is side bending: +1
Trunk Score: 1

Step 3: Legs

 Adjust: 30-60° Add +1, >60° Add +2
Leg Score: 1

Step 4: Look-up Posture Score in Table A
 Using values from steps 1-3 above, Locate score in Table A
Posture Score A: 3

Step 5: Add Force/Load Score
 If load < 11 lbs.: +0
 If load 11 to 22 lbs.: +1
 If load > 22 lbs.: +2
 Adjust: If shock or rapid build up of force: add +1
Force / Load Score: 1

Step 6: Score A, Find Row in Table C
 Add values from steps 4 & 5 to obtain Score A.
 Find Row in Table C.
Score A: 4

Scoring
 1 = Negligible Risk.
 2-3 = Low Risk. Change may be needed.
 4-7 = Medium Risk. Further Investigate. Change Soon.
 8-10 = High Risk. Investigate and Implement Change
 11+ = Very High Risk. Implement Change

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

 Step 7a: Adjust...
 If shoulder is raised: +1
 If upper arm is abducted: +1
 If arm is supported or person is leaning: -1
Upper Arm Score: 4

Step 8: Locate Lower Arm Position:

Lower Arm Score: 2

Step 9: Locate Wrist Position:

 Step 9a: Adjust...
 If wrist is bent from midline or twisted: Add +1
Wrist Score: 2

Step 10: Look-up Posture Score in Table B
 Using values from steps 7-9 above, locate score in Table B
Posture Score B: 6

Step 11: Add Coupling Score
 Well fitting Handle and mid rang power grip: **good: +0**
 Acceptable but not ideal hand hold or coupling acceptable with another body part: **fair: +1**
 Hand hold not acceptable but possible: **poor: +2**
 No handles, awkward, unsafe with any body part, **Unacceptable: +3**
Coupling Score: 1

Step 12: Score B, Find Column in Table C
 Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.
Score B: 7

Step 13: Activity Score
 +1 1 or more body parts are held for longer than 1 minute (static)
 +1 Repeated small range actions (more than 4x per minute)
 +1 Action causes rapid large range changes in postures or unstable base

Table A: Neck

	1				2				3			
Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture	1	2	3	4	1	2	3	4	1	2	3	4
Score	1	2	3	4	1	2	3	4	1	2	3	4

Table B: Lower Arm

	1			2		
Wrist	1	2	3	1	2	3
Upper Arm	1	2	3	1	2	3
Score	1	2	3	1	2	3

Table C

Score A	Score B											
	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	1	2	3	3	4	5	6	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	10	10	11	11	11	11
8	8	8	8	9	10	10	10	10	11	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	11	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score: 7 + Activity Score: 0 = REBA Score: 7

Figure 39: REBA assessment of a body posture that occurred during single-person mounting of the final concept.

6 Discussion

This section discusses the methods and processes that contributed to the development of the project's final concept. It critically reflects on the advantages and limitations of selected methods used throughout the project, as well as how these methods were applied during the different project phases.

The discussion is structured around the initial, middle, and final phases of the project and examines how methodological choices influenced the results. In addition, the final concept is discussed from both sustainability and ethical perspectives, including underlying assumptions and constraints that may have affected the project outcomes.

6.1 Initial phase

During the initial phase of the project, information was gathered through a user study employing several complementary methods. These methods were considered appropriate for the scope of the project, as the overall aim was to gain an in-depth understanding of how the Arcos XL can be further developed to increase customer value. Consequently, it was important to collect both quantitative data and qualitative insights, allowing users to interact with the cargo box in realistic usage contexts.

6.1.1 Quantitative method

To collect quantitative data and reach a broad range of respondents, a survey was conducted. The intention was to target individuals who were familiar with the Arcos XL or other rear-mounted cargo solutions. However, the majority of respondents had experience primarily with roof-mounted cargo boxes rather than rear-mounted alternatives. While this limited the extent to which direct feedback on rear-mounted cargo boxes could be obtained, it also provided valuable insights into common disadvantages associated with roof-mounted solutions. These insights were useful in the development of the Arcos XL, as they highlighted features and characteristics that should be avoided in future design iterations.

In total, 28 respondents completed the survey. Although a larger sample size would have increased the statistical robustness and credibility of the findings, the responses received showed a high degree of consistency. This consistency suggests that the results are indicative

of shared user experiences and perceptions, thereby providing a reasonable level of credibility despite the limited number of respondents.

6.1.2 Qualitative methods

To target more specific user groups and gain insight into how users interact with the Arcos XL, several qualitative methods were employed, interviews, observations, and user tests among others. These methods made it possible to capture behavioral patterns, instinctive reactions, and subjective experiences, thereby providing a solid foundation for the continued development of the product.

However, as with the survey, the number of participants involved in the qualitative methods was relatively limited. This implies that the perspectives collected may not fully represent the entire customer base. Nevertheless, different participants were involved across the various qualitative methods, which increased the breadth of perspectives. Moreover, many of the insights and opinions expressed by participants showed a high level of consistency across methods. This consistency strengthens the credibility of the findings and suggests that the identified issues and user needs are likely representative of a broader group of Arcos XL users.

6.2 Middle phase

During the middle phase of the project, the data collected from the user study were analyzed using several different methods. Some of these methods are well-established and familiar both to the researchers and within the product development field, while others (such as the RICE-model) were new to the researchers prior to this project.

This phase also included idea generation and concept creation, followed by evaluation of the proposed solutions. The present section discusses the less familiar analysis methods used during this phase, as well as the advantages and limitations of how the different solutions were evaluated through proof-of-concept testing.

6.2.1 Analysis of the result

One of the methods used to analyze the collected data was the RICE-model. The RICE-model is a prioritization tool commonly used by product development teams to compare and prioritize functions or solution alternatives. In this project, the model was applied specifically to prioritize identified functions.

One advantage of the RICE-model is its ability to structure and condense a large amount of data into a clear and widely recognized decision-making framework. This enables developers to systematically compare multiple functions based on defined criteria. However, a limitation of the model is that the evaluation relies heavily on subjective judgments made by the researchers. Since each function is scored based on estimated values, there is an inherent risk of bias. Researchers may unintentionally assign higher or lower scores based on personal preferences, which could result in certain functions being prioritized over others, while important customer needs risk being overlooked.

