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Development of an Interface Between a Carrier and any Add-on Module

Unique attachment system for Audi Genuine Accessories

Master of Science Thesis

Björn Granström

Department of Product and Production Development
Division of Product Development
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden, 2013

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Björn Granström

Supervisors:

Prof. Magnus Evertsson, Chalmers University of Technology

Sebastian Schierk, Audi AG

Department of Product and Production Development

Division of Product Development

CHALMERS UNIVERSITY OF TECHNOLOGY

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Cover:

The figure shows the new tor bar mounted basic carrier, mounted on an Audi Q5. The developed interface module attaches add-on modules onto the carrier.

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Gothenburg, Sweden, 2013

SE-412 96 Gothenburg

Sweden

Telephone: +46 (0)31-772 1000

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Abstract

In order to be competitive on the car-accessory aftersales market, Audi strive to provide Audi unique add-on modules for their new tow bar mounted carrier system. The aim of the thesis was to develop an interface between the tow bar mounted rear carrier and an arbitrary add-on module. The interface should be designed in such a way that it is as Audi unique as possible. Research showed that the uniqueness of the interface could be reached in different levels and directions. Based on the research, design rules for unique interface design was defined.

Three different directions of reaching the uniqueness was studied; electrical uniqueness, material and process uniqueness and uniqueness through mechanical analogies. After evaluation it was decided to reach the uniqueness of the interface through mechanical analogies. Six different existing attachment solutions were studied as benchmarking products and were further also used as inspiration for the concept generation. Two concepts were generated and after improvements in their design, the two was evaluated towards each other.

The selected solution consists of four attachment points, two in the front and two in the rear end of the carrier. The front interface is based on a plug-in principle and the rear interface has analogies to a door lock mechanism. The developed interface also contains a tilt mechanism, which enables access to the trunk of the car. All functions of the interface are controlled through one control element. Through thorough evaluations as well as different analyses conducted, the developed interface is shown to be difficult for any competitor to replicate. A patent application of the result can also contribute to the uniqueness.

The thesis work resulted in a developed concept of an interface module with a unique attachment system for Audi, yet fulfilling a convenient use for the customer as well as low complexity and weight on the carrier system. The result can contribute to strengthen Audi's position on the accessory aftersales market.

Keywords:
Product Development; Interface; Uniqueness; Patent; Car-accessory; Aftersales Market

Table of content

Preface

This thesis was carried out on site at the department of Audi Genuine Accessories (I/EG-57) in Ingolstadt, Germany during the two first quarters of 2013.

Thanks to the close relationship with the engineers at the department I/EG-57, questions and issues related to the thesis work always got its attention. Although a lot of people have been involved, I would especially direct a thank you to my supervisor Sebastian Schierk as well as the development engineers Michael Schäfer and Christian Bürger. Furthermore a sincere thank you to Markus Ofner for his support in the creation of the graphic content in this report.

The possibility to participate on the weekly meetings of the main development project gave me a holistic overview of the product in its context. Therefore, I would like to thank development engineer Steffen Roß at I/EK-P3 for his showed interest in the thesis work.

For the manufacturing of the prototype, I would like to thank all the involved from the workshop at the department I/EG-54.

I would also like to thank my supervisor Prof. Magnus Evertsson at Chalmers University of Technology for his availability for questions and discussions, despite the geographical distance.

Finally, I would like to thank everybody involved for his or her patience of any linguistic barrier.

Thank you,

Ingolstadt, June 2013

Björn Granström

1. Introduction

The automotive industry facing many challenges related to meeting new political incitements and legislations. In addition, the car producers have to develop cars that appeal customers, preferably with a brand specific uniqueness. Doing the later is a great challenge for a car producer that aims for a worldwide market with different demands, (Bornemann & Alwert, 2011).

1.1. Background

With its appr. 69 000 employees and over 1.4 million delivered cars during 2012, the German car manufacturer Audi manage to be competitive in the premium brand market segment of the automotive by still increase their sales per year, (Audi AG, 2013). Audi is a part of the Volkswagen AG concern, that contains firms like Volkswagen AG, Lamborghini, SEAT and Skôda to only mention a few, (Volkswagen AG, 2012).

Audi strive to delight their customers through four main areas expressed in the strategy for year 2020, with the vision to be the leading premium brand on a worldwide market, (Audi AG, 2013). The vision is shown in figure 1.

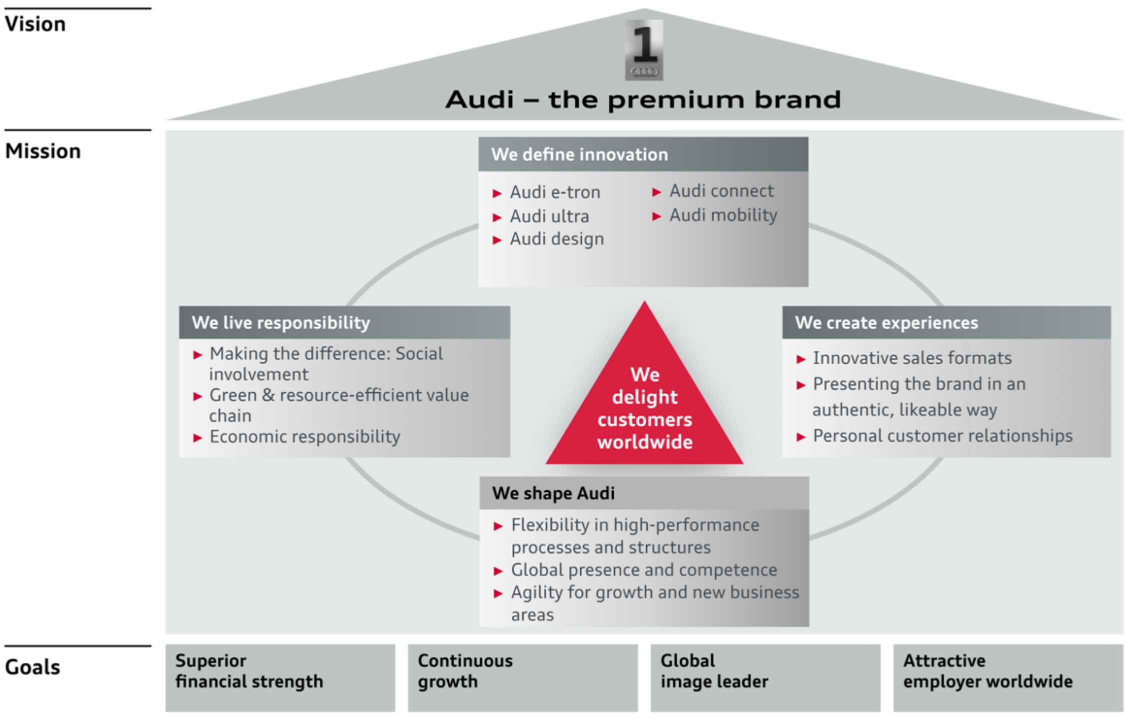


Figure 1 - Audi Strategy 2020 (Audi AG, 2013)

Audi's headquarter is located in Ingolstadt, Germany. The main part of the development takes place here and Ingolstadt is also Audi's largest production site. Audi currently have 12 different models available; from the smallest A1 to the luxury A8, and Q3 to Q7 in the SUV segment. Audi produce their cars mainly in Europe but have also productions sites in Aurangabad in India, Changchung in China and early 2016 the first car will leave the factory in San José Chiapa, Mexico.

1.1.1. Audi Genuine Accessories

As a way to delight their customers Audi also provide accessories to their cars. The department Audi Genuine Accessories, AOZ, (Ger: Audi Original Zubehör) has responsibility to provide all Audi models with accessories. The product portfolio of accessories varies between the different car models, but consist mainly of roof racks and carriers, child seats, rims, car mats, phone adapters etc. Most of the accessories that the department provide are model specific, meaning that for example a roof rack is unique for the specific Audi model and cannot be used on another car. This means that other car brands are not considered as competitors. However, the free aftersales market of car accessories competes with AOZ, (Schierk & Schäfer, 2013).

For transportation AOZ currently provide a range of accessories. The range consists of a traditional roof rack, on which various add-on carriers can be mounted, see figure 2. The roof rack system are widely used on all cars and depending on the car model it can take up to 100 kg weight, with roof rack and carrier weight included. Further, for transportation outside of the car, AOZ also provide accessories for the tow bar. The tow bar mounted bike carrier is shown in figure 2.

Figure 2 - Roof rack with box (left) and tow bar mounted bike carrier (right), provided by AOZ

1.1.2. The Carrier System

In order to always further delight their customers Audi constantly develops new ideas. One of the newest ideas is a tow bar mounted basic carrier system. The carrier consists of a structure that can be mounted on the tow bar. Different add-on modules can be mounted on the structure, (Schierk & Schäfer, 2013). The new tow bar mounted basic carrier is shown in figure 3.

Figure 3 - The new tow bar mounted basic carrier

The new tow bar mounted carrier will be designed for a pay load weight up to 100kg. The weight of any add-on module will then be included in the load weight. In comparison to other similar existing systems, this will be a unique loading weight capacity. Also, the possibility that the system contains of a basic framework on which any add-on module can be added is unique on the market, (Schierk & Schäfer, 2013).

Currently on the market, only Westfalia provide a similar system. It is however a tow bar mounted bike carrier, on which other add-on functions could be mounted, for example a box or a ski rack, see figure 4.

Figure 4 - The tow bar mounted carrier (left) and the same mounted with a box (right) provided by Westfalia, (Westfalia, 2013)

The tow bar mounted carrier structure is currently in the predevelopment stage and Audi's focus lays on the carrier and its performance. However, little effort has been put on the complementary add-on modules, neither on the interface between the add-on module and the carrier.

1.2. Problem definition

For the current available transport systems, there is a standardized interface for attachment. The roof racks have a so-called "T-bolt", and for the rear-mounted carriers, the spherical ball on the tow bar is the interface. The standardization makes it easy for competitors to replicate the interface and provide competitive products.

The new tow bar mounted carrier system by Audi will be, as mentioned above, unique on the market. Therefore it is important that the interface between the carrier and the add-on modules are designed in such a way that competitors not are able to replicate the interface and hence not provide competitive accessories for the Audi carrier system, (Schierk & Schäfer, 2013).

1.2.1. Purpose

The purpose of the thesis was to strengthen Audi's position on the accessory market, by develop an interface that makes it as difficult as possible for competitors to provide the accessories for the new carrier system, but still provide premium products.

Since the interface was considered as a "black box" between the carrier and any add-on module, a part of the thesis was also to research what types of add-on modules that can be requested from the market in the future.

1.2.2. Questions

The thesis will answer two main questions:

Q1. What add-on modules will Audi's top ten markets demand in the future?

Q2. How can the interface between the tow bar mounted carrier system and the add-on modules be designed so that add-on modules for the new tow bar mounted basic carrier provided by AOZ are unique on the market?

1.2.3. Goal

Along with the questions to be answered, the project has two goals to fulfil:

- To present a number of suggestions to Audi of how the new carrier system can be used in the future, and hence what kind of accessories that could be provided.
- To develop a concept of an interface between the carrier system and an arbitrary add-on module. The interface should be as difficult as possible for any competitor to replicate.

1.3. Limitations

The research focused on the top markets defined by Audi, meaning; Germany, China, USA, Italy, United Kingdom, France, Russia, Japan, Spain and Belgium and India, see figure 5.

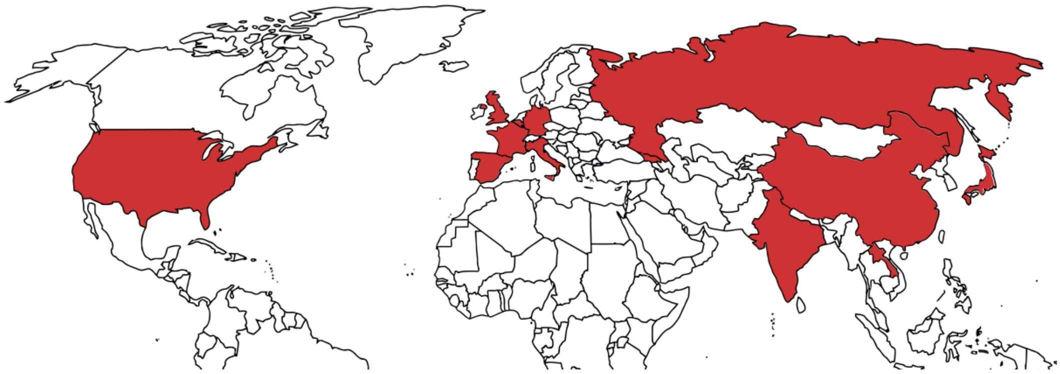


Figure 5 - Audi's top markets that was used during the research for the add-on module potential

The research only focused on the transport potential on the rear end of the vehicle and within its constraints. Hence, no focus laid on transport on other areas of the car.

Though the project was conducted under a limited time period, and some pre-work already were conducted, no potential customer was interviewed, because of the time limitation.

Only the interface between the carrier and the add-on module was developed. The add-on modules will only be considered as ideas and no further attention on its design will be paid.

1.4. Outline

This report aims to present the work conducted throughout the thesis work. The report is written with the intention that the reader has a rough understanding of the content during a development project as well as a basic technical understanding. The report contains of another five chapters, with the following content:

Chapter 2 - Research

In chapter two the result from the conducted research are presented. The research consisted of two parts; the research of the potential use of the carrier system and the possible attachment techniques for the interface. The chapter starts however with a description of the method used during the research.

Chapter 3 – Development Interface

The development of the interface is described in chapter three. It also starts with an introduction to the method presented by relevant literature, followed by the method used for the development work. The chapter then proceeds with a description of the development work. In the end of chapter three, the excluded concept will be presented together with a motivation why it was excluded.

Chapter 4 – Selected Solution

Chapter four presents the final solution of the development work, meaning the developed interface. Together with a description of the advantages of the product, a verification of the final solution shows that the product fulfils the defined goal.

Chapter 5 – Discussion

In chapter five the conducted project is summarized and discussed. The analysis is divided into three areas; method, uniqueness and general. Also recommendations for future work are presented in the end of the chapter.

Chapter 6 – Conclusion

In the final chapter the research questions from chapter 1 is recalled and the most important conclusions are drawn.

2. Research

In this chapter, the conducted research will be presented. It starts with a description of the method used, followed by the result from the two research areas; the potential add-on modules for the carrier system and possible attachment techniques.

2.1. Methodology

A part of the thesis contained a research of potential user situations for the new carrier system. That implied a research of upcoming trends within lifestyle and thereby potential transport needs. Due to the nature of the research, the sources had to be relatively up-to-date. Therefore different blogs, articles and reviews available on the Internet have been used. Also an interview has been conducted with representatives from China, i.e. employees at Audi China.

As a start of the second part of the development of the interface, a thorough research of potential technologies to be used in the interface was conducted. The research has been made through research in books and reviews as well as interviews and meetings with engineers in the area. For the patent research part, the internal patent research system, VIPS (Volkswagen Intellectual Property System) have mainly been used. In order to collect and engage interaction between different competences and experiences at AOZ, a few workshops at the department have been organized.

2.2. Add-on modules potential

In order to know what types of add-on modules to be considered during the development of the interface, potential add-on modules for different use purposes was researched. During the research a lot of pictures and ideas of transport solutions was found. All these were only used as inspiration for the creation of the different ideas presented below. A compilation of the sources from the research of potential add-on modules can be found in appendix I. Further, the focus during the project was the top markets defined by Audi, among those was China. As a part of the research an interview was conducted with engineers from Audi China. The outcome of the interview was only used as a source of inspiration to the below presented ideas. A transcript of the interview can however be found in appendix II.

The research resulted in three defined areas where the new carrier system can be used. For each category presented below, ideas was created and illustrated. However, only selected ideas are presented in this chapter. For more illustrations of potential add-on modules, see appendix III.

2.2.1. General transportation

In general it was found that a customer would like to freight all the type of goods that he or she doesn't can, nor would freight inside the car. Examples can be garbage, clothes containing allergic substances, gas cans etc. For all these types of goods, ideas came to create general transport solutions. Example can be a hard box, similar to the roof box, however mounted on the rear carrier system. Another example can also be a soft box, meaning a box made of a foldable material, for example textile, see figure 6. By having a soft material, the module can be foldable and easily stored in the trunk of the car.

Figure 6 - A box of a soft, foldable material

For the goods that are less sensitive of weather, i.e. do not need to be covered; a transport basket can also be possible add-on module. The transport basket only contains a framework where the goods can be fastened. However, the basket can also be designed as a shell for finer or even floating goods like sand, leaves and snow.

2.2.2. Active lifestyle

For transporting a bike on a car today, there is a number of solutions. The bike can be transported on the roof, with a bike carrier for the roof rack. It can be transported on a tow bar mounted bike carrier, or on a trunk lid mounted bike carrier. The advantage of the new carrier system is the loading weight. The 100 kg loading weight mean that that the new carrier system theoretically can take up to four bikes, which not the tow bar can manage. The weight advantage of the basic carrier is also adopted for the upcoming trends of e-bikes, meaning that together with the add-on module for bikes, three e-bikes can be transported. Bikes is also a transport mean that is widely used over the world, meaning that the bike module together with the carrier system have potential to be sold in many countries.

When e-bikes are transported, they could concurrently be charged trough the 12V power outlet available on the car. An expansion of the bike carrier could be a carrier for a scooter. However, the weight of a scooter is to be considered, since its lays in the span from ca. 85 kg and more.

On the current market, only a few snow and surf board carriers exist and only for roof rack mounted purposes. Therefore, a transportation solution can be to create for example a Kite-surfing kit for the rear carrier system. A Kite-surfing kit does not only meet the up-coming Kite-surfing trends, but will also be unique in terms of a rear mounted board carrier. The kit can contain a box for the sail and a rack for the boards, see figure 7. Since the boards and sail are designed in lightweight materials, the weight issue for the carrier can be neglected.

Figure 7 - Kite-surfing kit

Many activities connected to lifestyle come down to basics demands. When it comes to camping, there are a lot of possibilities for use of the rear carrier system. Except from general transport of camping equipment, a camping kit containing for example foldable chairs and a table can be a module on the carrier. As concluded earlier, the rear carrier system can be used to transport things that cannot be, or not want to be transported in the trunk of the car. A portable toilette or a shower can therefore also be a way to use the tow bar mounted carrier system.

2.2.3. Professional use

Audi's cars are also used for professional purposes. Therefore the rear carrier system can come in consideration for professional use cases as well. The research shows an increased use for Segways for patrolling polices and security personnel. The Segway can be transported on the rear carrier system, see figure 8. As for the e-bikes, the Segway can also be charged during the transport.

Figure 8 - Segway carrier

The advantage with the rear carrier system always available gives possibilities for not stationary craft men to always have a worktable present. With for example a foldable solution, the table does not require much space and other parts of the vehicle like roof and trunk can be better used for other transport purposes.

One can also consider the rear carrier system as a tool for maintenance professionals. Apart from the general transport add-on modules already mentioned, an extension to the transport shell can be a tilt mechanism so that for example leaves or sand in the shell easily can be deposed. Further for winter season use, a spreader for sand or salt can also be mounted on the carrier system.

2.3. Attachments techniques

Since one of the main purposes was to develop an interface unique for Audi, a thorough research of different attachment technologies was conducted. It was found that the uniqueness could be reached through three different techniques or areas; Material and manufacturing technologies, electrical protection and analogies with mechanical attachment solutions. This section describes the findings for each area respectively.

2.3.1. Material and manufacturing technologies

One way to fulfil the purpose could be to develop a component with extraordinary mechanical properties. Therefore, research about materials and manufacturing techniques has been conducted.

A material with extreme properties is titanium. Titanium has a very high strength per density ratio, meaning that the material is strong and light. Also, the resistance towards corrosion is very high. Titanium is though a very expensive material, (Callister, 2007).

Another material with extraordinary properties is Magnesium. Magnesium have a very low density, however not a remarkable high strength. One of magnesium's negative properties is its ability to ignite, (Callister, 2007).

In order to design a material to its required properties, composite materials can be a solution. A composite material is a mix of two materials, which are mixed together during the manufacturing process, this in order to capture the properties from the both materials. It can for example be the density from a polymer and strength from a carbon fibre, (Callister, 2007).

Machining is often used as a post-processing technique, in order to get higher finish and tolerances. Examples of machining processes can be turning or milling, (Ashby, 2011).

Forging is a deformation process, aiming to form a metal to a three-dimensional geometry. Forging can either be done cold or hot, relative the melting temperature of the metal. Hot forging allows larger deformations, but gives reduced tolerances and surface finish. Cold forging gives better finish of the part, but allows for smaller deformations and larger deformations forces, (Ashby, 2011).

Powder metallurgy is a discrete forming technique of metals, which gives a three-dimensional part as result. The technique is a material efficient method, since very little material is wasted during the process. A metal powder is compressed in a die, where after the powder geometry is heated up in an oven and the powder is through diffusion attached to each other. The heating phase is called sintering. Sintering is often used for small parts that cannot be forged, nor casted or machined, (Ashby, 2011).

2.3.2. Electrical protection

It could be possible to make the interface unique by using electronic components. This makes it possible to define the uniqueness of the interface by a code through software or an electrical actuator to lock or unlock the interlocking mechanism, (Kupfer. et.al., 2013).

For implementing an electrical solution in the carrier, some additional components are required. An extra control unit is needed for controlling of the signals; current power is required to the foldable module. Though the power for the lights is available, an additional caballing is required in order to make it work. Almost independent of how the final solution will be designed, the weight for the extra equipment needed to encode the interface, will be added on the foldable module and not on the add-on-module, (Kupfer. et.al., 2013).

Another way to encode the interface could be to use components or technology that already is available on the vehicle, meaning that the encoding is made through the already Audi related uniqueness. The car key is today unique for each car and contains an electronic unit for communicating with the car. The control unit in the car tells when the used pushes the unlock button of the key, and unlocks the car. The communication system from the car key could also be connected to the accessory and for example only allow attachment and detachment between the add-on module and the carrier when the key are within a current distance, (Kupfer, et.at., 2013).

2.3.3. Mechanical attachment analogies

The research showed that it could be possible to find a unique solution for the interface through analogies from already existing attachment technologies. Therefore a benchmarking of current attachment technologies was conducted. As the products for benchmarking was search for, the haptic, function and feeling in the products were elements that was searched for in the products. Based on that, six different attachment solutions were selected and to be studied further. Below a presentation of each can be found, the technical analysis is however found in chapter 3.3.1.

ISOFIX attachment for child seats

ISOFIX is a standardization that producers of cars as well as for child seats have agreed upon to be the interface used for child safety. The ISOFIX is a metal bow that is hided on the seats, where the back lean meets the sit area. Onto the metal bow the child seat can be attached and in case of an accident the child seat are safety attached to the body of the car. A picture of the ISOFIX attachment system is shown in figure 9.

Figure 9 - Example of a child seat, attached with an ISOFIX attachment system, (Audi AG, 2013)

Seat belt bucket

The seat belt in a car is a product used in all car models. It attaches through a simple plug in movement, and is released through a push on a button. The haptic of the bucket mechanism was the main reason for why the seat belt attachment system was studied. A picture of the seat belt bucket is shown in figure 10.

Figure 10 - An example of a seat belt bucket, (Land der Erfinder, 2013)

Racing bike pedal

Some race biking pedals are equipped with an attachment system. The system attaches the pedal with the shoe of the biker. Due to the conditions the attachment system have to be simple and reliable, which is achieved through the design. The attachment is simply made through a tiny push of the shoe on the pedal, and the detachment is made through a turn of the shoe. A picture of the attachment system is shown in figure 11.

Figure 11 - The racing bike pedal attachment system is between the shoe and the bike pedal, (Bucks, 2012)

Cross-country ski binding

For cross-country ski runners, the shoes are simply attached on the ski. During skiing, it is important to keep the ski vertical as the shoe is moved. That means that the ski is free two move in 3 degrees of freedom, two translations and one rotation. Therefore the binding solution is rotatable. It attaches through a simple push on the shoe on the binding, and detaches with an active push on a button concurrent with a release of the shoe. A picture of the cross-country ski binding is shown in figure 12.

Figure 12 - The cross-country ski binding attaches the shoe to the ski, (Sport Mann, 2009)

Door look

An attachment system that most of us use every day is the door attachment system. The system is simple to use, and as just mentioned almost everybody is familiar to the use of it. For the interface solution a special door locking system was studied, the three positioned door lock system for toilet doors. It is based on one single grip, but with three positions; vertical means that the locking piston is out, down position means that the lock piston is in and pulled up means that the door is locked. A picture of the door lock is shown in figure 13.

Figure 13 - The door lock studied is common in public toilet doors, (ASSA ABLOY, 2013)

Vertical plug-in tow bar

The tow bar of a car comes in different configurations. Some can be pivoted out from the rear end, some are always mounted and some can be plugged in. The vertical plug-in tow bars do have a tolerance free system, called "three-ball-system, with an release system that is very convenient to use. In addition the system also takes up a lot of weight since it is able to pull a whole trailer. A picture of the tow bar can be found in figure 14.

Figure 14 - The vertical detachable tow bar, (AL-KO, 2013)

3. Development Interface

This chapter describes the second step of the thesis work, the development of the interface between the tow bar mounted basic carrier and any add-on module. It starts with a description of the method used and follows by the conducted development work. The development resulted in two concepts that were evaluated towards each other. In the end of the chapter a presentation of the excluded concepts can be found together with a description of why it was excluded.

3.1. Methodology

Since the development of the carrier was in its early phase when the project started, the development of the interface was also about to be an early phase development project. Therefore, the method "Front-end process" presented in the book "Product Design and Development", written by Karl T. Ulrich and Steven D. Eppinger was mainly used. The book is written in 2012, hence the information is relatively new, which also is an argument for why it was used.

For general project issues, such as methods for decision-making and project general work distribution, the book "Project Management" written by Harvey Maylor (2010), was used. Concerning general product development methods that was not covered by Ulrich and Eppinger (2012), "Revolutionizing Product Development" written by Steven C. Wheelwright and Kim B. Clark (1992) has been used. Wheelwright and Clark (1992) was also used to confirm some of the methods presented in Ulrich and Eppinger (2012).

This part starts with a description of the theory from the used literature, followed by a presentation of the methods used during the development part of the project.

3.1.1. Literature

In the beginning of a project, many things can be diffuse and vague. The problem might not be fully defined, neither communicated through the team. Hence, the uncertainty of the problem is high. The closer to the end of the problem the team gets, the more of the uncertainty are sorted out and communicated, (Wheelwright & Clark, 1992).

Taking decisions in a project can be crucial. Maylor (2010) suggests that in order to support the strategic choices and trade-offs that have to be made, the "iron triangle" can be used. The "iron triangle" is a triangle consisting of three extremities that is vital for any project, cost, quality and time, see figure 16. By defining where a specific project is on the surface, the "iron triangle" can be used as a support for decisions making, (Maylor, 2010).

During a development project, the concept development phase requires more coordination between the different functions, (Ulrich & Eppinger, 2012). The concept development process is therefore, further expanded by Ulrich and Eppinger (2012). The authors refer to the process as the "front-end process", which is showed in figure 15.

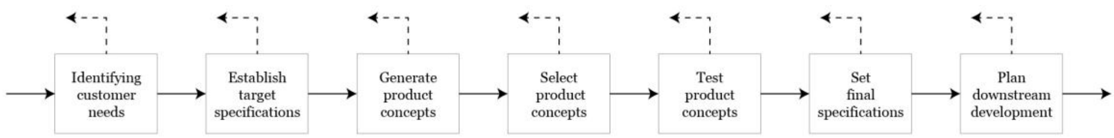


Figure 15 - The development process according to Ulrich & Eppinger (2012)

In the first phase, identifying customer needs, the aim is to clarify what problem to be solved and to understand the customers. This is mainly done during a raw data collection phase, followed by an interpretation of the data. As the raw data is interpreted, the needs should be organized into a hierarchy together with a relative importance. The identification ends with a reflection of the process, and questions like

”Is this really what the customer wanted?” and “Can the raw data be interpreted in another way?” should be asked, (Ulrich & Eppinger, 2012).

The next step in the front-end process is to establish an initial specification of the product. This should contain the customers’ needs as well as technical specifications that have to be fulfilled. The outcome should be a specification of the metrics with measurable values. Some metrics can be targets, and some can be fixed. In order to determine this, a benchmarking of similar products can also be of value to conduct, (Ulrich & Eppinger, 2012).

The concept generation phase is all about finding solutions that fulfils the metrics stated in the specification. This can be presented as simple hand sketches or by three-dimensional models. Ulrich and Eppinger (2012) suggest a five steps method, starting with clarifying the problem. The following two steps are to search for solutions for sub-problems, which can be done both internally as well as externally. After solutions are found to sub-problems, the solutions are furthered explored and further concepts are generated, for example with a Morphological matrix. As for the other phases, this phase ends with a reflection of the result.

When a number of concepts are generated and developed, the concept selection phase follows. Ulrich & Eppinger (2012) suggest a concept screening using “Pugh concept selection matrix“. The Pugh-matrix compares the different concepts between each other, for a number of criterions. The criterion can either be weighted or not. The outcome from the phase should be one or a number of concepts that fulfils the criterion. An example of a Pugh-matrix is shown in table 1.

	Reference Concept	Concept 1	Concept 2	Concept 3
Criteria 1	0	0	+	-
Criteria 2	0	+	-	0
Criteria 3	0	+	-	+
Criteria 4	0	-	0	-
Criteria 5	0	0	0	+
Sum of 0	5	2	2	1
Sum of +	0	2	1	2
Sum of -	0	1	2	2
Total	**0**	**1**	**-1**	**0**
Proceed?	-	**Yes**	**No**	**No**

Table 1 - An example of a Pugh-matrix

After one or more concepts are chosen, the concept should be tested. Questions like; “Does the concept fulfils the customers’ needs?” and “Does the concept performs as expected?” should be answered. As well as for the other steps in the front-end process, Ulrich & Eppinger (2012) suggest a number of steps for the concept-testing phase, starting with a definition of the purpose of the concept test. A survey population should be selected that correspond to the target customer. The survey can be conducted via a face-to-face interaction, a telephone interview, postal or electronic mail, or via a web based form. Which to choose between has to be decided for the specific project. The concept is communicated to the survey population and the result are measured and analysed. As for the other steps, the result has to be questioned on and reflected upon.

The two last steps in the front-end process, showed in figure 15, are “set final specifications” and “plan downstream development”. These two steps were not covered by the thesis, and hence not furthered explored in this chapter.

3.1.2. Used development method

Overall, one person conducted the project, with support from the development engineers on site at AOZ, followed a structured method described below. During the work, documentation was conducted on weekly basis and when necessary.

Since the project were constrained under the conditions of a thesis, the positioning in the iron triangle laid towards the time part of the triangle. Also, from the goal of uniqueness of the development of the interface, the focus moves down towards the quality part, see figure 16. Consider a decision-making situation where one direction will result in more expenditures but the result will be reached on time and the other direction will take longer time but be cheaper. Based on the positioning in the iron-triangle in figure 16, the more expensive but faster direction will be selected. This principle has been used during the project.

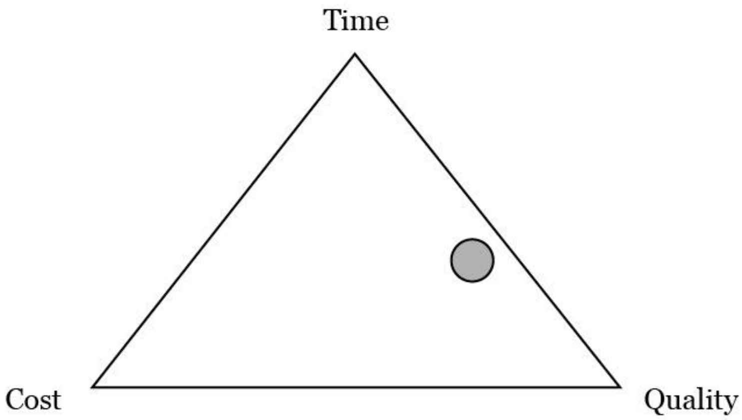


Figure 16 - The project's positioning in the iron-triangle

As a way to handle the uncertainty during the project, the list of requirement was used as a dynamic document and was filled in were after more information was gathered.

Since the development of the interface between the carrier and the add-on modules was a part of an already on-going development project, the time constraint was a limited factor. Hence, no customer-focused research, such as interviews with potential customers, was conducted since the customer is well known by the engineers at AOZ. Also, for the development process, only the first five steps in the front-end process, presented in the previous section was used, see figure 17.

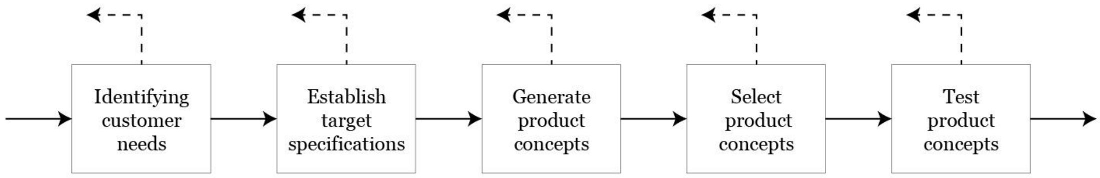


Figure 17 – The five first steps from the process in figure 15, which is the used process.

The product specification is presented in a list of requirements (LoR), containing the voice of the customer according to the engineers at AOZ, as well as the technical specifications.

During the concept generation phase, a similar approach as Ulrich and Eppinger (2012) describes was used. Since a significant specification for the interface is that the interface should be as unique for Audi as possible, patent research was an important input to the concept generation. As an external source, the supplier that was working with the development of the carrier was important.

As for the concept generation, the concept selection followed a similar approach as suggested by Ulrich and Eppinger (2012). Pugh concept selection matrix was used. Also simple pros and con lists was used for support of the reflection on the result. In order to compare the concepts, virtual and simple physical prototypes was used.

Design rules and principles like design for environment (DFE), design for manufacturing (DFM) and design for assembly (DFA) are also theories that Ulrich and Eppinger (2012) cover. The principles imply methods for considering environment, manufacturability and assembly during the development process. Ulrich and Eppinger (2012) present a structured step-by-step method for DFE and a thorough evaluation method for DFM including DFA. For the project it was however decided to put a secondary focus on the above mention principles, thereby not fully excluded.

3.2. Product specification

To be able to know what functions and performance the final solution of the development will fulfil, the product had to be specified. According to the method described in chapter 3.1., the final product was specified in different steps. This section describes the different steps conducted to reach the final specification, the list of requirements. The final list of requirements can be found in appendix IV.

3.2.1. Specification of a unique interface direction

In order to specify the main goal, an Audi unique interface, the question “What makes an interface unique?” was asked. Research resulted in two different points of views; towards the customers and towards the competitors.

By choosing the view of working towards the customers, the aim will be to find a solution focused on the customer. A possible solution in this direction could be to develop a product that attracts the customer to such an extent that independent of what the competitors provide the customer will still choose the Audi product. Another customer-focused solution would be to create a sell-offer for the customer. The customer can for example always get an add-on module included when buying the basic carrier.