When the RICE-model was applied in this project, efforts were made to minimize such bias. At the time of evaluation, the researchers had not yet begun the idea-generation phase and had not developed any predefined solution concepts. This reduced the risk of favoring specific functions and contributed to a more neutral and objective scoring process.

6.2.2 Concept creation and evaluation

To generate innovative solutions for the identified functions, brainstorming and brainwriting were employed during the idea generation phase. As a result, each function was represented by multiple solution alternatives at the end of the idea-generation phase, enabling comparative evaluation between different approaches. However, the time allocated to this phase was limited, which may be considered a limitation. There is a possibility that not all potential ideas were explored to their full extent. Some functions received more attention during idea generation, resulting in a larger number of proposed solutions, while others were explored more briefly. This imbalance raises the question of whether additional time spent on less-explored functions might have resulted in alternative or more effective solutions.

Nevertheless, the solutions generated were relevant to the scope of the project and addressed the identified functions in different ways.

To evaluate the proposed solutions and support concept selection, several proof-of-concept tests were conducted. This involved constructing mock-up models and testing them on the physical product where possible. All solutions included in Concepts A, B, C, and D were evaluated using different testing approaches in order to assess their feasibility and contribution to overall concept performance. However, certain solutions proved difficult to test due to challenges in creating sufficiently realistic mock-ups or integrating them into the physical product. As a result, some solutions were evaluated primarily through visualization and theoretical reasoning.

This type of evaluation provides a lower level of validation compared to physical testing with mock-ups, making the assessment more uncertain. Consequently, there is a risk that some solutions may have been excluded prematurely, despite having potential merit. With additional time and resources, enabling all solutions to be evaluated through physical mock-ups, a more comprehensive and reliable comparison could have been achieved.

6.3 Final phase

The final phase of this project consolidates findings from the previous stages into a single final concept that specifically addresses the challenge of single-person mounting. The concept integrates solutions intended to reduce physical effort, improve handling, and simplify the mounting and dismounting process.

By combining newly introduced features that support maneuverability, clearer positioning, and improved interaction between the cargo box and the platform, the final concept demonstrates how single-person mounting can be made more feasible. Rather than relying on a single design intervention for each function, the concept addresses the challenge through a set of coordinated solutions that together reduce ergonomic strain and enhance usability. As such, the final phase represents a synthesis of user-identified needs and informed design decisions.

6.3.1 Final concept

The objective of this project was to develop and present a conceptual proposal for how the cargo box could be designed to allow a single person to independently mount and dismount it

from the vehicle. Consequently, all newly integrated features were developed with this objective as a guiding principle.

The implemented features address the most frequently identified user problems related to the Arcos XL. The wheels mounted on the side of the cargo box address challenges associated with transportation and mounting. The extendable platform addresses issues related to limited clearance between the vehicle and the cargo box, which previously affected trunk access and connection of the light-transmitting cable. Additional implemented solutions further address the identified problem areas while being designed to function cohesively as an integrated system. Overall, the researchers consider the final concept to be well-substantiated and to meet the expectations of the project stakeholders, including Thule and the end users.

However, due to time constraints, the researchers were unable to reconnect with participants from the initial user study after the final concept had been developed. As a result, the project cannot present empirical user feedback regarding the newly proposed features. To fully evaluate the final concept and validate its effectiveness, follow-up studies involving the original participants (or a broader user group) would be required. Nevertheless, based on the findings from earlier phases and the identified user needs, the researchers are confident that the proposed features would be positively received by users.

6.3.2 Single-person mounting

As discussed in the previous section, all newly implemented features in the final concept were developed with the objective of enabling single-person mounting. The final concept and its associated features were designed under the assumption that an average-built individual, independent of gender, body weight, and prior experience, should be able to mount, use, and dismount the Arcos XL without assistance.

However, single-person mounting is not feasible for all potential users. Individuals who are shorter in stature, have reduced muscle strength, or experience mobility impairments may still encounter significant difficulties during the mounting process. These limitations highlight that, while accessibility has been improved, the final concept does not fully accommodate all user groups. Ethical considerations related to inclusivity and accessibility are further discussed in Section 6.5.

The objective of enabling single-person mounting was a specific request from Thule. During the user study, several participants emphasized the value of being able to mount the cargo box independently, without relying on assistance from a second person. Participants highlighted that single-person mounting would increase flexibility and independence in everyday use. With the implementation of the proposed features, single-person mounting has become possible, thereby enhancing the usability of the product beyond its basic functional purpose.

In its original design, the Arcos XL required multiple heavy lifts as well as a combination of precision, strength, and flexibility. In the final concept, most heavy lifting has been eliminated, with the exception of handling the platform. Nevertheless, the mounting process still demands precision and the coordination of several actions. For example, one side of the cargo box must be lifted while the box is simultaneously rolled toward the platform and guided into the alignment grooves. The introduction of more visually prominent grooves is intended to facilitate this step; however, it remains a physically and cognitively demanding operation that places requirements on the user.

To enable single-person mounting, certain components of the original design have been replaced, while others have been added. For instance, the original light-transmitting cable has been replaced with a coiled cable, and wheels mounted on the side of the cargo box have been introduced as additional components. As a result, the final concept exhibits increased mechanical complexity, which is likely to lead to higher manufacturing costs and longer production times. Despite this, the researchers consider the added complexity to be justified by the increased customer value, improved usability, and greater independence afforded to the user.

6.3.3 Ergonomic aspects

To evaluate whether the mounting, usage, and dismounting phases of the Arcos XL have become easier and more ergonomic, ergonomic assessment methods were applied to both the original design and the final concept.

Two REBA assessments were conducted. For the original design, the most demanding posture was identified during single-person dismounting of the cargo box. For the final concept, the most demanding posture occurred during the mounting process. The posture associated with

the original design resulted in a total REBA score of 12, corresponding to a *very high risk* level, for which immediate changes are recommended. In contrast, the most demanding posture associated with the final concept resulted in a total REBA score of 7, corresponding to a *medium risk* level, indicating that further investigation is required and that changes should be implemented in the near future.