If instead choosing the competitors-focus, the goal will be to find a solution that reduce, or even prevent, the possibilities for the competitors to provide their products for the tow bar mounted Audi carrier. This direction will put more focus on the interface itself and by that strives to find a technical solution that is difficult for any competitor to replicate.

By comparing the two points of views, the customer-focused view requires a more customer focused product development process. When develop a product with its aim to attract the customer the whole add-on module has to be developed concurrently with the interface. A thorough market research has to be conducted, to find out the demands and needs of the customer. The demands from the customer might also change over time; meaning that the customer-focused view will imply a larger risk and not be a long-term solution. The competitor focused point of view though, require a more theoretical development process, with focus on finding unique technical solutions for the interface. In comparison with the customer-focused view, a successful competitor-focused view will provide a more long-term solution. The two different views do not contradict to each other and can thereby also be applied concurrently. However, for the project it was chosen to emphasise the competitor-focused view. This decision was made mainly based on the need of focus on the whole add-on module when choosing the other direction, which was not possible due to project limitations.

3.2.2. Specification of a unique technique

As it was decided to go for the competitor-focused direction, i.e. a technical solution, the different areas of attachment techniques from the research conducted in chapter 2.3. were recalled. The three areas were now compared to each other towards selected criterion from the current state of the product specification. Five different criterions were used to differentiate the three areas from each other. Each area was evaluated towards the each criterion, and was given a number from 1 to 10, where 10 correspond to the most fulfilment of the criterion. The scale of the different criterion was defined in such a way that they correspond to each other, i.e. fulfilment of all criterions is the optimal product. The evaluation for each attachment area was only made upon the result from the research and the perception from the same. The result of the evaluation is shown in figure 18.

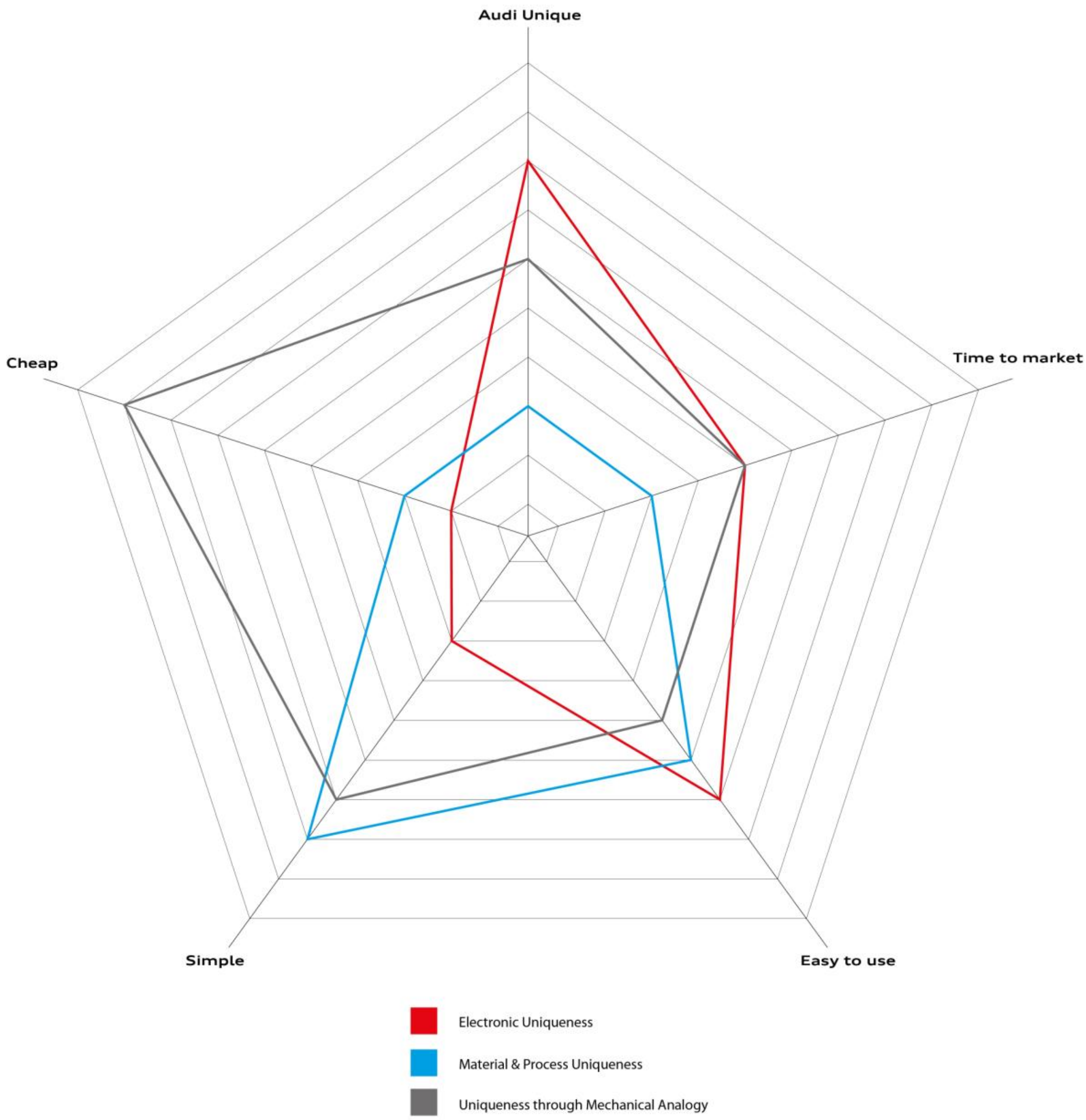


Figure 18 - The evaluation of the three different directions to reach uniqueness

Possibility to reach Audi uniqueness was one of the five criterions. Here the electronic solution had a clearly advantages in comparison to the other. By using an electronic control unit, the uniqueness could theoretically be fully controlled.

Time to market is important for the evaluation, however it is difficult to make a relative comparison. For this criterion value 5 correspond to a market launch as specified. The material and process exclusivity got for this aspect a lower score since the time to make a not conventional manufacturing solution compatible for a series production might take longer time.

The electrical solution also got the highest score on the usability criterion. By its nature, an electronic system has to be controlled with a button or similar. Also if the uniqueness could be build in with a sensor system, the usability for the customer will increase, in comparison to the other solutions.

In order to have the scale of the criterions comparable, the opposite of complex was defined as simple. The criterion refers to the construction itself and its integration to the rest of the system. By using a material or a process, the mechanical properties are what bring the exclusivity to the interface. Therefore the complexity of such a solution will be reduced for this area.

The costs to realize the solutions were also a criterion. Here it was meant that an already existing solution would be cheaper to reproduce in comparison to the other areas. However, it is important to mention that the mechanical analogies have to be redesigned and adopted to the rear carrier system if selected.

When studying the result showed in figure 18, the electrical solution do have some extremities, so do also the material and process uniqueness have. However, the solution of using a mechanical analogy has a more even distribution of the end points, a higher mean value seen numerical. Therefore it was decided that the development work would focus on reaching the uniqueness through a mechanical analogy.

The area of a technical solution, with a mechanical analogy was further studied. It was found that a not replicable interface could be reached in different levels, hereby called levels of uniqueness. The three levels are also different difficult to achieve, meaning that they have different amount of solutions. The different levels of uniqueness are further described below, and showed in figure 19.

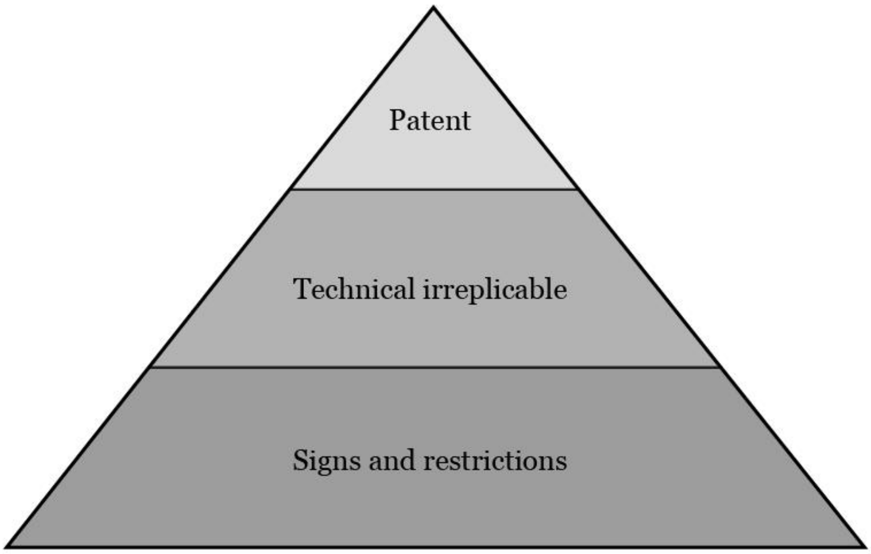


Figure 19 - The three levels of uniqueness, patent technical irreplibale and signs and restrictions. The span of solutions decreases higher up in the triangle.

Protection trough patent

It is a possibility to make the interface unique by protect it through a patent. A patent is when the solution is protected by the inventor, meaning that only the inventor have the right to produce and sell the invention. A patent can cover a larger part of a solution, and also a detail of the whole solution, (Ilnseher, 2013).

There currently exist a large number of patents in the area of attachment between two parts, meaning that finding an invention that not already is protected is difficult. However, the possibility exists to find a solution that is used in one area and translate it in the area of the basic carrier. Another solution of using a patent could be to combine three patents or more, and through that come up with a new solution that could be patentable, (Ilnseher, 2013). This means that when searching for a solution that already exist, like an analogy, the area where it is used in is preferably not accessories in the car industry.

To create a technical solution that is technically unique for Audi

For creating a technical solution of the interface that will be difficult for competitors to replicate, one main question had to be answered; what makes an interface difficult to replicate?

To answer this question, the benchmarking as well as other existing interface applications was studied. It was identified that for the situation on the carrier, the counterpart of the interface mounted on the basic carrier is the one that is left for the competitor to attach any add-on module on. Therefore, the design of existing counterparts was studied. Nevertheless, at this stage no specification of the interfaces position was made why any side of interfaces was studied. The study resulted in some general design rules for replication, presented in figure 20.

The design rules in figure 20 are based on the result from the different attachment products that were found during the research in chapter 2.3. In general it is found that a geometry fit is easier to replicate in comparison with a force fit. The difference between the geometry and force fit are deeper analysed by smaller components that are studied. Part of the geometry fit is the open geometry, that allows the ease of attach something to it. The orientation of the geometry has also an influence of the replication. A hole is more difficult to use as an attachment point in comparison to the outer free geometry. Further is it defined as easier to attach around irregularities in comparison to a smooth surface. The relation to the whole system has also its influence. It is easier to attach around a free positioned geometry in comparison if the geometry is hidden.

Protection through signs and restrictions

One of the important themes in automotive industry is safety. This is also an important factor to consider when develop the interface, since it will attach goods transported outside the car. For the interface, as will be further explored later, the main function is to keep the add-on module on the carrier. Based on experience from AOZ, any add-on module can be fastening on the carrier in one way or another. To reduce the risk that Audi is responsible for any misuse related accident, the carrier can be equipped with signs that shows where and how safe attachments are allowed. Also a thorough description of how to use the interface, in an instruction manual can solve the problem. It can also be important to restrict the use of the carrier by from Audi's point of view by in an instruction recommend to use add-on modules that are provided by AOZ.

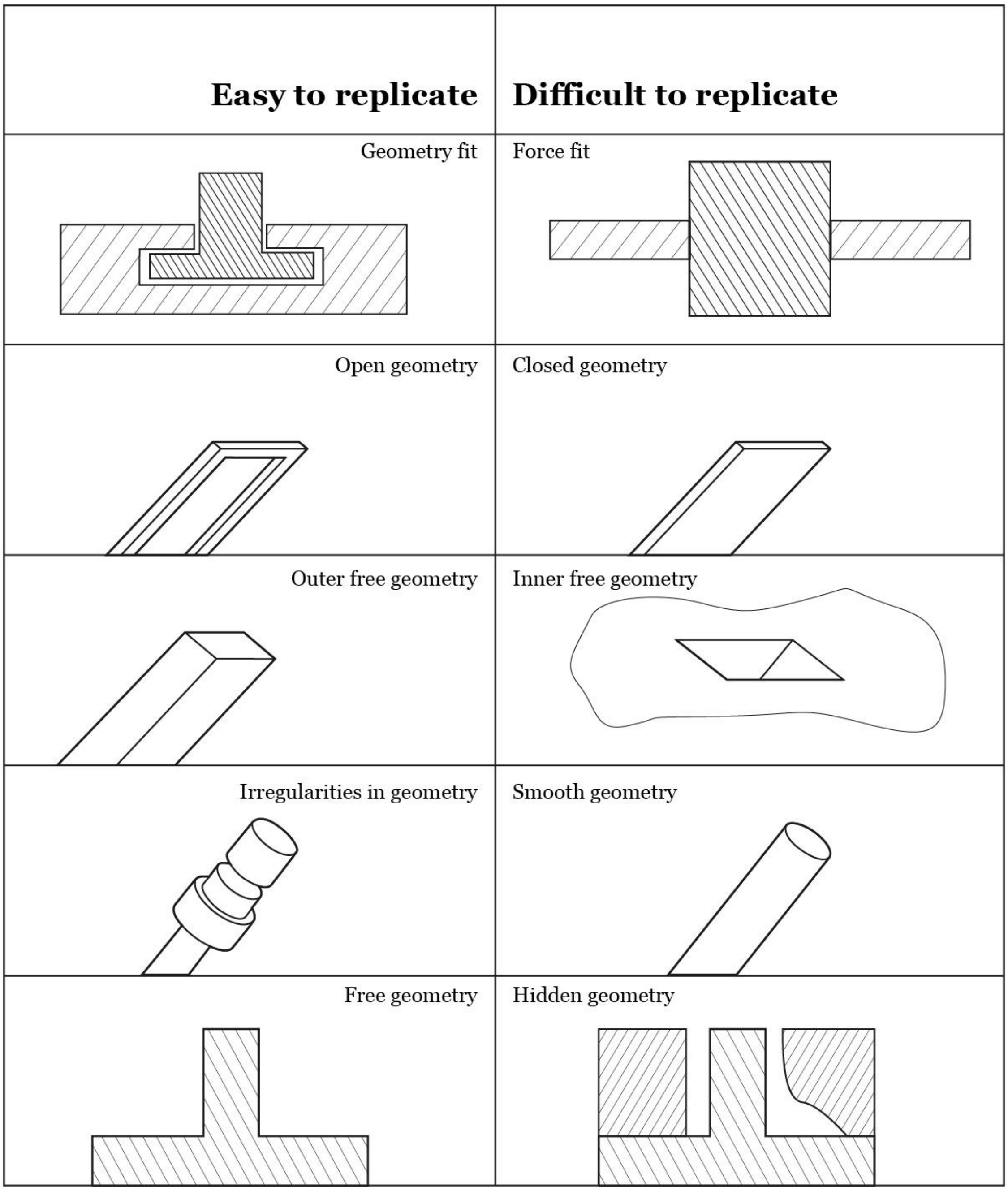


Figure 20 - The different design rules for replicability

The three levels of uniqueness described above were use as part of the specification of the final product, as well as a mean during the development and design of the interface. The level of protect it through signs and restrictions got less attention since it not direct affect the development work and can independently of the result be added afterwards.

One important specification in the unique interface was that the uniqueness must not negatively affect the customer. This specification was defined in order to avoid an Audi unique solution that not can be replicated by any competitor, but is however much complicated and inconvenient for a customer to use.

3.2.3. General specifications

From the research conducted in chapter 2.2, it was shown that there is a wide range of different add-on modules that can be used on the basic carrier. In order to reduce cost of a future production of different add-on modules, the product “interface” is from here on seen as a black box of the add-on module, see figure 21. This means that the developed product will be an integrated sub-module of any add-on module that in the future is developed by AOZ. Hence, any possible add-on function such as bike carrier, box or Segway carrier must be considered during the development.

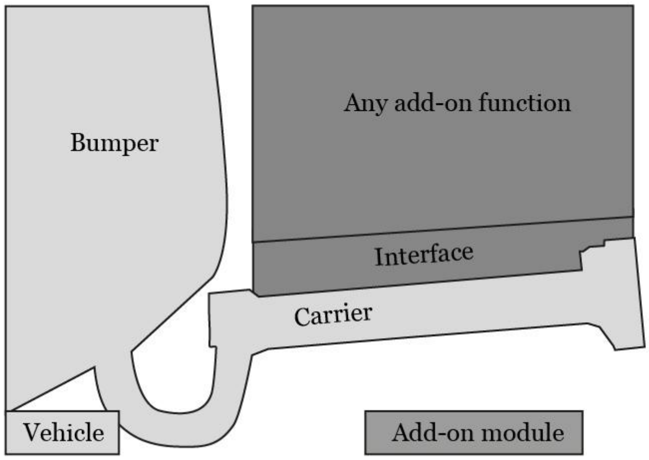


Figure 21 - The black-box representation of the interface-module

As an initiation of the product specification the geometrical boundaries in relation to the products environment was defined. The geometrical specification is from now on called the construction area. Since the product was an interface it contained two sub-areas, the area for the add-on module as well as the area for the carrier.

For the interface on the add-on module, things to consider was the bumper of the car, the height over the street as well as the length that is not allowed to be longer than the carrier. From the engineers at AOZ, a whish was to strive towards a size of a foldable add-on module similar to a briefcase, in order to have the possibility to store the add-on module in the trunk of the car. This also affected the maximum construction area for the interface part of the add-on module. When considered the different modules from chapter two, any grip, button or other control element has to be placed in the area over the identification sign, both in order to be reachable and not collide with any add-on function. This resulted in a box that was used as a base to the design work. The box is graphical shown in figure 22.