These results demonstrate a substantial reduction in ergonomic risk between the original design and the final concept. The REBA score decreased by five points, from a very high risk level to a medium risk level. Although a medium risk classification indicates that the posture still presents an ergonomic concern, the lower score suggests that handling the final concept is significantly less demanding and hazardous than handling the original design. The reduction in risk can be attributed to the newly introduced features, which reduce physical load and improve handling during the most demanding phases of use.

To further evaluate the ergonomic aspects of handling and maneuvering both the original design and the final concept, a PEPA assessment was conducted. In the initial PEPA assessment, which analyzed single-person mounting of the original product, the sequences associated with the highest physical effort and load were transportation of the cargo box between the storage area and the vehicle, lifting the platform onto the towbar, and lifting the cargo box onto the platform.

In the subsequent PEPA assessment of single-person mounting of the final concept, the sequences associated with the highest effort and load were limited to transporting the platform from the storage area to the vehicle and lifting it onto the towbar. This indicates that several of the previously most demanding processes have been significantly reduced in terms of physical effort and load.

However, the single-person mounting process of the final concept involves a greater number of individual steps before the cargo box and platform are fully installed. Despite this, the reduction in physical demand during the most strenuous sequences appears to compensate for the increased number of steps. Overall, the PEPA results suggest that the final concept shifts the workload from fewer highly demanding tasks to a larger number of less physically strenuous actions, thereby improving the ergonomic profile of the mounting process.

6.3.4 Further development

As stated previously, the outcome of this project is a conceptual proposal. Consequently, the work does not include finalized technical drawings or verified manufacturing processes for the newly introduced features. Material selections and manufacturing approaches are therefore presented as well-grounded suggestions rather than validated solutions. As a result, further development and engineering refinement would be required prior to any potential implementation, particularly since cost considerations were not included within the scope of this project. These aspects would be critical if Thule were to further develop or implement any of the proposed solutions.

Some of the newly introduced features require less additional development than others. Components such as the miniature spirit level, the coiled cable, and the tool-clamp holder are based on existing solutions and technologies. As a result, these features may not require extensive further development, although their placement and detailed design would need to be adapted and validated in relation to the final product.

In contrast, the extendable platform represents a feature that requires substantial further development. Although inspiration has been drawn from existing solutions, the redesigned platform is not an off-the-shelf component. To validate its functionality, durability, and safety, the platform would need to be manufactured and tested under realistic conditions. Within the scope of this project, the platform was only subjected to limited loading during testing, which does not correspond to realistic operational loads. Consequently, there is no guarantee that the platform and its adjustable offset function would perform reliably when exposed to the full weight of the cargo box, both in loaded and unloaded conditions.

Furthermore, the extendable platform would need to be tested under varying environmental conditions, such as rain, snow, and dirt exposure. Particular attention should be given to how contaminants affect the interaction between the telescopic square hollow sections (SHS), as debris or moisture could impair functionality or increase wear.

The extendable platform relies on spring-loaded latches to secure the platform in both its intended and extended positions. These latches have only been evaluated in a CAD

environment and have not been physically tested under load or exposed to different weather conditions. In addition, if the platform were to be implemented in a production-ready product, the latch mechanism would need to undergo crash testing at various speeds to comply with safety requirements. Such testing was beyond the scope of this project but would be essential prior to real-world implementation.

Finally, additional safety aspects should be considered in future development, including the risk of finger pinching during platform extension and the general risk of injury during handling of the cargo box and platform. Addressing these aspects would be necessary to ensure both regulatory compliance and safe user interaction.

6.4 Sustainability aspects

In the current global context, consumption patterns in many industrialized countries exceed what the planet can sustainably support. As a result, existing behaviors and practices must be critically examined to minimize their environmental impact. Overconsumption is one factor that contributes significantly to environmental degradation, which places increased responsibility on how products are designed, manufactured, used, and disposed of.

From a sustainability perspective, it is therefore essential to consider the environmental impact of a product throughout its life cycle, including material selection, manufacturing processes, and end-of-life handling. The Arcos XL is a product designed for long-term use; however, it contains a substantial amount of plastic and is directly associated with vehicle-based transportation, which is inherently linked to energy consumption and emissions. This section discusses the environmental implications of the material choices used in the Arcos XL, as well as the climate impact associated with the product during its use phase.

6.4.1 Material impact

The shell of the Arcos XL is primarily manufactured from UV-protected ABS plastic. ABS offers several advantages due to its durability and resistance to impact, mechanical stress, and harsh environmental conditions. However, from a sustainability perspective, the use of ABS plastic also presents several disadvantages that may negatively affect the environment.

Recycling ABS plastic can be challenging, as the material consists of a combination of polymers along with various additives and potential contaminants. These factors complicate separation and recycling processes. On the other hand, the material's durability contributes to a long product lifespan, which can partially offset its environmental impact. Thule provides a five-year warranty for its bicycle carriers and cargo boxes, although many of these products remain functional for considerably longer periods.

If a cargo box remains in use for 20 years or more, the environmental impact associated with the material choice may be mitigated by the reduced need for replacement products. In such cases, extended product longevity can compensate for the environmental costs of production by lowering overall material consumption and waste generation over time.

6.4.2 Climate impact during use

The Arcos XL cargo box is intended to be used in combination with a vehicle, with the primary purpose of extending the vehicle's available cargo space. The need for additional cargo capacity is often associated with longer trips or journeys that require more equipment, which in turn may result in increased environmental impact. However, this impact is largely related to the nature of the trip itself rather than the cargo box alone.

The cargo box can be used in combination with both fuel-powered and electric vehicles. In both cases, it is important that the cargo box does not significantly increase fuel consumption or reduce driving range. As presented in the theoretical framework (Section 2.1.4), roof-mounted cargo boxes can have a substantial negative impact on the driving range of electric vehicles due to increased aerodynamic drag. In contrast, rear-mounted cargo boxes, such as the Arcos XL, do not have the same aerodynamic effect.

According to studies provided by Thule, the use of a rear-mounted cargo box on an electric vehicle can result in an increased driving range of approximately 5 km, which represents a positive outcome from a climate perspective. The newly introduced features are not expected to negatively affect the driving range of electric vehicles and are assumed to perform similarly to the original design in this regard.

The modifications made to the platform are likely to increase its weight, as the redesigned structure incorporates telescoping square hollow sections (SHS). As a result, the platform weight is expected to increase from approximately 9 kg to around 12 kg. It remains uncertain whether this additional weight will have a measurable effect on vehicle driving range. However, given the relatively small increase in mass, it is considered unlikely that the impact on energy consumption or driving range would be significant.

6.5 Ethical aspects

The Arcos XL cargo box may not be suitable for all users due to its relatively high weight and large dimensions, which can pose challenges during transportation and installation. Nevertheless, compared to other cargo solutions (such as roof-mounted cargo boxes) the Arcos XL has the potential to accommodate a broader range of users by positioning the load at a lower and more accessible height.

In its original design, the Arcos XL is difficult, and in some cases nearly impossible, to use for individuals with certain disabilities. Users who rely on a wheelchair, have reduced grip strength, or experience limitations in bending and general mobility may encounter significant difficulties when transporting and installing the original cargo box. The requirement to lift the cargo box during handling and mounting presents a physical challenge not only for users with disabilities but also for many able-bodied users, given the product's weight and bulky proportions. For individuals with reduced physical strength, these challenges are further amplified.

The redesigned Arcos XL presented in the final concept (see Chapter 5) incorporates features intended to include a wider range of potential users. Although the new features improve usability, certain installation steps remain challenging for users with limited mobility. The integration of wheels on the underside of the cargo box significantly reduces the need for lifting and enables easier transportation. For a wheelchair user, the wheels allow the cargo box to be maneuvered alongside the wheelchair by gripping the shorter end of the box. Similarly, users with reduced muscle strength may be better able to transport the cargo box independently due to the reduced physical effort required.

Furthermore, the mechanism that allows increased clearance between the vehicle and the cargo box facilitates both loading and unloading of the vehicle's trunk and connection of the light-transmitting cable. Although the available space remains limited, the increased clearance provides the user with greater freedom of movement during these tasks. While connecting the light-transmitting cable still requires a certain degree of mobility and fine motor skills, the additional space makes the process more manageable compared to the original design.

Despite these improvements, the installation process remains demanding for users who rely on a wheelchair or have severely limited mobility. Lifting one side of the cargo box high enough to position it onto the platform, as well as bending into the cargo box to operate the spring-loaded latches, may still be infeasible for some users. However, once the cargo box is mounted onto the platform, loading, and unloading become considerably more accessible. Due to the relatively low mounting height, many users (regardless of disability) are able to load and unload the cargo box without assistance.

Certain features in both the original and redesigned Arcos XL are not specifically adapted for users with disabilities. For example, the slide-lock mechanism used to open and lock the cargo box requires a relatively high level of finger strength. Additionally, connecting the light-transmitting cable to the towbar requires the user to work close to the ground and to possess adequate fine motor skills, which may present challenges for some individuals.

When comparing the Arcos XL (both in its original and redesigned versions) with alternative cargo solutions such as roof-mounted cargo boxes, several ethical advantages emerge. Roof-mounted cargo boxes generally have a similar weight to the Arcos XL but require lifting the load above shoulder height during installation, which is infeasible for many users. Furthermore, loading and unloading a roof-mounted cargo box often necessitates the use of a step, ladder, or the vehicle's door sill, increasing physical strain and risk. These limitations highlight that the Arcos XL offers a more accessible solution for users with movement-related disabilities.

Although the redesigned Arcos XL could be further developed to include an even wider range of users, the implemented features significantly improve accessibility and usability for many

individuals. As a result, the potential user group has been expanded, even though the product does not fully accommodate all users.

6.6 Usage of AI

To support the writing process, Microsoft Copilot was used as a complementary tool for language editing and formulation suggestions. The tool assisted in enhancing readability and ensuring a consistent academic tone throughout the report. However, Copilot did not generate or influence the substantive content of the report; all decisions regarding the content were made independently by the authors.

6.7 Conclusion

The objective of this report was to develop and present a conceptual design proposal that enables single-person mounting, usage, and removal of the Arcos XL cargo box. The discussion has focused on how the development process and the resulting final concept address this challenge, as well as on the methods that contributed to the outcome. The applied methods provided a solid foundation for identifying user needs and guiding the concept development process; however, limitations related to time, implementation, and evaluation should be acknowledged.

The final concept demonstrates that it is possible for a single individual to manage the mounting, usage, and dismounting phases of the Arcos XL through a set of cohesive and well-integrated design solutions. Rather than relying on a single intervention, the concept shows how coordinated features can collectively facilitate single-person handling and improve overall usability. Nevertheless, the concept does not accommodate all potential users, as individual physical conditions and capabilities vary. Despite this limitation, the introduced features are aimed at expanding the user group compared to the original design.

From a sustainability perspective, the final concept incorporates materials that may have a negative environmental impact, particularly due to the extensive use of plastics. However, the product is designed for long-term use, which may mitigate this impact by reducing the need for replacement over time. If the cargo box remains functional for many years, the

environmental cost of material use may be offset by increased product longevity and reduced consumption.

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8 Appendix

Appendix 1 - Survey



* Obligatoriskt

This form is part of a degree project at Chalmers University of Technology, in collaboration with Thule Sweden AB. The purpose is to investigate users' experiences and needs when using vehicle load carriers. Participation is voluntary and the survey is anonymous. No personal data that can identify you will be collected. You may withdraw your participation at any time by leaving the survey. The collected material will only be used for this degree project and will be handled in accordance with current data protection legislation (GDPR). If you have any questions regarding the study, please contact us via email: carba@chalmers.se / loviasv@chalmers.se

Thank you for taking the time to help us!

How old are you? *

- ☐ 18-29
- ☐ 30-49
- ☐ 50-69
- ☐ 70+
- ☐ Prefer not to say

What type of cargo box do you have experience with? *

- ☐ Towbar-mounted cargo box
- ☐ Roofbox
- ☐ Both types
- ☐ Neither

Experience of towbar-mounted cargo box

Below are a few questions for those of you who have previous experience using a towbar-mounted cargo box.