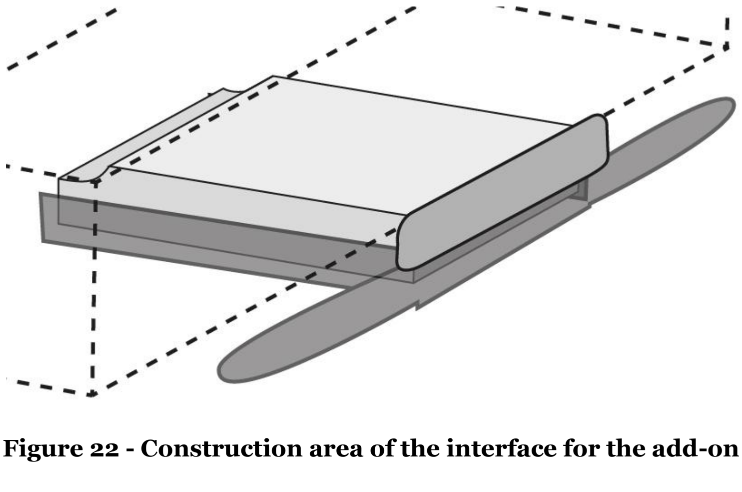


Figure 22 - Construction area of the interface for the add-on module part

For the other side of the interface, the construction area of the carrier was further defined. It started with the box given from the box from the add-on module, since the opposite interface not could be bigger that the corresponding part on the add-on module. Another wish from the engineers at AOZ was that the counterparts of the interface should contain four attachment points, two in the front and two in the back. In order to reach stability of the system, the four attachment points were placed in each of the corners of the basic carrier. Thereby, the construction area of the carrier part was defined, showed in figure 23.

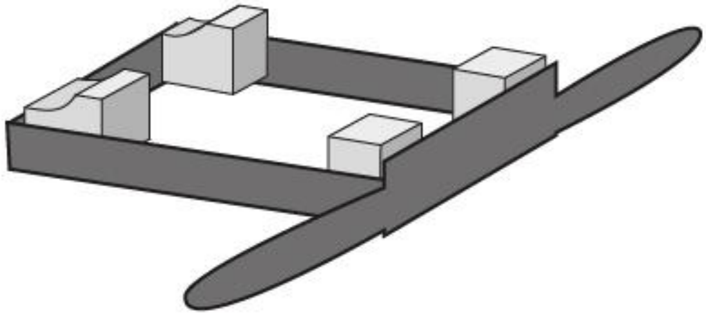


Figure 23 - Construction area of the interface for the carrier part

Further, the specification of the product from the point of view from AOZ, was specified together with the engineers on site. Apart from technical specifications such as measures and mechanical capacity, the desired function of the interface was defined. The maximum required actions was defined for mounting; attach front, fold down and attach back. Demounting was considered as the reverse actions of mounting. The two actions required for mounting are shown in figure 24. One important function for the interface module is a tilt function in order to enable the opening of the trunk lid. It is also important that the add-on module stays in its tilted position. The tilt function is shown in figure 24.

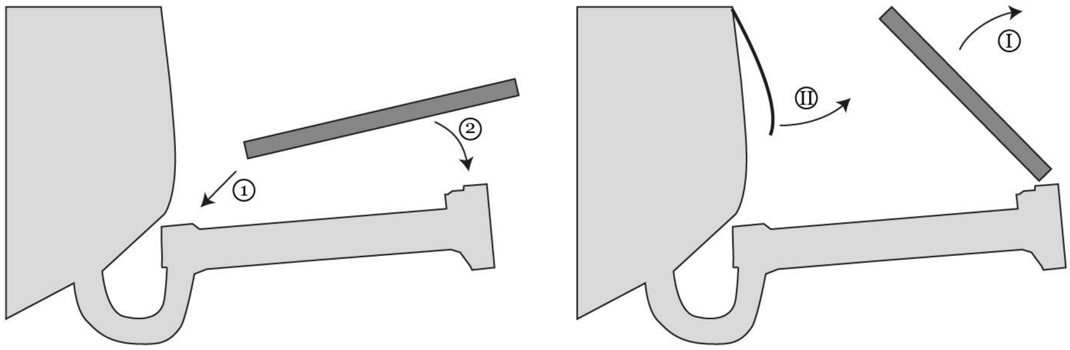


Figure 24 - Maximum actions for mounting an add-on module (left), and for tilting the add-on module (right)

3.2.4. Project general specifications

Since the development of the tow bar mounted basic carrier was an on Audi on-going development project, it was important to consider overall project goals as specifications for the interface, meaning Audi specific specifications.

One aim of the tow bar mounted carrier is that it will have a size, suitable for the spare wheel compartment. This gives the possibility for the customer to always have the basic carrier available in the car. Therefore one requirement for the carrier is that any complexity related to weight, must be concentrated on the add-on module in order to reduce the weight transported in the car. Further, the aim of the basic carrier development project at Audi was to launch the product on the market 2016. Therefore, the interface will have the same market launch to strive towards.

One general project specification was cost. Audi strive towards that, the retail price for the tow bar mounted basic carrier together with a bike holder add-on module must be lower than the price for a tow bar mounted bike carrier. Since the interface will be a part of the add-on module, the cost requirements for the interface will be difficult to estimate. An attempt to estimate the accepted cost was however made, see the cost requirement in appendix IV.

3.3. Concept generation

As the product was specified, the project went into the concept generation phase. It started with a benchmarking of the attachment analogies from chapter 2.3. With the benchmarking in mind, ideas were generated in the morphological matrix. This section describes the way through the concept generation phase.

3.3.1. Benchmarking of attachment analogies

At this stage it was decided to reach the uniqueness in the interface through a mechanical analogy. Therefore, the different benchmarking products from chapter 2.3 were closer studied in order to learn how the interfaces could be defined and differentiated. Table 2 summarize the findings from the study.

The table contains a description of how the two parts in the interface attaches together. Further, the general function was studied. Two types of functions were found among the benchmarked products; a two-position attachment system, open and closed, and a one-position system. It was also found that all the studied products contained a spring for its function.

Some of the specifications from chapter 3.2 were recalled. In order to analyse the potential of misuse of the interface, it was asked if the benchmarked products could attach without a corresponding part. Two examples are the door lock and the seat belt bucket. The door lock can be in the locked position without the doorframe, whereas the seat belt bucket only can reach the locked position when the counterpart on the belt is plugged in. If the mechanism could attach without a counterpart, it would mean a risk of an imaginary attachment, which preferably will be avoid in the product. Further, it was studied if the interface could be rotated or not, with the mind-set to possible integrate the tilting in the interface. Also, to recall the previous design rules for replication, it was defined if the interface attaches through a geometry or a force fit.

	Description	General function	Spring	Attach without counterpart	Geometry fit or force fit	Rotatable interface
ISOFIX for child seats	Torque spring loaded geometry fit that locks in the periphery	Two-position system with interlocking	Yes	Yes	Geometry	Yes
Seat belt bucket	Bended steel plates is by the plug in of the male part moved and locks the position mechanism	Two-position system with interlocking	Yes	No	Geometry	No
Racing bike peal	Two spring loaded jaws, grips around a corresponding metal geometry	One-position system with a spring loaded interlocking	Yes	No	Geometry	No
Cross-country ski binding	Push spring loaded, geometry formed steel plate is translational moved and created a geometry fit	One-position system with a spring loaded interlocking	Yes	Yes	Geometry	Yes
Vertical plug-in tow bar	Three balls is through a conic core pushed in radial direction and attaches in a rim in the corresponding hole	One-position system with a spring loaded interlocking	Yes	No	Geometry	No
Dorr lock	A spring loaded shim is in a guide mechanism translated and grasp in the counterpart	One-position system with a spring loaded interlocking	Yes	Yes	Geometry	No

Table 2 - Result from the benchmarking study

3.3.2. Product architecture

From the specification from chapter 3.2, a product architecture of the interface module was defined. The product will consist of three separate sub-functions; front interface, rear interface and tilt mechanism. All these functions will be controlled through one control element. Hence the product will consist of four sub-functions; interface front, interface rear, tilt mechanism and control element. A graphical representation of the product architecture is shown in figure 25.

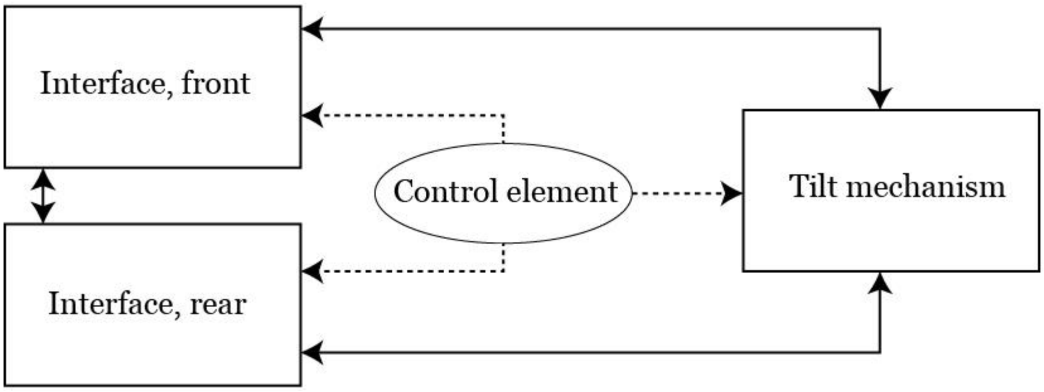


Figure 25 - The product architecture of the interface module with its four sub-functions

A solid line in the figure shows the different sub-functions that are connected to each other through the construction. Since it is decided above that the design will be based on a mechanical solution, the control element will communicate with the different functions through a mechanical energy flow, indicated through a dashed line in the figure.

3.3.3. Morphological Matrix

To generate concepts to the final product, a morphological matrix was used. The four different sub-functions from the product architecture were inserted in each column. For each of the sub-functions ideas was generated.

Even though the morphological matrix contained four different columns, the main focus laid on the two interfaces, front and rear. Therefore, the two columns of interfaces had more ideas in comparison to the two others. Ideas for the interfaces were mainly based on the benchmarking of attachment analogies, but also other sources were used. For example, workshops at AOZ were organized in order to generate a diversity of ideas.

In order to get an understanding of the different ideas, each idea was designed in CAD. During the CAD construction the aim was to communicate the different ideas, hence little attention was put on the dimensioning of the different parts. The morphological matrix, filled with the different solutions is showed in figure 26.

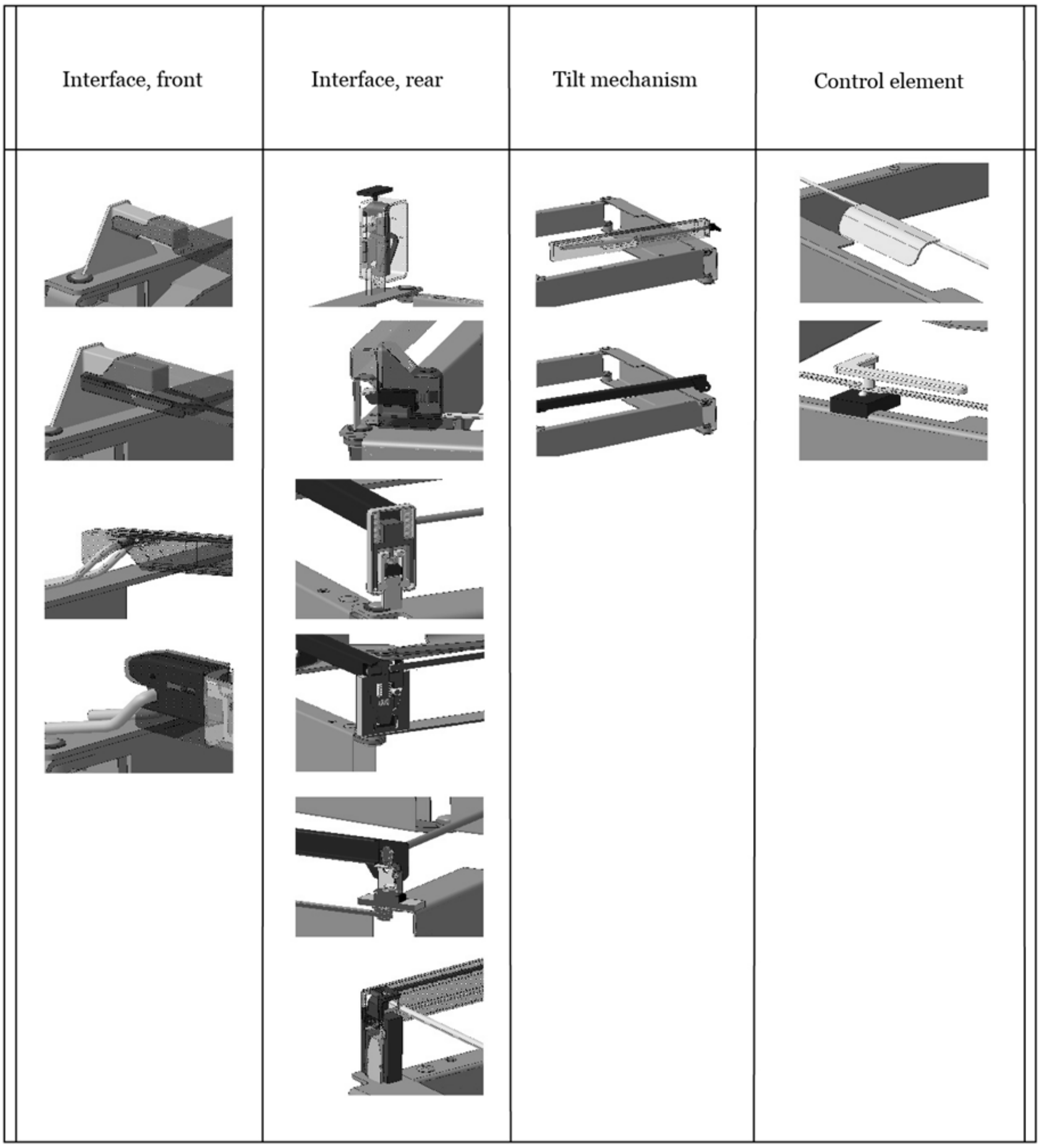


Figure 26 - The morphological matrix with generated ideas of all sub-functions

3.4. Concept selection

From the morphological matrix, the ideas were combined into concepts. However, since the theoretical numbers of combinations were unrealistic, a screening of the concepts served to reduce the number. The combined ideas were later evaluated and redesigned in two steps.

3.4.1. Screening

In order to reduce the number of ideas for the front and rear interface, a Pugh-selection matrix was used. The different solutions for the front and rear interfaces were compared to each other. The criterions for the Pugh-matrix were selected from the list of requirements.

One of the important criterions was to what extent the solution fulfilled the main function; prevent relative movement between the carrier and the add-on module. The intended use of each idea was also a criterion, as well as the ghost locking. Ghost locking means the possibility to reach the locked state without actually being locked. In terms of time to market, the ideas were compared to how much estimate development time that was required to bring the product on the market. Since the uniqueness was the main focus, the ideas were compared based on the design rules defined in 3.2.2. Complexity and sensibility towards tolerances and dirt was also two criterions that were used in the Pugh selection matrix.

Since the Pugh-matrix only compare two concepts toward each other, as a relative method, it was important to repeat the evaluation with all the different ideas as a reference to get a reliable result. The results from the concept screenings are shown in table 3 and 4, the Pugh-matrices can however be found in appendix V.

Reference concept:	Compared concepts: Without locking (with tilting)	Without locking (without tilting)	ISOFIX	Cross-country ski binding
Without locking (with tilting)	0	-2	-4	-7
Without locking (without tilting)	2	0	-2	-3
ISOFIX	3	5	0	-2
Cross-country ski binding	4	4	1	0
Mean value:	2,25	1,75	-1,25	-3

Table 3 - Result from concept screening of "interface, front"

Reference concepts:	Compared concepts: Racing bike pedal	Seat belt bucket	Door lock	Two-cylinder system	TZ-system	Inverted two-cylinder system
Racing bike pedal	0	0	1	-1	0	1
Seat belt bucket	0	0	3	1	0	2
Door lock	-1	-3	0	-4	-4	0
Two-cylinder system	1	-1	4	0	1	1
TZ-system	0	0	4	-1	0	2
Inverted two-cylinder system	-1	-2	0	-1	-2	0
Mean value:	-0,17	-1,00	2,00	-1,00	-0,83	1,00

Table 4 - Result from concept screening of ”interface rear”

From the concept screening the result shown in table 3 and 4 was studied. For the rear interface, table 4, the two ideas with the highest mean value were selected as the ideas to proceed with. For the front interface however, the two ideas with the highest mean value was very similar to each other. Therefore, the ideas with the highest and third highest mean value were selected as ideas to proceed with. Doing so, a variation of the ideas could be ensured in the proceeding work.

The outcome from the concept screenings was further combined with the other elements from the morphological matrix into complete concepts. The decision of how the concepts should be combined was trivial due to technical impossibilities for some of the combinations. Therefore, the two combinations were the only possible combinations. The morphological matrix with the different combinations is shown in figure 27.

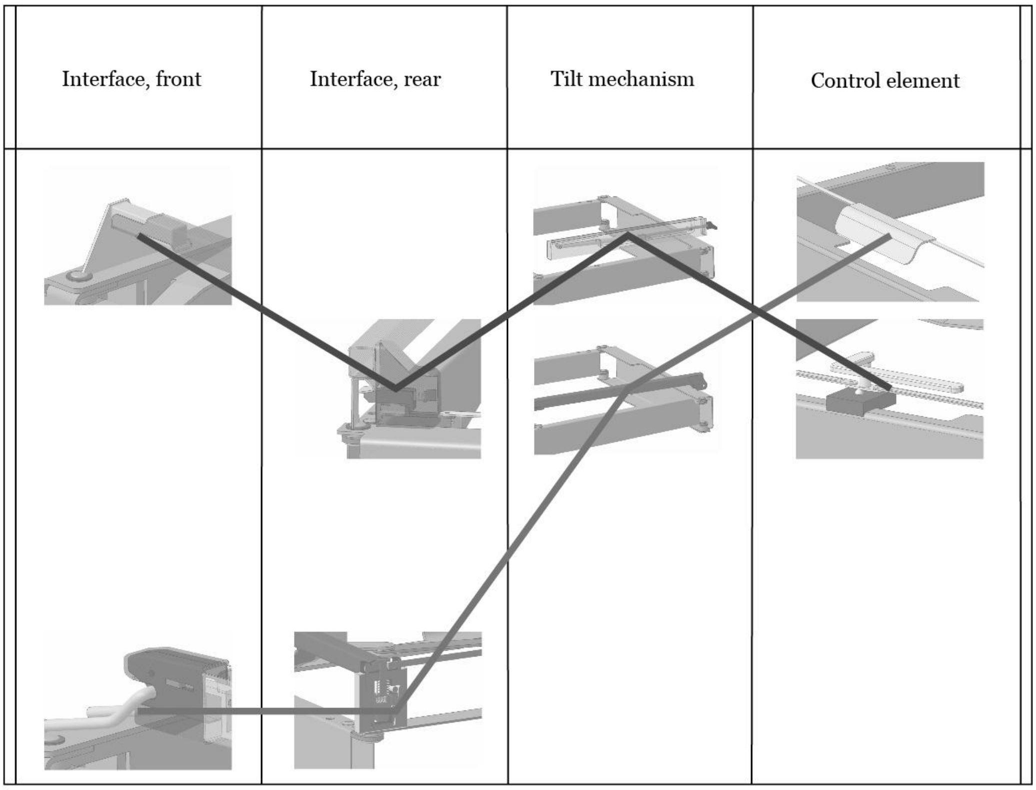


Figure 27 - The combinations from the morphological matrix that was combined to the two concepts

The two concepts that were combined from the ideas generated were just combined without any thought about the integration to a whole product. Therefore the concepts were redesigned so that the ideas were integrated with each other. During this stage design rules like for example DFM, DFA and DFE was applied. Even though the concepts were redesigned, it was important to keep the main idea of each sub-solution unchanged, especially for the interfaces.

3.4.2. First evaluation

The now redesigned concepts went through another redesign cycle after comparison towards another list with criterion mainly from the list of requirements. This first evaluation was based on criterions that had a system perspective. The evaluation can be found in table 5.

One criterion was if there existed a synergy in the construction. By synergy it was meant the influence from each sub-solution on the whole product. Presence of synergy is a subjective criterion and was here defined as a positive quality. Usability was also a criterion. In comparison to the usability criterion in the concept screening, the usability here was seen from the holistic product point of view. The achievement of the main function as well as the complexity was as well judge based on the holistic product overview. The impact on the whole carrier system was also one of the criterions used for a first evaluation of the redesigned concepts.

Each criterion was weighted for the importance, i.e. each criterion got a number from 1 to 3, where 3 was defined as very important criterion. The concepts were then evaluated in each criterion and also given a number from 1 to 5, where 5 correspond to a complete fulfilment of the criterion. Along with the number, each concept got a motivation to the given number. The number from each criterion was multiplied with the weighting, followed by a summation. The sum gave an indication of the current state for respectively concept.

Table 5 was further analysed. Some of the negative aspects were aspects that could not be fixed, whereas some were aspects that could be fixed. The two concepts went therefore through a third redesign before the second and final evaluation. Explosion drawings of the two concepts, at the design stage that went in to the second evaluation can be found in appendix VI.

3.4.3. Second evaluation

For the second, final evaluation of the concepts a selection of the most important criterions from the list of requirements was used. The selected criterions could differentiate the two concepts from each other. Also criterions for the main focus, the ability to replicate the interface, were selected to the evaluation. A summary of the evaluation can be found in table 6.

The cost of manufacture the two concepts was one criterion that was selected. For the cost calculation each component was studied. The manufacturing steps were detailed defined and for each a labour cost and a machine cost was defined. Since no exact values of the labour or machine cost were available, a simplification was made. The cost was divided into two cost levels and the machine in four levels. For example, a stamping machine is cheaper pro hour in comparison to a laser-cutting machine and a machine operator cost different for the manufacturing company depending on the complexity of the task. The weight of the material multiplied with the price of the material gave the cost of the material for each component, but in order to cover the cost for rest material such as edges of plates and cutaways the material cost was added with 25 %. The cost for the manufacturing of each component was calculated by multiply the processing time with the labour and machine cost respectively. To cover extra add-on cost for manufacturing such as group leaders and tuning time, 20 % was added to the manufacturing cost.

Some components, like for example bulk components such as springs and washers were only given an estimated single cost. In the estimated single part cost, everything was assumed to be included. For all components that should be manufactured with injection moulding, a supplier of plastic component was asked to support the cost calculation. Therefore only the single cost as well as the tool cost was given for each of those components. Other tool costs was also estimated together with the engineers at AOZ. The result from the cost calculation is found in table 6, the full calculation can however be found in appendix VII.

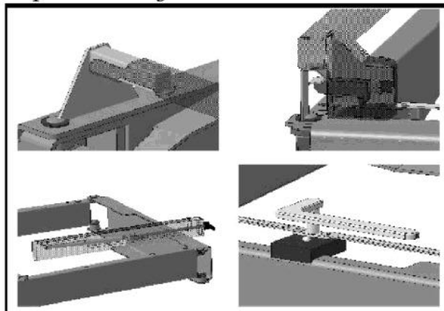
During the cost calculation, only the manufacturing of the required components was considered. No consideration of the assembly cost or add-on costs for profit was made. It was however estimated to be similar for both of the concepts and would therefore not affect the result of the evaluation.

As the carrier are mounted on the tow bar of the vehicle, it will contribute to the weight the vehicle have to transport. For both fuel consumption reasons as well as carbon dioxide emission reasons, the weight of the two different concepts was one important criterion. The weight was calculated based on the CAD models of the two concepts. As for the cost calculation, the weight calculation was based on the current state of the two concepts.

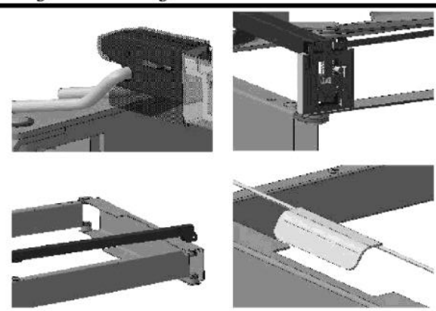
Since the product is to be used by customers, the usability was also considered for evaluation. The intended use was the base for the evaluation and the decisions was based on the experience from the engineers at AOZ as well as design rules for ergonomic advantage.

The ability for any competitor to replicate the interface was also used as one of the criterion used for the concept selection. To determine which of the two concepts that provide a more Audi unique design, the part of the interface that belonged to the carrier was studied. It was asked both internally, as well as by a supplier to Audi, which of the two interfaces that potentially could be easier to replicate.

Separate tilting



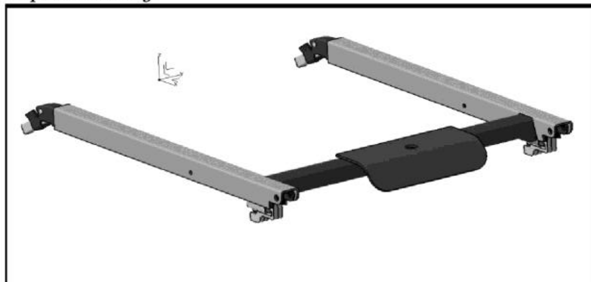
Integrated tilting



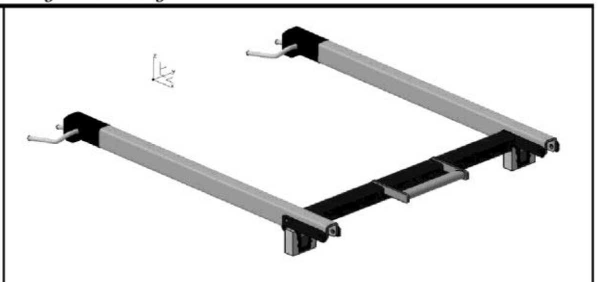
Criteria	*Weighting*	*1 to 5*	*Sum*	*Motivation*	*1 to 5*	*Sum*	*Motivation*
Synergy in the construction	*2*	3	6	The system give a synergic impression. Espesially the control mechanism for tilting, so as the support damper	2	4	Synergies exists, although the individual components are more important alone.
Usability	*2*	5	10	Control element for tilting and locking are separated. Unlocking have two steps, no concurrent use. During tilting is the add-on module slightly rotated to indicate the fulfilment of the action to the customer.	4	8	The system have only one control element, with multiple positions. During attachment, activates the realser the attachment system, and no active grip is thereby needed.
Fulfilment of main function	*3*	3	9	The system fulfil the main function. However, there is no sufficient reaction force in driving direction.	5	15	The system fulfils the main function sufficient. The positioning is blocked in all degrees of freedom.
Complexity (1=Complex, 5=Simple)	*1*	4	4	Few components. No control element between the rear and front interface units. The front interface do not have any locking mechnism.	3	3	A lot of components estimates to be needed. Both interface modules consist of a filigree construction. The tilt mechanism is however not contributor to any additional components.
System impact	*3*	3	9	Simple construction on the basic carrier. Complexity are concentrated in the add-on module. Weight in add-on module are estimated as relatively high.	4	12	The hole mechanism for the rear interface have a complex geometry. Additional weight are concentrated in the add-on module.
			38			42	

Table 5 - Table of the first evaluation

Separate tilting



Integrated tilting



Description	*Weightning*	*1 to 5*	*Sum*	*Motivation*	*1 to 5*	*Sum*	*Motivation*
Synergy in the construction	*2*	4	8	Synergy exist in the construction, especially the translation between the control element and the locking mechanisms.	3	6	Synergy exists partly. Rear interface body also serves as body for the tilting.
Usability	*2*	5	10	The action of the control element correspond to the activated functions.	3	6	The action of the control element correspond to the activated function. Detachment of the whole add-on module can however be complicated.
Fulfilment of main function (prevent realtive movement)	*3*	5	15	Both interfaces take forces in all directions.	4	12	The system of interfaces take forces in all directions. The rear interface do not take any forces in driving direction.
Fulfilment of main function (tilting)	*3*	4	12	Tilted position is clearly defined. Works independent of the state of the add-on module.	3	9	The tilted position require that the center of gravity on the add-on module are behind the tilting's rotation point.
Complexity	*1*	3	3	The construction have few moving parts	2	2	Both interfaces have a filigree design
Technical completed	*1*	4	4	Some design changes are required for manufacturabillity	4	4	Some design changes are required for manufacturabillity
Potential to reach Audi uniqueness	*3*	4	12	Analogies with other attachment systems exist. The counterparts are difficult to use for another attachment solution.	3	9	Analogies with other attachment systems exist. The counterpart of the rear interface is difficult to use for another attachment solution. The front counterpart is easy to use for another attachment solution.
System impact	*3*	4	12	Complexity is concentrated in the add-on module	4	12	Complexity is concentrated in the add-on module
Component cost	*2*	3	6	42,02 €	4	8	31,71 €
Tool Cost	*2*	4	8	148 200 €	4	8	149 000 €
Weight	*2*	3	6	2 665 g	4	8	2 333 g
			96			84	

Table 6 - Table of the second evaluation

3.5. Excluded concept

After the second evaluation of the two concepts, one was clearly standing out as the better concept and it was decided to proceed with it. Although the excluded concept had some issues to be solved, the whole concept or parts of it can be used for further development of interfaces. For that reason, this section describes the other concept with its functions and issues.

The excluded concept was also based on mechanical analogies. The front interface was designed as an ISOFIX child seat attachment, however with a 90° turned opening. The turned opening of the ISOFIX is due to the ability to be vertically detached in case of use of the tilting mechanism. The rear interface was designed as the vertical detachable tow bar, also known as the "three-ball-system". For patent infringement reasons as well as for system adaption, the interface was designed as a two dimensional system. Hence, the developed interface could be seen as a two-cylinder-system. The ISOFIX as the front interface, and the two-cylinder system as the rear interface, was both connected through a rotatable joint behind the rear interface. The joint also served as rotation point when tilt mechanism was used. The two interfaces were controlled through a grip, placed over the licence plate. When pulling the gip upward, the two-cylinder system was detached, and when pulled down, the ISOFIX was detached. For pictures of the interfaces, see figure 28 and 29.

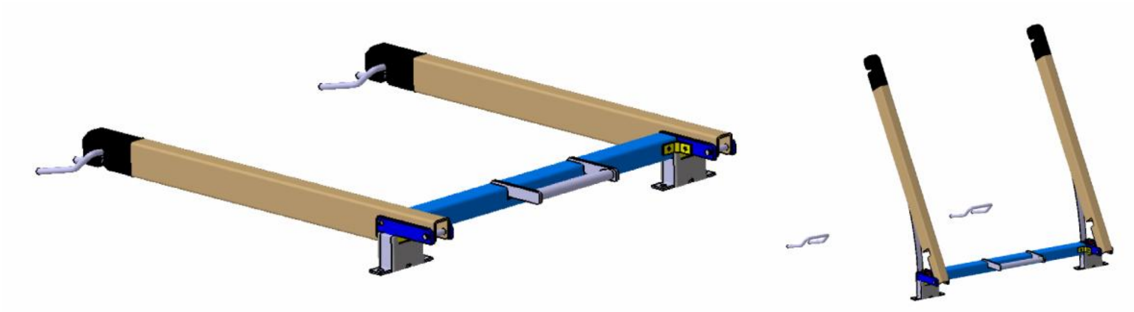


Figure 28 - The excluded concept in mounted (left) end tilted (right) position

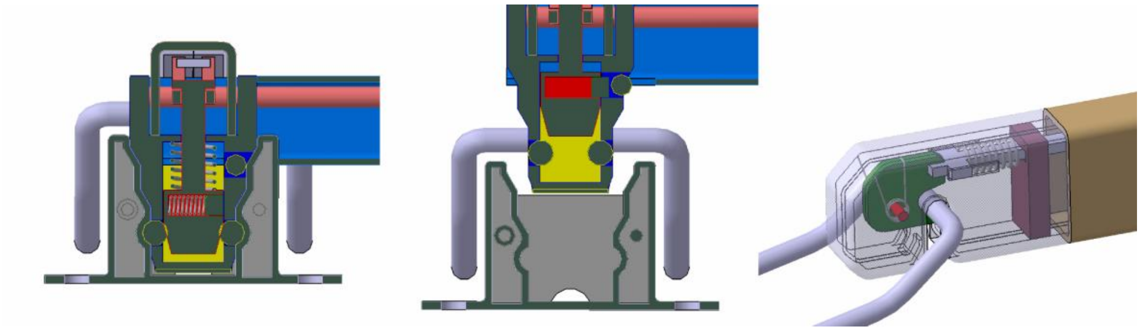


Figure 29 - The interfaces of the excluded concept. Rear interface in a attached (left) and detached (middle) state, the front interface analog to an ISOFIX (right)

Some of the critical issues that excluded the concept for further development were the following:

- The design of the rear interface was very filigree and would only work within small tolerances. Hence, the cost for manufacturing the part with sufficient tolerances would be high. This is an assumption made through discussion of the concept with the engineers at AOZ, the increased cost is however not showed in the cost calculation in 3.4.3.
- The decision to stretch the rotation joint over the licence plate generated a lever, which in the tilted position will generate a torque on the rear interface, see picture 30. Since the position of the tilting rotation couldn't be moved, the torque on the interface would demand a very high strength performance on the

parts in the interface. Seen from a system point of view, the system will only have two reaction points in the tilted position, in comparison to four as the selected concept have.

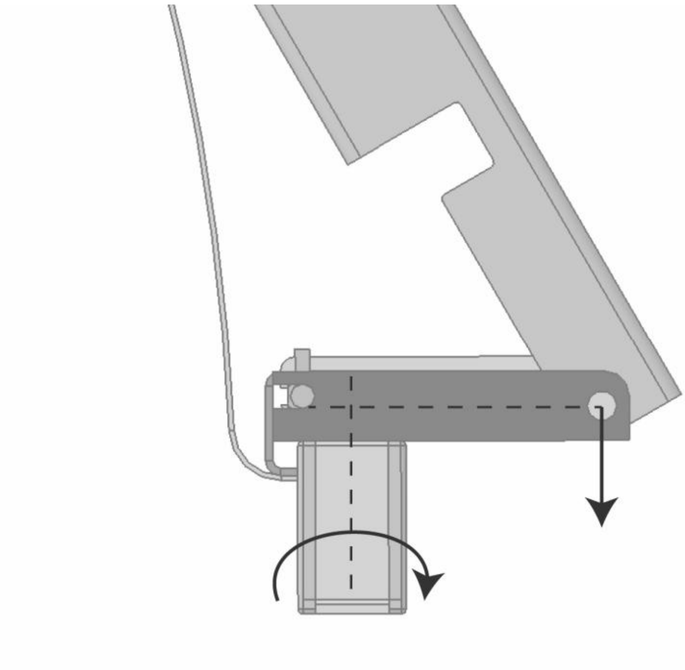


Figure 30 - The design of the rear interface generates a torque in tilted position

- For the detachment of the add-on module, the grip first had to be lifted up to detach the rear interface. By lifting up the rear end of the module, the customer concurrently had to pull down the grip in order to detach the front interface, followed by a lifting action to release it. These actions were not considered as convenient for the customer.
- The front interface left an open and free geometry, which according to the previous defined design rules is easy to replicate. The rear interface, leaves however a free inner geometry, which according to previous defined design rules is more difficult to replicate. In comparison to the selected concept this was considered as a weaker point.