How often do you use your towbar-mounted cargo box? *

- ☐ Weekly
- ☐ Monthly
- ☐ Seasonal
- ☐ Yearly
- ☐ Less often

What is the primary activity you use the box for? *

(Multiple answers possible)

- ☐ Vacation
- ☐ Family trips
- ☐ Transport of sports-gear
- ☐ Transport of big items
- ☐ Annat

Which factors made you choose a towbar-mounted cargo box? *

(Multiple answers possible)

- ☐ Easier to load/unload
- ☐ Easier to mount compared to a roofbox
- ☐ Better fuel consumption compared to a roofbox
- ☐ Less noise from wind
- ☐ No roof rails
- ☐ Annat

How pleased are you with your towbar-mounted cargo box? *



Is there anything you find negative about towbar-mounted cargo boxes?

For e.g. problems with mounting, lock, vibrations, sound....

How do you perceive the accessibility to the trunk with the box mounted on the towbar? *

Very bad	Bad	OK	Good	Very good
☐	☐	☐	☐	☐

How do you perceive the mounting process of a towbar-mounted cargo box? *

Very difficult	Difficult	Neither	Easy	Very easy
☐	☐	☐	☐	☐

How much do you think the towbar-mounted box affects the car's driving characteristics? *

Very much	Much	No difference	A little	Very little
☐	☐	☐	☐	☐

How do you perceive the stability of a towbar-mounted cargo box? *

Very unstable	Unstable	Neither	Stable	Very stable
☐	☐	☐	☐	☐

Other comments:

Experience of roof-mounted cargo box

Below are a few questions for those of you who have previous experience using a roof box.

How often do you use your roof box? *

- ☐ Weekly
- ☐ Monthly
- ☐ Seasonal
- ☐ Yearly
- ☐ Less often

What is the primary activity you use the box for? *

(Multiple choices possible)

- ☐ Vacation
- ☐ Family trips
- ☐ Transport of sports-gear
- ☐ Transport of big items
- ☐ Annat

Why do you use a roof box instead of a towbar-mounted cargo box? *

(Multiple choices possible)

- ☐ My car don't have a towbar
- ☐ Roofboxes are more flexible
- ☐ Habit / Always had
- ☐ More volume
- ☐ Annat

How pleased are you with the roof box? *



Is there anything you find negative about roof boxes?

For e.g. problems with mounting, lock, vibrations, sound...

How do you find the process of mounting the roof box? *

Very hard	hard	Neither easy or hard	Easy	Very easy
☐	☐	☐	☐	☐

To what extent do you feel the towbar-mounted cargo box affects the car's driving characteristics? *

Very much	Much	No difference	A bit	Very little
☐	☐	☐	☐	☐

Would you consider switching to / using a towbar-mounted cargo box? *

- ☐ Yes
- ☐ No

What would encourage you to switch to a towbar-mounted cargo box?

(Multiple choices possible)

- ☐ Lower price
- ☐ Better design
- ☐ More volume
- ☐ Better fuel consumption
- ☐ Easier mounting
- ☐ Higher safety
- ☐ Better recommendations
- ☐ Annat

Other comments:

Experience with both roof boxes and towbar-mounted cargo boxes

"Below are a few questions for those of you who have previous experience with both towbar-mounted cargo boxes and roof boxes

How often do you use a cargo box? *

- ☐ Weekly
- ☐ Monthly
- ☐ Seasonal
- ☐ Yearly
- ☐ Less often

What is the primary activity you use the box for? *

(Multiple choices possible)

- ☐ Vacation
- ☐ Family trips
- ☐ Transport of sports-gear
- ☐ Transport of big items
- ☐ Bigger cargo space
- ☐ Annat

Do you prefer a roof box or a towbar-mounted cargo box? *

- ☐ Towbar-mounted cargo box
- ☐ Roof box
- ☐ I don't prefer neither of them
- ☐ Depends on the situation

Why do you prefer that type of cargo box? *

(Flera svar möjliga)

- ☐ Easier to load
- ☐ More cargo space
- ☐ Less impact on fuel consumption
- ☐ Less noise from the wind
- ☐ Better access to the car boot
- ☐ Better driving characteristics
- ☐ More flexible and usable in different situations
- ☐ Annat

Is there anything you find negative about the other type of box?

(Multiple choices possible)

- ☐ Harder to mount
- ☐ Requires lifting above shoulder/head height
- ☐ Impacts fuel consumption too much
- ☐ Restricts visibility, light, or access to vehicle features
- ☐ Seems harder to store
- ☐ Annat

If you could keep one of them - which one would you keep? *

- ☐ Towbar-mounted cargo box
- ☐ Roof box
- ☐ Neither
- ☐ Unsure / Depends

Why would you choice that one?

No experience of using cargo boxes

Below are a few questions for those of you who do not have any previous experience using a vehicle cargo box.

Why do you not use a cargo box? *

(Multiple choices possible)

- ☐ I dont have the need of bigger cargo space
- ☐ I think they're too expensive
- ☐ I don't have roof rails / a towbar
- ☐ I want to avoid increased fuel consumption
- ☐ I'm unsure of safety
- ☐ I think they seem hard to mount
- ☐ I don't know what a cargo box is
- ☐ Annat

Have you considered using a cargo box? *

- ☐ Yes
- ☐ No
- ☐ Maybe

If yes, why didn't you buy one?

(Multiple choices possible)

- ☐ Cost
- ☐ Lack of space for storage
- ☐ Unsure of what type suits me
- ☐ My car is not compatible
- ☐ Seems inconvenient
- ☐ Annat

How do you solve your need for extra luggage space today? *

(Multiple choices possible)

- ☐ I adjust my luggage and bring less
- ☐ I use a trailer
- ☐ I put more luggage in the cabin
- ☐ I borrow equipment when i need
- ☐ I don't have the need of extra cargo space
- ☐ Annat

Do you have any other thoughts or reflections regarding the use of cargo boxes?

Closing questions

Have you considered switching to a different type of cargo box than the one you use today?

*

- ☐ Yes, to a towbarmounted cargo box
- ☐ Yes, to a roof box
- ☐ No
- ☐ Don't know

What would make you consider switching or upgrading your cargo box? *

(Multiple choices possible)

- ☐ Lower price
- ☐ More cargo space
- ☐ Easier mounting
- ☐ Better access to the cars boot
- ☐ Less wind resistance / fuel consumption
- ☐ Annat

Do you have any additional comments or experiences you would like to share?

Appendix 2 - Interview guide, Arcos User

Interview guide – Arcos User

Usage patterns

18. May we record?
19. Which model of the Arcos do you own?
20. How often do you use your Arcos, and in what types of situations?
21. What was the main reason you chose the Arcos specifically?

Mounting & handling

22. How do you experience the installation of the Arcos, both the platform and the box itself? What works well, and what works less well?
23. How does it feel in practice to handle the box's weight and size? Do you usually mount it on your own or together with someone?
 - When lifting?
 - When moving/carrying it?
 - When adjusting/alignment?
24. Have you encountered situations where the installation has been difficult or frustrating?

Packing & access

25. What do you typically pack in the box?
26. How do you experience the opening and access to the inside of the box?
27. How do you experience access to the car's tailgate/boot - does it work well, or do you find it inconvenient?

While driving

28. In your experience, has the box affected fuel consumption or the driving feel?
29. Are there situations (e.g., motorway driving, parking, winter roads) where the box works especially well or especially poorly?

Storage & handling when not in use

30. How do you store the Arcos L at home, and how does that work in practice?
31. What challenges have you experienced with storage or handling it outside the car?

Problems, frustrations & areas for improvement

32. What are the biggest problems or irritations you've experienced with the Arcos?
33. Are there any features you're missing or wish the box had?
34. If you could improve one or two things, what would make the biggest difference for you?

Future & value

35. Is there anything you think we should know in order to develop the next version of the box?

Appendix 3 – Interview guide, store staff

Interview questions for store staff and customers at Thule in Gothenburg

Store staff

1. What are the most common problems or objections you hear from customers who are looking at towbar-mounted cargo boxes?
2. Which parts of using the box (mounting, loading, driving, storage) do customers find the most troublesome?
3. Is there any feature or detail on today's boxes that customers are often dissatisfied with or question?
4. What seems to be the biggest reason customers decide not to buy, despite being interested?
5. What recurring questions or misunderstandings do you encounter about the box's function or use?
6. What types of complaints, returns, or support cases do you most often see related to the boxes?
7. Are there any specific situations where customers seem to run into problems after purchase (e.g., travelling, winter conditions, parking)?
8. How do customers experience the mounting process—does anything in the design often cause frustration?
9. Which aspects of handling (weight, size, grip, maneuvering) seem to create the most challenges?
10. What do customers describe as the biggest issues when storing the box when it's not in use?
11. Are there accessories or features that customers ask for spontaneously but that don't exist today?
12. Which features or characteristics do you think would solve the most problems for customers?
13. If you could improve three things about today's towbar-mounted cargo boxes—what three things would you choose, and why?

Appendix 4 – KJ

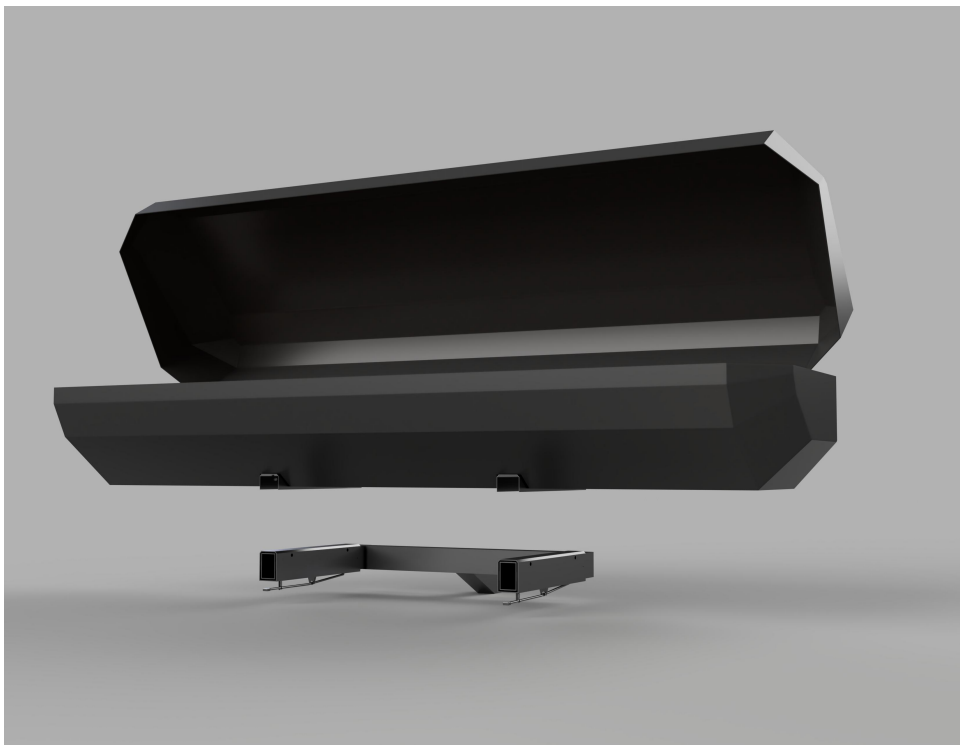
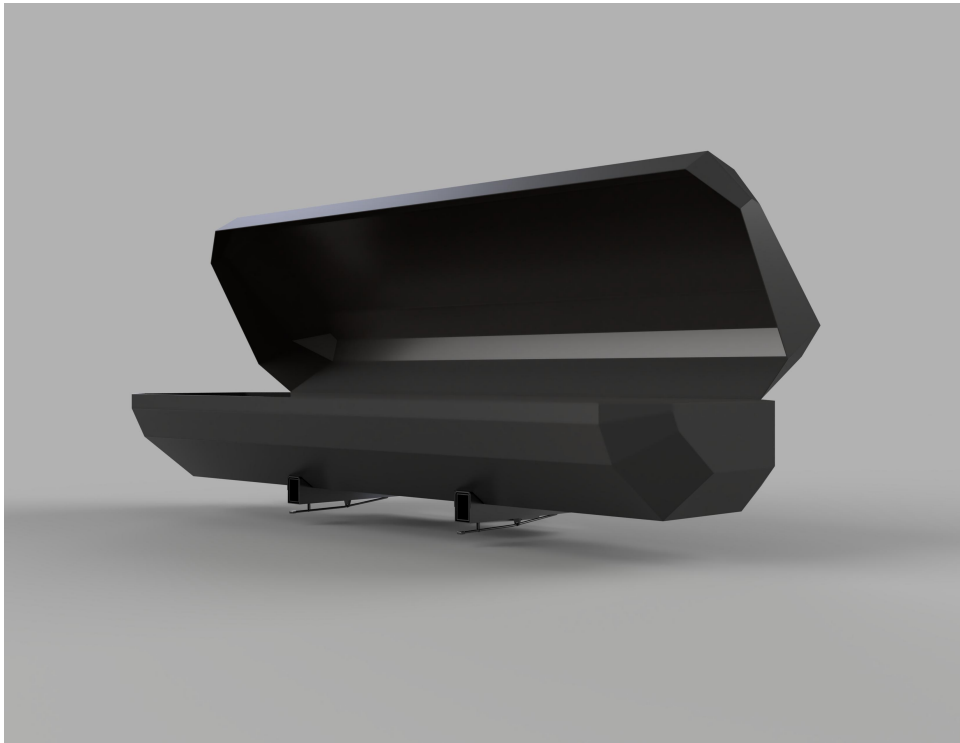