4. Selected Solution

This chapter describes the selected solution of the developed interface. It starts with a general description of the solution together with its advantages from the concept selection, followed by verification towards the different requirements from chapter 3.

4.1. Selected concept

The selected solution consists of a frame that is mounted on the tow bar mounted rear carrier through four attachment points. The frame has two different attachment solutions, one type in the front and one type rear. For tilting there are two additional longitudinal beams that are connected on the main frame through a bolt. Over the licence plate a grip is placed, through which the attachment and detachment as well as the tilting mechanism are controlled. Pictures of the selected solution are showed in figure 31, and drawing cut-outs are showed in figure 32. For an expanded drawing of the concept, see appendix VIII.

Most of the components of the interface module are made of steel in order to manage the carried load though its slim design. The counterparts are also made of steel, so that they can be welded on the steel basic carrier. In order to reduce weight, some components that take secondary loads are made of different plastic mixtures. For the material choice for each component, see the cost calculation in appendix VII.

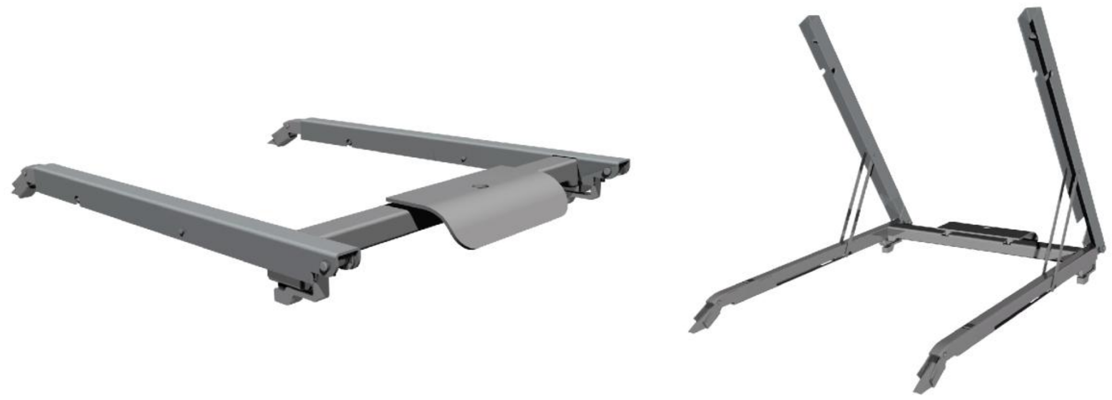


Figure 31 - Pictures of the final solution. The basic state (left) and the tilted state (right)

4.1.1. Attachments

The attachment is divided into two parts, front and rear. The front attachment contains of a hollow profile that is plugged in around an inverted geometry fasten on the carrier, see figure 32 (view D-D). To simplify the use for the customer, a bolt through the hollow profile gives an indication of the correct position to the customer. The two attached profiles have a small relative angle to each other in order to give a pre-tension in the system. Hence vibrations or rattling is reduced.

The rear attachment has analogies to a door lock mechanism. A shim is through a spring force pressed out to its position, whereby the mechanism are locked, see figure 32 (view B-B). During mounting, the shim shape serves as support for the mounting action. The shim slides in a rail and due to the spring force it is pressed back in position. For detaching an eccentric part is rotated and slides the shim back in the rail, whereby the system can be lifted up. The parts that are mounted on the carrier are a corresponding shape to the shim. The bottom part of the attachment house will lie on the carrier, and hence support the weight forces. Since contact surface between the shim and the counterpart is slightly angled, there will always be a contact between the two parts. Thereby is any tolerance compensated and the attachment becomes free from vibrations and rattling. It also provides a self locking solution.

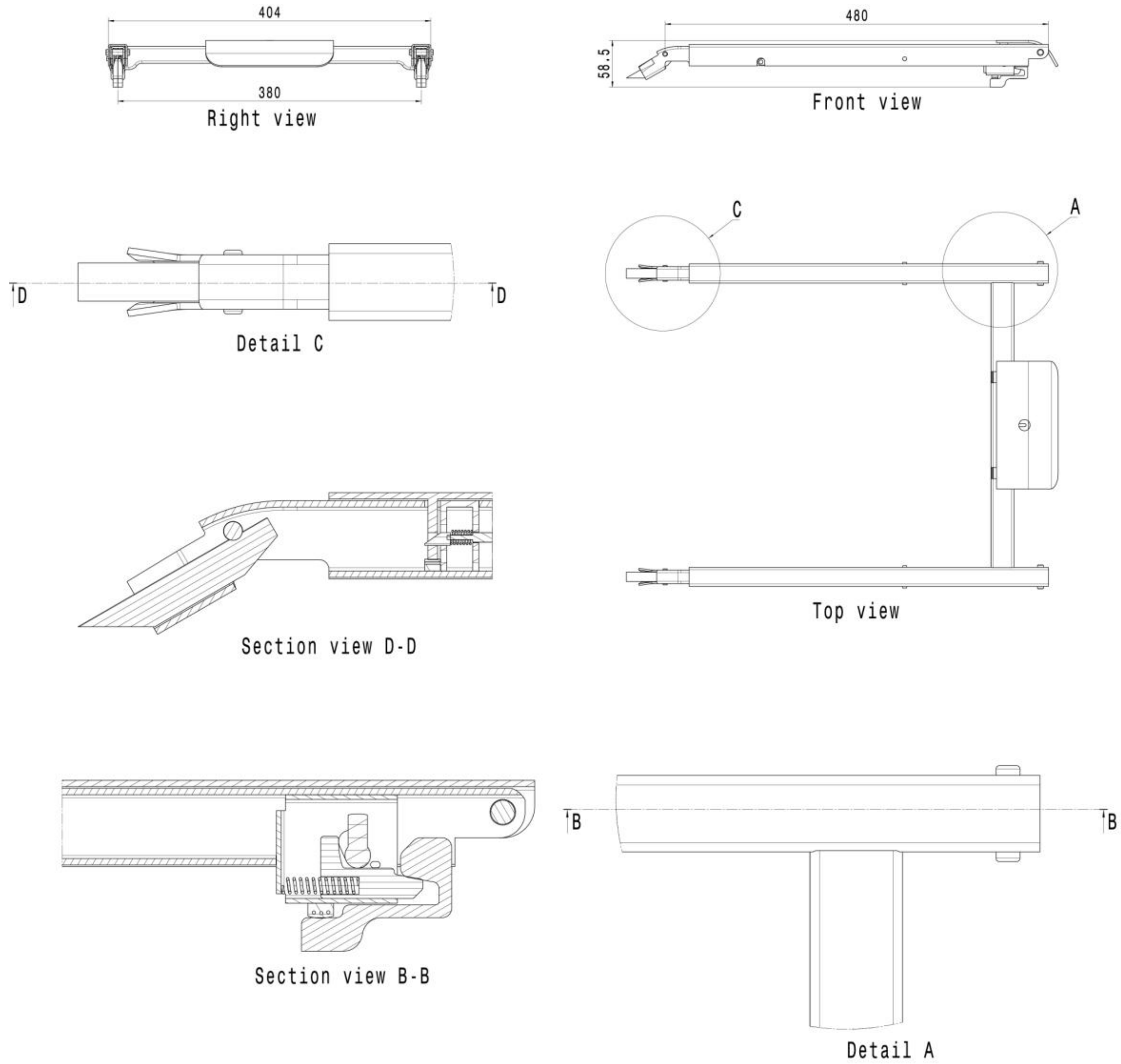


Figure 32 - Technical drawing of the final solution and its interfaces

4.1.2. Tilting

The tilting function is separated from the frame of the interface module in such a way that tilting takes place through a separate rotation point, placed behind the rear interface. Hence, the rotation for tilting is not integrated in the interfaces. The tilting is locked in the front part of the frame, and is controlled by the grip. The tilting itself has to be done by the customer. During the tilting, two bars follow the tilting movement and concurrently slide a position holder in the frame. The position holder slides in position and keep the tilted angle fixed. For tilting back to the original position, the customer has to tilt over a dead point so that the position holder is deactivated, see figure 33.

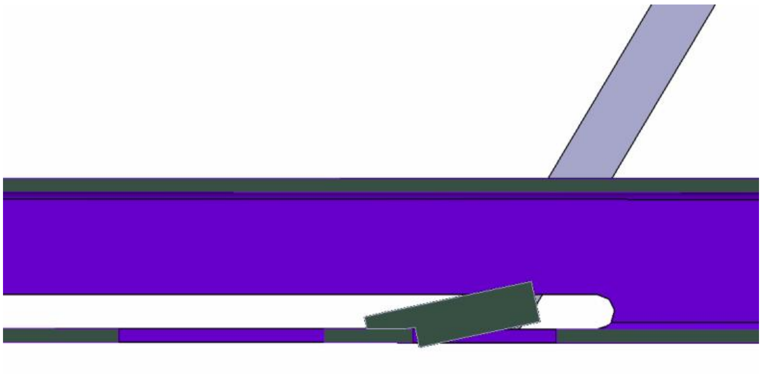


Figure 33 - The position holder in tilted position

4.1.3. Grip

The grip is placed over the licence plate and is connected to an axis cross through the construction. On each end of the axis an eccentric component is attached. The eccentric component is also attached to a wire that pulls the locking for the tilt mechanism. This means that the grip can be pulled in two directions, up and down. Up correspond to unlock the rear interface and pull down correspond to unlock the tilt mechanism, see figure 35.

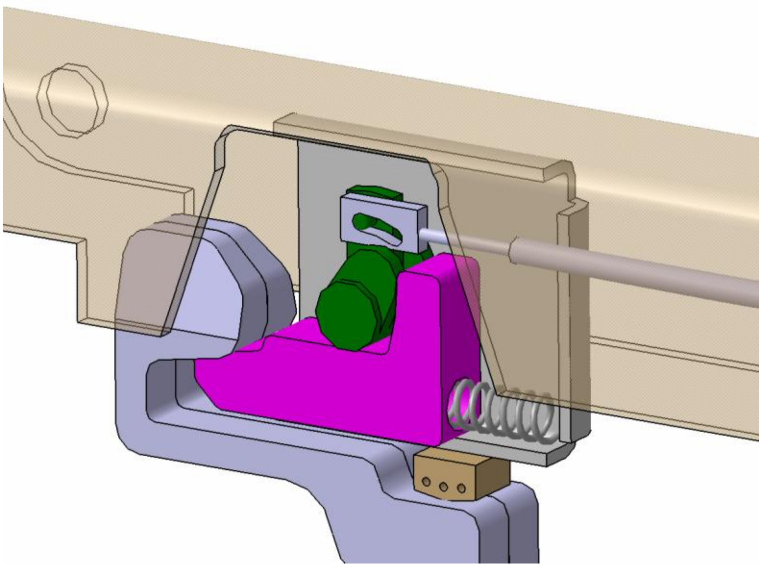


Figure 34 - The excentric part (green) have two functions when it is rotated in two directions

4.1.4. Advantages

From the second evaluation, some parts of the final solution were outstanding in comparison to the excluded concept. The advantages are presented below:

- Since the tilt mechanism is separated from the front and rear interface, the position of the interface module itself is fixed independent on the tilted position. That means that the system has four independent support points that secures the position independent on the tilted position.
- The counterparts mounted on the basic carrier leave little freedom to attach add-on modules with another attachment solution. In particular the rear interface counterpart is integrated in the design of the basic carrier. The design of the both counterparts follows the design rules defined in chapter 3.
- The two direction of the grip good correspond to the function of the product. Lifting up the grip meaning detach the rear interface, and pulling down meaning release the tilt mechanism.

4.2. Prototype

In order to make a proper evaluation of the function, and to learn if the final solution worked as intended, a prototype was build. Since the main theme of the thesis was the development of the interface, the prototype was a simplification of the final solution.

For the prototype the tilt mechanism was fully excluded. That meant that the prototype only contained of the two interfaces and the grip. By excluding the tilt mechanism, the complicated eccentric component could be simplified. To simplify manufacturing, some complicated, non-load carrying parts was made in ABS plastic in rapid prototyping. Parts that was taking up load and had a relatively simple design, was manufactured in aluminium and steel in the workshop at the department of AOZ.

Since the prototype was build to evaluate the function of the final solution, a replica of the carrier had to be designed. The replica of the carrier contained of a framework of aluminium, on where the counterparts of the interface were mounted. It was realized that it could be a problem with the exact measured of all parts. Therefore the length of the framework could be adjusted, as well as the height of the counterparts in the front. Pictures of the prototype are shown in the figure below. Drawings of the prototype can be found in appendix IX.

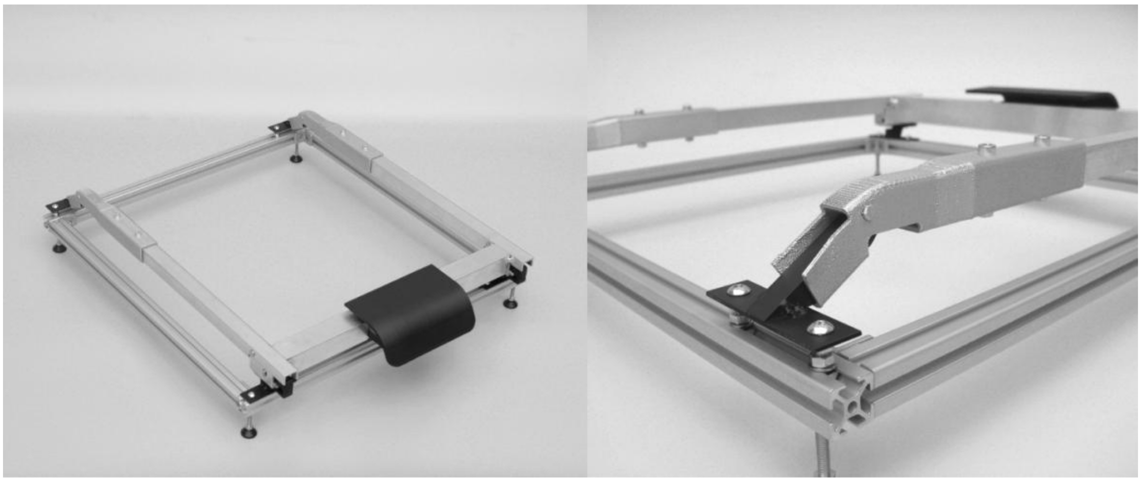


Figure 35 – A picture of the prototype (left), and a detail view of the front interface (right)

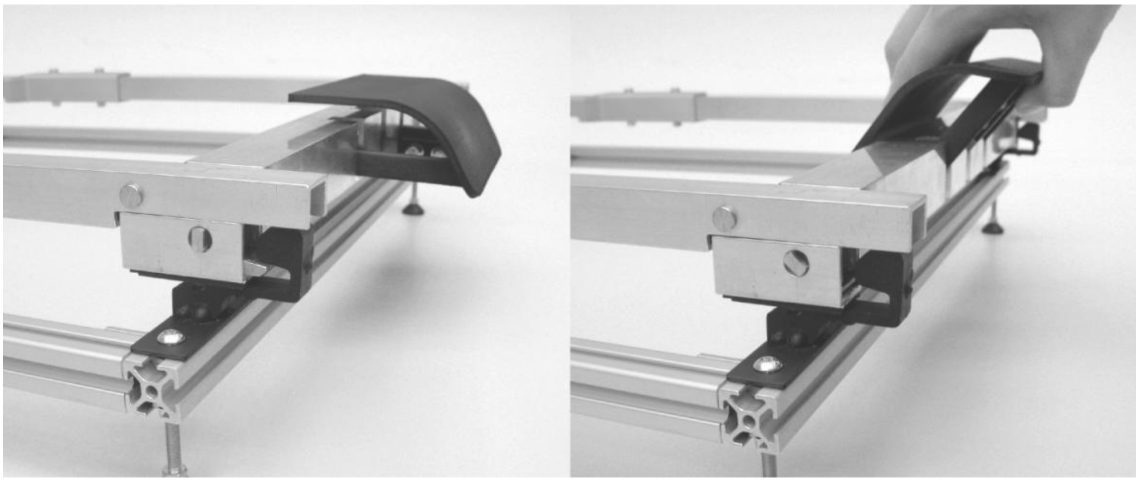


Figure 36 - Detail views of the prototyped rear interface in a closed (left) and a open (right) state

4.3. Evaluation

It is important to evaluate the final solution to justify its functionality and performance. Even though evaluations were conducted throughout the development process, a final evaluation was conducted in order to verify the final solutions towards the specification defined in the product specification phase of the project. Apart from the evaluation towards the list of requirements, categories like the ability to replicate the interface and its function as well as usability were more thoroughly evaluated.

4.3.1. List of requirements

As the intention of the List of Requirements was, the different requirements were verified towards the final solution. For each requirement it was decided if the final solution fulfilled the requirement or not. The evaluation towards the list of requirements was mainly based on the prototype. Since the prototype however was a simplification of the final solution, some requirements had to be based on the CAD model. For some requirements, neither the prototype nor the CAD model could answer, therefore no evaluation of those requirements could be made. The fully evaluation of the list of requirements can be found in appendix IV.

Overall most of the requirements were fulfilled by the selected solution, some were however not fulfilled. The requirement that the front interface should have an open and a close state was not fulfilled. The plug-in design does not provide a distinctive open nor a closed state, its state is dependent on the rear interface. For the mechanical performance requirements, only a static load case simulation have been conducted, see part 4.3.3., therefore no other data was available for the validation. Neither is any simulation nor test made to evaluate its performance towards impact from the environment, such as ice and dirt.