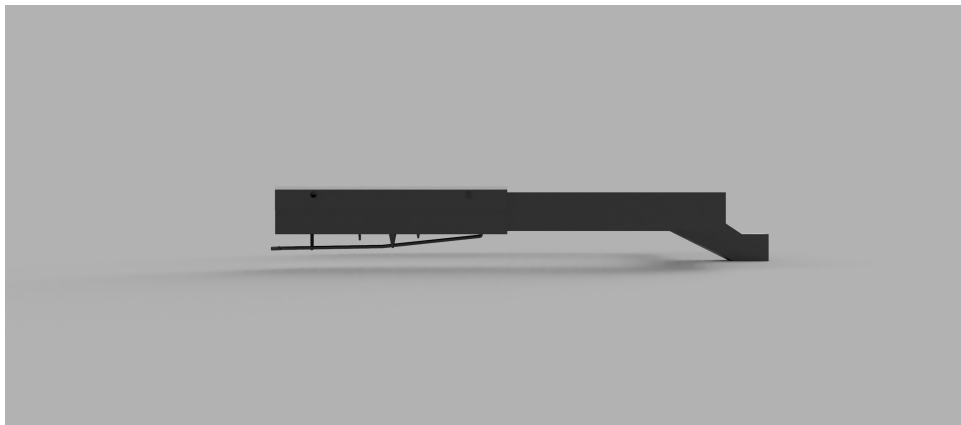
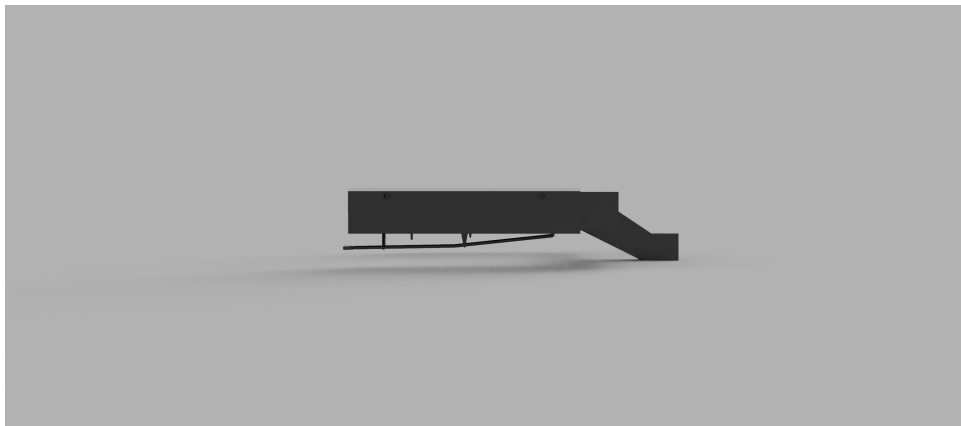
Appendix 5 – PMI