One requirement was that the interface should provide an anti-theft system. The selected solution has been designed for implementing a lock-cylinder, it is however not considered further. For material and process selection, choices have been made among Audi known material suppliers and manufacturing methods. Since Audi do have control of their suppliers in terms of meeting emission demands, the emissions of any dangerous emissions as well as emission of carbon dioxide is covered.

4.3.2. Replicablability

The main focus of the development has been on the exclusivity of the interface. Therefore, one important evaluation is if the interface is unique for Audi or not. To evaluate the exclusivity, the design rules for exclusivity defined in chapter 3 were recalled. When evaluated how unique the interface was, only the counterparts on the carrier was considered since those are left for any competitor to attach any add-on modules.

The aim with the exclusivity was to make the interface difficult for competitors to replicate. Hence, one of the competitors to AOZ was asked to give their opinion in terms of ability to replicate the interface. The competitor is a German manufacturer of accessories for cars, mainly tow bar mounted. The company was concurrently with the thesis work involved in the predevelopment of the rear carrier system at Audi, meaning that they had a non-disclosure agreement with Audi. Therefore they could be asked for this purpose.

In comparison to the design rules of exclusivity, both the front as well as the rear interface of the final solution is geometry fit interfaces. According to the design rules, a geometrical fit is easier to replicate. However, if the further categories are evaluated the interface provide both a closed geometry as well as a hidden geometry in the system solution. It is important to keep in mind that the design rules not are defined and distinctive steps. For the rear interface the component is free, the area to attach in is an inner closed geometry though. Also the rear interface provides a smooth geometry, with a small groove as exception.

Even though the interfaces on the final solution not fully follow all the design rules for exclusivity, it still will be considered as a difficult interface to replicate. This conclusion is also supported and confirmed by the analysis of the interface done by the competitor.

One of the levels of uniqueness from figure 19, was to reach the set of solution that protect the interface, or part of it, through a patent. In order to determine the patent potential of the final solution, the two interfaces was found interested to study further. The patent department at Audi conducted a research of the possibility to apply for a patent. The result of the research showed that no infringement to current patents existed, and it was therefore decided to do a patent application.

4.3.3. Mechanical analyses

Even though the main focus was the uniqueness of the interface, the thesis work also aimed to develop a concept of an interface module between the carrier and any add-on module. Some of the requirements from the list of requirements were related to mechanical performance. For example, the interface should withstand a normal use case with 100 kg loaded weight.

The main focus during the design of the concept was not the dimensioning for each component. Hence, a mechanical stress analysis will give an indication were strengths and weaknesses are. Since a simulation only will be an indication, no advanced simulation software was used. The simulation has been made in the FEM-module of Catia V5. The simulation of a load case was done of the components for each interface where concerns of its strength were and where critical areas were identified.

For the front interface, the hollow profile on the add-on module part was defined as critical. A simulation of a vertical applied force was made on the critical part. A picture of the component, as well as how the boundary conditions were defined is shown in figure 37. For the rear interface the counterpart on the carrier was defined as critical, and hence a simulation of that component was conducted. The component and how the conditions for the simulation were defined are shown in figure 37.

The requirement of the mechanical performance was that it should carry a load of 100 kg during a normal use case. Even though normal use case would be during driving, hence dynamic load case, it was decided to do a static analysis of the two components as an initial indication of the design. The static load case was defined as pulling in upward direction. The 100 kg was assumed equally distributed between the four attachment points, meaning 25 kg on each attachment point. For simplicity, a force of 250 N was applied on each component in figure 37. For both simulations were the material defined as medium carbon steel, with yield strength of 350 MPa and Young's Modulus of 210 GPa, (Ashby, 2011). The simulation gave two important results respectively; the von Mises stresses in the component and the distribution of stress concentration in the component.

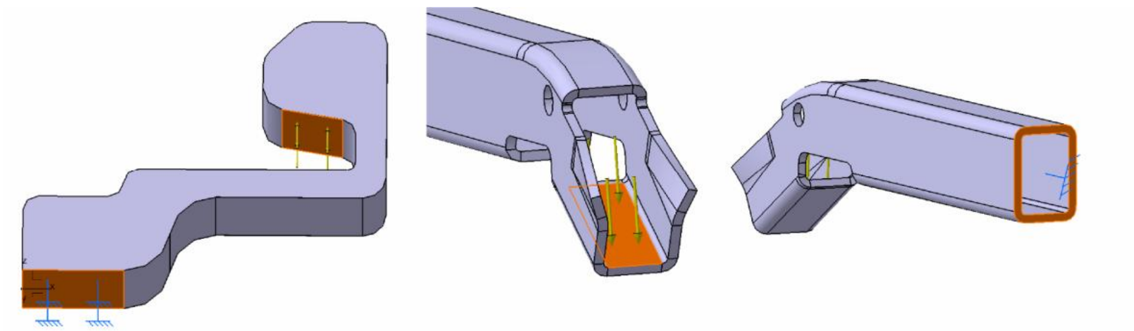


Figure 37 - The counterpart rear (left). The bottom part is fixed in all directions, and the force is applied upwards in surface marked with arrows. The simulated section of the front interface is applied with a force on the surface marked with arrows (middle) and fixed in the intersection surface (right)

Figure 38 shows the result from the simulation of the front interface. The maximum stress in the component is calculated as 39,7 MPa. From the colours in the figure it can be seen that there is a high stress concentration close to the fixed end and on the under side where the cut-out begins. When comparing the maximum calculated stress in the component with the yield strength of the material, the calculated stress is around a factor 10 lower. Hence, the component will not deform during a static load case as defined in the simulation. Further, the stress concentration in the back can be neglected due to the defined conditions in the simulation. Critical stress concentrations are however the ones in the opening. These have to be considered in a further development of the component.

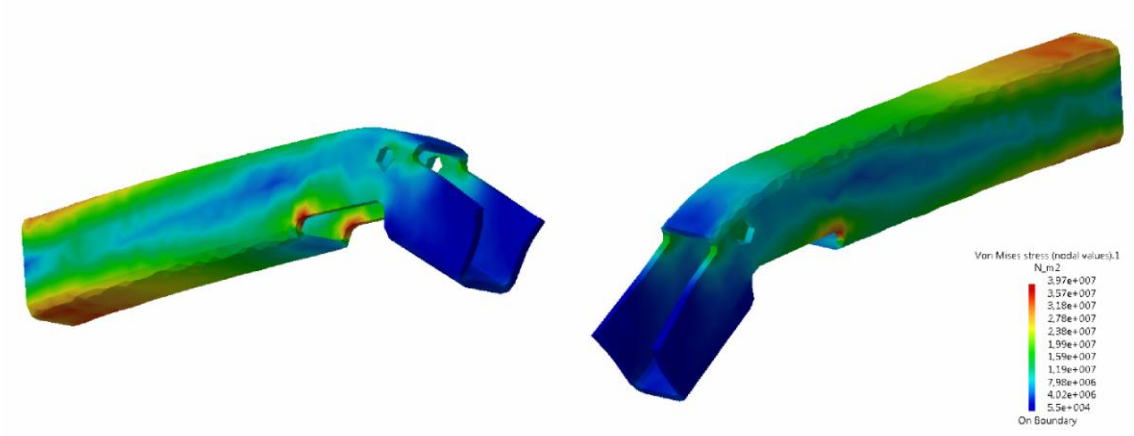


Figure 38 - Result from the simulation of the front interface showing the von Mises stresses in the component

The result from the simulation of the rear interface is shown in figure 39. The maximum von Mises stress are calculated as 48,8 MPa. As for the front interface the counterpart of the rear interface will be steel, meaning that there is a factor 10 between the material yield strength and the calculated maximum stress in the component. That also means that the component will not be deformed. Studying the stress distribution it can be seen that the two areas where the concentration is high is where the colour is red. Also here, the stress concentration in the component can be considered during a redesign or further development.

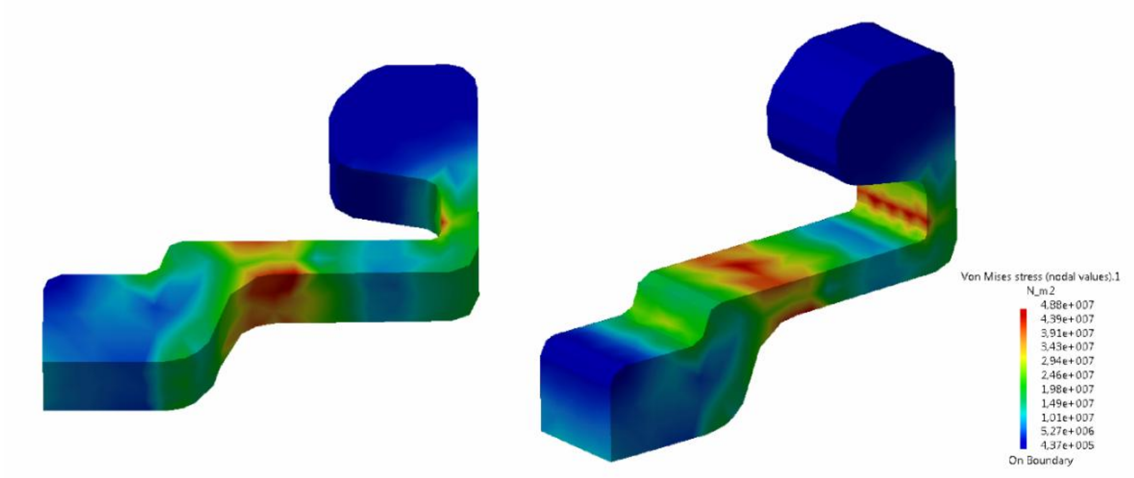


Figure 39 - Result from the simulation of the rear interface showing the von Mises stresses in the component

One requirement from the list of requirement was the ability to manufacture the different components, i.e. the design form manufacturing (DFM). The DFM rules were partly considered during the cost calculation and partly considered during the design of the prototype. The conclusion is that all parts can be manufactured but all components are not optimized.

4.3.4. Prototype testing

One of the purposes with building the prototype was to justify the function of the concept. Since the tilting was excluded on the prototype, the focus of the prototype testing was the front and rear interface.

One of the concerns was the front interface, and its attachment. The plug-in solution did work as expected. However, it was found difficult to know when the interface was in position. To make the attachment more convenient, the counterpart can be redesigned with a clearer definition of the groove. The carrier can also be equipped with a stopper to indicate when the plug-in movement are enough. These are however issues that is possible to solve. Further it must be mentioned that the interface module will never be mounted as it is on the prototype, it will always be a part of the add-on module. That gives extra weight to handle, which can affect the attachment of the front interface positively.

The rear interface also worked as expected. The construction was however very filigree and didn't gave a solid and robust impression. During pull-down movement of the attachment, a high force has to be applied. This is due to the selection of the spring that supports the shim. As for the front interface, extra weight from the add-on module can give an advantage for this issue.

Since the front part of the interface was made in ABS plastic, it gave a non-desired flexibility in the system. Therefore, the ghost locking, meaning that the rear interface not can be attached if the front not is sufficient attached could not be tested. If the front interface was plugged in too much, the ABS component only flexed when attaching the rear interface. This is however only a prototype issue and the assumption is that it will not appear in the real product since the front interface will be a steel component.

5. Discussion

The following chapter aims to summarize and reflect upon the conducted work. The analysis will be based on the work process, the final solution and the prototype. The chapter also contains recommendations for a further work with the result of this thesis.

5.1. Analysis

There are many things that can be discussed in a master thesis project. In this section the conducted work are analysed in three categories; method, uniqueness and general.

5.1.1. Method

During the project, the method suggested by Ulrich and Eppinger (2012) have mainly been used. Already early in the project some parts of the methods were selected to be used, some parts not, see chapter 3.1. Even though the initial plan was to follow the process in figure 17, adjustments in the plan was made when new conditions emerged. The process that actually has been used during the project is shown in figure 40.

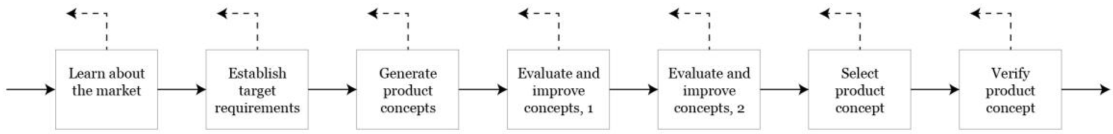


Figure 40 - The conducted development process

The main differences between the planned process and the actual used process were the first initial work and the way from the generated concepts to the concept selection. The initial work did not contain any customer-focused research, such as the first step in figure 17, "Identifying customer needs". It rather contained research focused on learning about the market and the context of the product. The customer need was however covered by feedback from the engineers at AOZ. During the process to a concept selection decision, it was found that the two concepts not was designed and elaborated enough for a decision. Therefore, the step from figure 17 called "Generate product concept", was followed by two steps of evaluations and improvements in order to get sufficient basis for the concept selection.

The fact that the project has been conducted on site with the engineers at AOZ had resulted in both advantages as well as some drawbacks when it comes to the used method. On the advantage side, support and suggestions have always been present in terms of the work progression. The use of defined methods have however not been supported to the same extend.

Further it must be mentioned that a wider range of different methods could have supported the work even more. The literature used covers the main product development methods, especially the early phase that have been used in for the thesis work. If more literature had been used, the selected methods could have been supported and confirmed even more. A wider range of literature could also have provided more examples. From the inspiration from examples could have supported the progression of the some time stagnated work.

CAD was used already from the early phase as a mean to communicate all different ideas and solutions. Since many of the ideas and solutions have been complicated and difficult to draw on a piece of paper, the different CAD models have supported as a useful tool. As described in section 3.3.3, for the first CAD models of the ideas dimensions were not considered in order to keep the focus on the representation of the idea. During the later phase, when the dimensioning were more important it became difficult to change the measures since they already was defined. Further, when the prototype was built it was realized that the dimensions hade been set in the lower limit of the realizable level, which resulted in a very filigree design. That resulted in a negative impression when studying the prototype. On one hand, the dimensioning gave opportunity for improvement but on the other hand it took focus from the actual function. For example, a simple hand sketch in the initial idea generation phase could have helped to avoid the dimensioning problem.

5.1.2. Uniqueness

The aim of creating an Audi unique interface has been the key focus during the whole project. Even though it was clear from the beginning that the uniqueness should be the focus, it has also been the theme that has caused most issues and concerns during the project.

During the early phases in the project, it was defined what a unique interface was. The search for a definition was found important for the proceeding work, since a definition would support the definition of a clear goal. Nevertheless, no distinctive definition of a unique interface was found. The defined design rules in chapter 3 for replicability replaced the lack of a definition to some extent. The design rules were also not the optimal solution since they not were distinctive rules, but more suggestions of how to design an interface that is difficult to replicate.

During the research of different attachment techniques, a paradox occurred. The research focused on finding solutions that was difficult to replicate. However, when something was found in the research, it apparently could be replicated. The optimum would have been to have an idea that could not be found during the research. It was like doing a research and afterward ask the question; what have not been found?

At the same time the ability to replicate must not be a matter of yes or no, there is also a grey zone to consider. The ability to replicate can be considered as yes for some competitors but as no for other. In some cases a competitor can be able to replicate in a way that were not considered from the first place. In the worst case everything can be fasten with cable straps and tape.

The early decision of excluding a material and process uniqueness and the electrical uniqueness can also be reconsidered. The factors that lied behind the decision were the secondary focus that the product should be able to realize in a close future and able to use by a customer. If the weighting of the uniqueness had been stronger, the electrical solution would be the best solution. This is also shown in figure 18, where the electrical uniqueness got the highest potential to reach the Audi uniqueness. Also here it must be mentioned that there is no distinctive difference between the different categories mentioned. The possibility of combining an electrical system with a high performance material, inspired form an already existing solution still exists. For the conducted project, it was however decided to consider the three areas as separate solutions.

The developed concept of the interface module does fulfil the defined design rules for replicability. The patent research also showed that it is a possibility to protect the interface through a patent, why a patent application has been made. If the developed interface actually will provide Audi with uniqueness on the market can at the end of the thesis work not be decided upon. If the patent application is accepted, Audi has the possibility to launch add-on modules with an interface protected through the patent. Competitors can however still provide their add-on modules with another attachment solution for the Audi carrier system. If they will do that is difficult to predict, the only way for Audi to learn if is to launch their add-on modules and see.

5.1.3. General

Even though the project had its main focus on the uniqueness, the selected solution had to be a functional product. Therefore functions like the tilt mechanism and the usability also were considered. These have however not got the same attention as the interface solution.

If the tilt and the usability have been fully excluded from the development process the interface would also reach another outcome and also a higher level of uniqueness. This does not mean that the integration of the tilt mechanism and the consideration of the usability are bringing disadvantages to the product, it more spread out the focus from only the interfaces to the interface module.

In the end of chapter 3, two evaluations of the two concepts were conducted. The evaluations were based on the CAD model as well as the mental image of the two concepts. Such evaluations were found difficult since the two concepts had reached different levels of fulfilment. Some parts of the first concept had got lot of attention for the design, whereas other parts have got less attention. For concept two it was the opposite. This made the evaluations difficult to make, and the different levels of design fulfilment could have contributed to a misleading result of the evaluation. Nevertheless, the mental image as well as the idea of each concept has always been kept, meaning that the evaluation anyhow is based on comparable grounds.

5.2. Future Recommendations

During the conducted work some themes have been excluded or overlooked in order to keep the content within the framework of the thesis. This section describes recommendations that can be considered for future work of the topic.