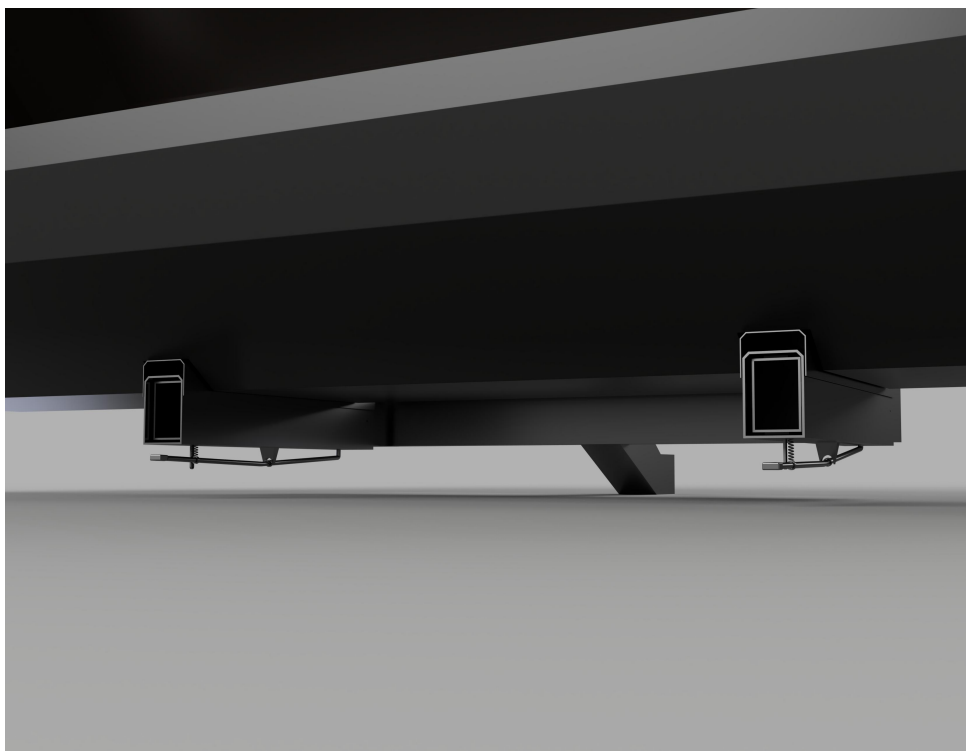
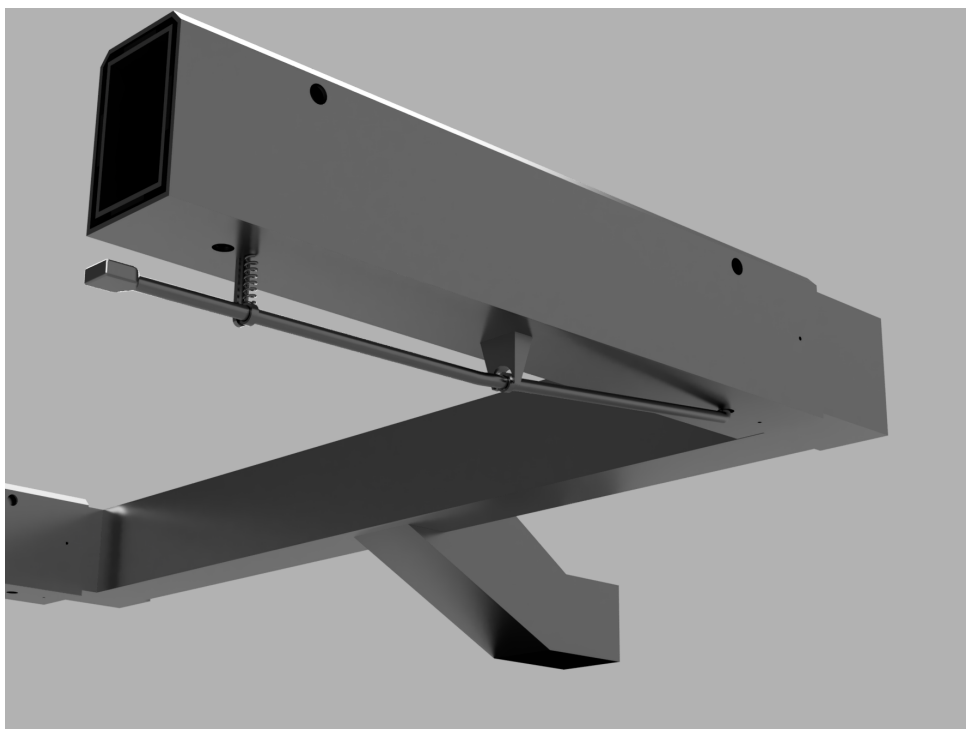
Area	Function	Solution	Plus	Minus	Interesting	Ranking
Platform	Communicate positioning	1.1 2D-spirit level	- Simple - Low cost	- Does not account for the slope of the ground - Does not account for torsion	- Often mounted on a flat surface - The handle on the Hercules blocks the view	1
		1.2 Angle hook	- Accounts for all directions	- Additional component - Difficult to design so that it fits all vehicles	- Will likely be in the way for the Hercules handle	2
		1.3 Ground reference setup	- Stable	- Does not account for torsion - Additional component - Bulky/big	- Storage?	6
		1.3 Fine-adjustment mode	- Flexible - Easier to handle	- Likely complex to construct	- Possible to achieve by making the handle easy to tension	3
		1.4 Foldable support legs	- Stable - Integrated solution	- Platform sits at different heights - Does not account for the slope of the ground - Does not account for torsion - Additional material usage	- Must be adjustable since tow hitches sits at different height on different vehicles	5
		1.5 Markings	- Bare minimum solution - Low cost	- Risk of not making any noticeable difference	- Where should they be placed? Just one line on the platform that aligns with the vehicle.	4

Area	Function	Solution	Plus	Minus	Interesting	Ranking
Mounting/dismounting	Secure cable	2.1 More robust construction	- Existing type of construction already available	- Will it actually improve the user experience?		5
		2.2 Tool clamp	- Existing solution used in other contexts - Self-explanatory	- How is it attached? - More complex construction than the current one - Likely more expensive	- Cost?	1
		2.3 Bottle holder	- More stable construction - Durable materials	- More material required - Requires more volume	- Difficult to access - How does the cable sit?	2
		2.4 Cable clamp	- Simple solution - Existing product	- Risk of damaging the connector	Can it withstand the weight of the connector?	4
		2.5 Elastic strap	- Simple solution - Low cost	- Unstable - Not weather resistant - High wear	Requires two hands	3
	Communicate engagement	3.1 Transparent plastic	- Best for visually communicate engagement	- Variation of plastics - Complicates construction	- You still just see the metal rails from above?	5
		3.2 Click system	- Best for audibly communicating engagement	- High demands on durability	- Depending on the design, it may be difficult to access - Are the pins located on the platform or on the box? - Some kind of metal watchers in the existing mounts that create a clicking sound	2
		3.3 Reversed sliding motion	- Existing solution		- May not actually make it easier	4
		3.4 More visible groovers	- Builds on the existing solution - Can easily be combined with other functions	- More complex solution	- Groovers are already relatively clear today; can they be further enhanced?	1
		3.5 Markings	- Bare minimum - Low cost - Does not require major design changes	- Requires explanation in instruction manual	- Does it actually make it easier?	3
	Facilitate movement	4.1 Wheels on short side	- Easy to move - Similar solution used on another model	- Requires redesign of the underside of the box - Reduces volume		1
		4.2 Canoe cart	- Existing solution	- Additional component	- Not required to be attached all the time	3
		4.3 Skidplates	- Not visible	- High wear	- Does this actually work?	2
		4.4 Trolley	- Stable	- Unnecessarily expensive and bulky product		6
		4.5 Hand truck	- Existing product	- Unnecessarily expensive and bulky product	- Any hand truck can be purchased - Does not facilitate the mounting process itself, only facilitate movement from A to B	7
		4.6 Wheels on platform	- Can move both the platform and the box simultaneously	- Becoming wide when moving with the box mounted	- Requires the box to always be mounted on the platform to fulfill the purpose - Does it work to pull it on that side? - Works well to attach, but worse to remove for one person	5

Appendix 6 – Renders of final concept









CHALMERS