The decision to proceed with a mechanical analogy solution was based on the fact that the interface module also should fulfil the requirement of usability, low complexity and cost, to mention a few. If a future adaptation or redesign of the interface will be made with a stronger focus of the uniqueness, the solution of reaching the uniqueness through an electrical solution can be further studied. Implementing an electronic interface solution, other possibilities emerge. The carrier can communicate with the car and for example indicate the attachment state of the add-on module to the driver. In terms of uniqueness, an electrical attachment solution gives possibilities not only to communicate with the add-on module as suggested in chapter 2.2. The carrier can sense if the add-on module is an Audi add-on, and if not a message on the display can be showed; “Your add-on module is not provided by Audi”.

The developed interface is developed to a concept state. That means that for a future market launch further development have to be made. During the manufacturing of the prototype it was found that the design of the concept had very small dimensions. Even though simulations have been made for the counterparts with successful results, the dimensioning have to be considered for a future ramp-up development. Also requirements like crash safety have not been considered during the development, why the dimensioning as well as the design must be further considered. Future work can also be to conduct the test required to complete the evaluation towards the list of requirements.

The integration of the interface module into any add-on module has not been considered in the project. The developed product provides however a possibility to attach or integrate any of the suggested add-on modules from chapter 2.2. For a future development of add-on modules, the design of the tilting bars of the interface module can be considered in order to better fit the design of the add-on module. Further work can also be conducted on the cost calculation. During the conducted cost calculation, only the manufacturing of the components was calculated. For a future development of the interface, the assembly cost have to be considered.

6. Conclusion

This chapter present the conclusions of the conducted project, based on the analysis in chapter 5.1. The initial research questions from chapter 1.2.2 are recalled and the conclusions from the project are aimed to answer these questions.

The two questions that were defined early in the project were:

Q1. What add-on modules will Audi's top ten markets demand in the future?

A1. The initial research showed that there is a wide range of potential add-on modules that can be used for transportation of the basic carrier. Three areas of transport were defined; general transport, active lifestyle and professional use.

Q2. How can the interface between the tow bar mounted carrier system and the add-on modules be designed so that add-on modules for the new tow bar mounted basic carrier provided by AOZ are unique on the market?

A1. There are many factors that influence what a unique interface is and how a unique interface can be designed. However, during the conducted study of existing interface applications design rules for unique interface design were defined.

A2. Through structured product development methods as well as the defined design rules for unique interface design, an interface between the tow bar mounted carrier and an arbitrary add-on module has been developed. The interface contains of two sub-interfaces, front and rear. The front interface is attached through a plug in principle and fixed through the attachment of the rear interface. The rear interface is analogue a door lock, with a shim that clamps into a corresponding counterpart.

A3. The evaluation made of the selected solution shows that the interface fulfils the requirement specified in the early phase of the development process. It also shows that uniqueness is reached, partly though the technical difficulty to replicate the interface and partly through a patent application.

A4. The thesis work resulted in a developed concept of an interface module with a unique attachment system for Audi, yet fulfilling a convenient use for the customer as well as low complexity and weight on the carrier system. The result can contribute to strengthen Audi's position on the accessory aftersales market.

7. References

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8. Appendices

The appendices referred to in this report aims to give the interested reader an expansion of the material. The appendices are:

I. ***Compilation of the sources from the research of potential add-on modules***
II. ***Summary of the interview with the colleagues from Audi China***
III. ***Compilation of all ideas for potential add-on modules***
IV. ***List of Requirements***
V. ***The Pugh-matrices used in the concept screening***
VI. ***Explosion drawings of the two concepts***
VII. ***Cost calculation***
VIII. ***Drawing of the final solution***
IX. ***Drawings of the prototype***

Appendix I – Compilation from the research of the add-on module potential

General carrier solutions:

Sawiko:
http://sawiko.de/ [21.01.13]

MFT Transport systems:
http://www.mftgmbh.de/ [18.02.13]

Pro-user:
http://www.pro-user.ch/index.php?page=428/ [18.02.13]

Tow box:
http://www.towbox-deutschland.de/ [20.02.13]

Home usage:

Garden:
http://www.a-endruweit.de/egholm2100/ese_egh_2100tiptrail.htm [21.01.13]

Salt or sand spreader:
http://www.snowexproducts.com/salt-spreaders/salt-spreaders [18.01.13]

General lifestyle:

Report from survey of general Lifestyle:
http://www.ons.gov.uk/ons/rel/ghs/general-lifestyle-survey/2010/index.html
[04.02.13]

Biking:

E-bikes:
http://www.electric-bicycle-guide.com/electric-bicycle-statistics.html#gallery[pageGallery]/0/ [31.01.13]

Statistics purchased bikes:
http://www.ibike.org/library/statistics.htm [31.01.13]

Habits Biking:
http://usgovinfo.about.com/cs/healthmedical/a/aawalking.htm [27.02.13]

Trends E-Bikes:
http://www.auto-nachrichten.net/alternative-antriebe/e-bikes/e-bike-im-urlaub-eine-neuer-trend/ [27.02.13]

Scooter carrier:
http://www.sawiko.de/hebo-matic.php [21.01.13]

Skiing:

Forum with carrier solutions for VW-Multivan:
http://www.t4forum.de/wbb3/board19-technik-bereich/board120-umbauten-tuning/board8-tipps-und-tricks/121901-gr%C3%B6%C3%9Ftester-und-bestester-heckkoffer/ [18.01.13]

Fiat 500 ski carrier:
http://www.langer.de/net/index.php?option=com_content&task=blogcategory&id=251&Itemid=1438&titelspezial=Fiat+Dachtr%E4gersysteme&ford=1 [18.01.13]

Kite surfing:

Kite buggy:
http://www.kitesail.de/kitesailing_tips-infos/kitesailing_kitebuggy.htm [17.01.13]

Kite surf statistic:
http://www.sbckiteboard.com/search_article?news_id=418&uniqid=1996 [31.01.13]

Segway:

Segway use:
http://www.segway.com/about-segway/media-center/index.php [17.01.13]

Segway for car integration:
http://auto.pege.org/2007-iaa/flextreme-segway.htm [24.01.13]

Opel E-flex:
http://ipony.de/?p=291 [24.01.13]

Rescue Segway:
http://www.segway.de/type-rettung.php [24.01.13]

Craft men:

Craft men mobility:
http://isuzu-rostock.de/index.php?id=34 [21.01.13]

Toolboxes:
http://www.preisregen.com/produkte/werkbank-werktisch-arbeitsbank-stabil-und-robust-mit-haken-5043632 [21.01.13]

Camping:

Foldable camping table with chairs:
http://1-geo.de/Campingmoebel/Camping-Tische/Tischgestell-Alu-Bambus-150x86cm-campart-travel-TA-0821-Picknicktisch-A::2108.html [21.01.13]

Camping integration in VW-Multivan:
http://de.autoblog.com/2012/04/03/2-in-1-vw-t5-van-and-camper-zum-ausziehen/ [31.01.13]

Camping integration in other car models:
http://www.manager-magazin.de/fotostrecke/fotostrecke-85200.html [31.01.13]

Car-integrated shower:
http://tinyhousetalk.com/extreme-car-camping/ [13.02.13]

India:

Mountain biking India:
http://www.indiaafricaconnect.in/index.php?param=news/5087/culture-tourism/111 [24.01.13]

Paragliding:
http://www.atoai.org/activity/activity-image.html?sn=17 [24.01.13]

Trekking:
http://www.imaginative-traveller.com/activity-holidays/walking-trekking-holidays/trek-equipment [24.01.13]

USA:

Car mounted toilet, Bumperdumper:
http://bumperdumper.com/bumper2.htm [25.01.13]

Appendix II – Summary of the interview with colleagues from Audi China

Interview conditions: Telephone meeting 18 February 2013.

Aim:
To get a brief understanding from the lifestyle in China, and find possible areas where the tow bar mounted rear carrier can be used.

1. **Presentation of participators and of the research topic.**
   a. Björn Granström – Master Thesis Worker, AOZ, (Ingolstadt, Germany).
   b. Sebastian Schierk – Engineer, AOZ, (Ingolstadt, Germany)
   c. Jakob Christmann – Engineer, Audi China, (Peking, China)
   d. Chen Yao – Engineer, Audi China, (Peking, China)
   e. Xiwei Fan – Engineer, Audi China, (Peking, China)

2. **Presentation of the specific rear carrier and the intended solution.**
   a. Topic presented, pictured supports as aid for the participators in Peking.
   b. General thoughts about the carrier is following:
      i. Chinese people have difficulties to understand the purpose of the system, since tow bar does not exist in China.
      ii. It will be difficult to get it allowed in China. Due to legislation there is not possible to get another license plate for the vehicle.
      iii. People would rather use the, in China popular, roof rack.

3. **How is the current lifestyle in China?**
   a. Not so stressy as in Germany. The air is bad in Peking. What do you mean by lifestyle more specific?

4. **How is the life in China disposed, (time at work, time at home, time spending doing activities).**
   a. During the weekends the work takes up a big part of the time. I have to spend at least 2-3,5 h by car to get to my office. With an 8-10 h working days and another 2-3,5 h for going home, there is not much time left for doing activities during the weeks. However, during the weekends there is time for shopping and other activities. The shopping malls do have open Sundays as well, which not the German malls has.
   b. When doing activities during the weekends we for examples take the car, or bikes, and going up in the mountains. We can have a barbecue or just walk around. We don´t sleep in the mountains, we just stay for the day.

6. **What types of activities are currently up-coming trends? (comp. USA – Segway riding)**
    a. Typical Chinese activities that are becoming popular are for example: Skiing, Snowbording, wake boarding and of course biking. Kite surfing is an upcoming trend but is more an activity that has expanded in Vietnam.
    b. Other activities that the tow bar mounted basic carrier can be used for can be diving and mountain bikes. However is diving not so popular in China.
    c. E-bikes are a good idea, however is the e-bikes prohibited in some cities.

7. **Does some of these activities require special equipment? What for equipment?**
    a. Wake-boarding as well as Kite-surfing requires a board, where Kite surfing also requires a sail. The bikes and skis are obvious.

8. **Can the required equipment be transported on the rear carrier?**
    a. Yes definitively.
    b. Another suggestion could be a picnic basket mounted on the carrier. When we go somewhere the car is almost always full.

9. **Concluding and summing up questions.**
    a. For maintenance reasons in the cities will not the carrier be considered. The government that response for the maintenance will not choose Audi cars for that purpose.

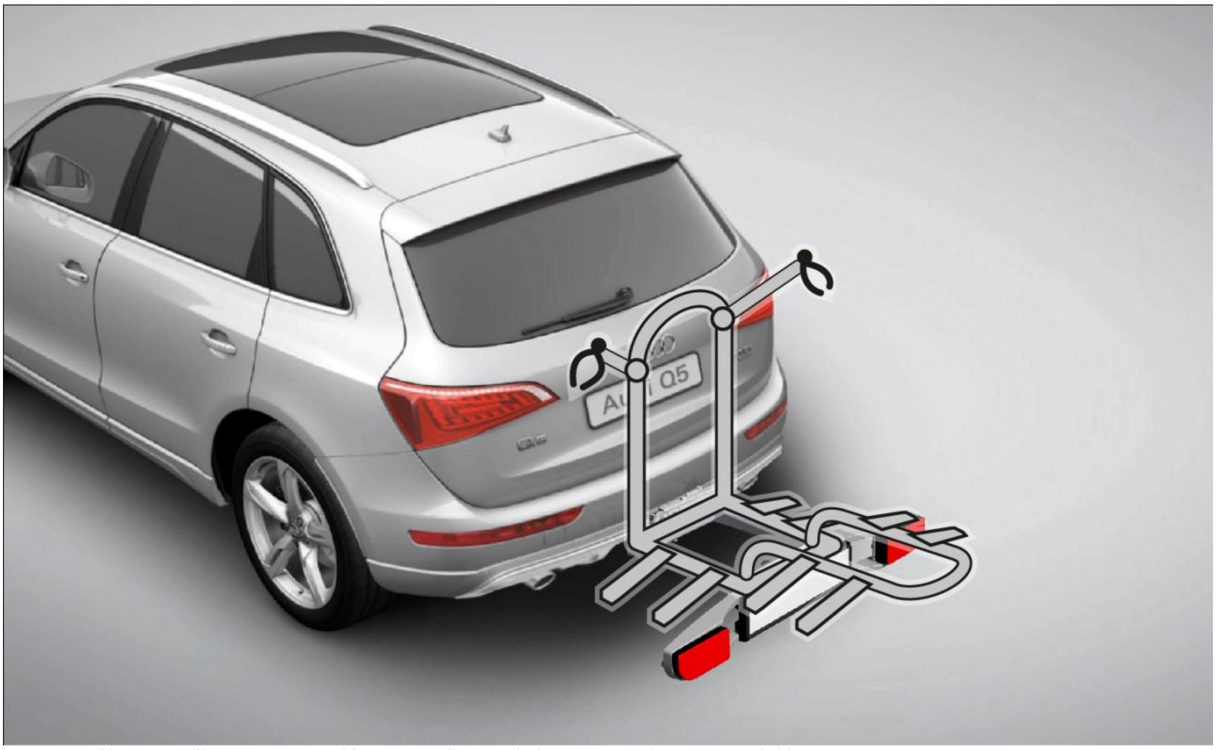
Appendix III – Pictures of potential add-on modules

During the research conducted in chapter 2.2. more ideas that the one showed in the report was generated and illustrated. Below, a compilation of them can be found, here without categorization.

Appendix III, figure 1 - Hard box

Appendix III, figure 2 - Soft box

Appendix III, figure 3 - Bike carrier

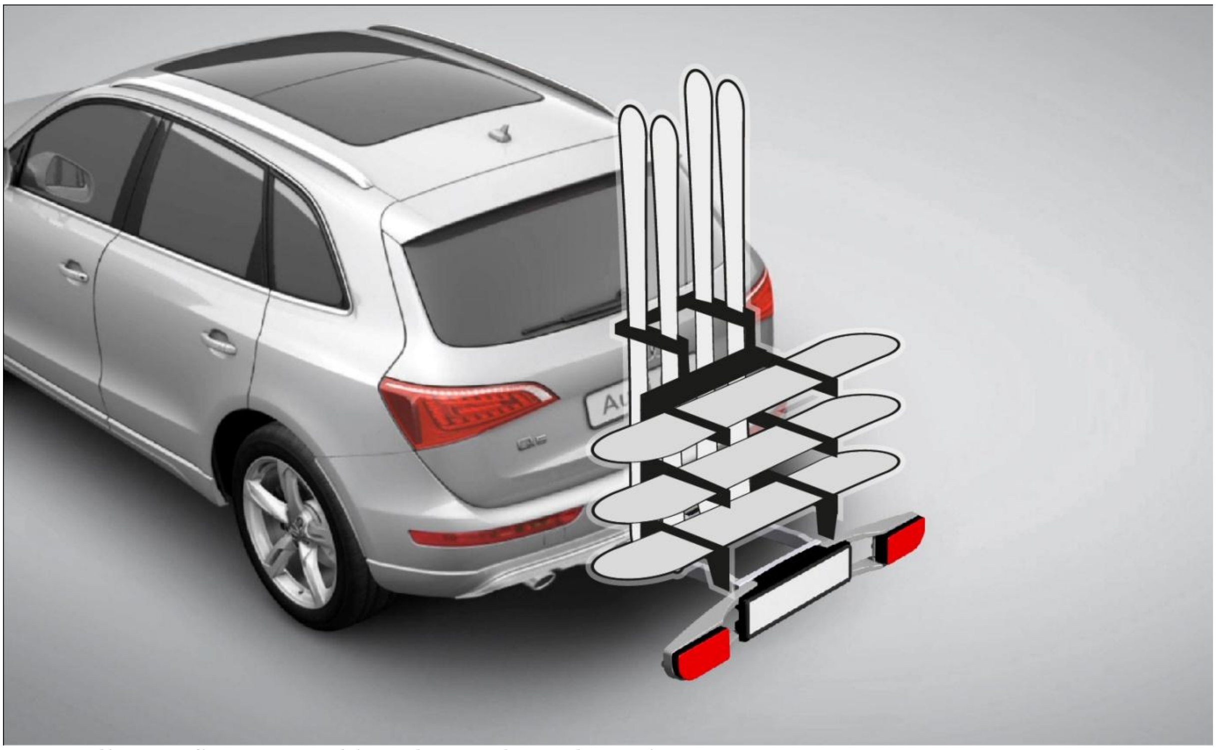


Appendix III, figure 4 - Bike carrier with extension to 4 bikes

Appendix III, figure 5 - Basket

Appendix III, figure 6 - Tiltable shell carrier

Appendix III, figure 7 - Kite surfing kit



Appendix III, figure 8 - Ski and snowboard carrier

Appendix III, figure 9 - Scooter carrier

Appendix III, figure 10 - Segway carrier

Appendix III, figure 11 - Camping table with chairs


Appendix III, figure 12 - Shower

Appendix III, figure 13 - Toilet

Appendix III, figure 14 - Salt or sand spreader

Appendix III, figure 15 - Work table

Appendix IV - List of Requirements

"Development of an interface between a carrier and any add-on module"

AOZ - Audi Genuine Accessories (Ger: Audi Original Zubehör)
PDP - Predevelopment project of the tow bar mounted basic carrier

Number	Cathegory	Level			Sub-cathegory	Requirement	Measurement	Origin	Date	Validation	Comment
1	Function	1			Interface, front	The front interface prevent relative movement	Yes/No	AOZ	30.01.2013	Yes	Main function
2	Function		2		Interface, front	The front interface prevent relative movement through an active action	Yes/No	AOZ	13.02.2013	Yes	
3	Function		2		Interface, front	The front interface enables realtive movement through an active action	Yes/No	AOZ	13.02.2013	Yes	
4	Function	1			Interface, front	Enable rotation through an cross axis	Yes/No	AOZ	30.01.2013	Yes	
5	Function	1			Interface, front	The front interface have two sub components	Yes/No	AOZ	30.01.2013	Yes	
6	Function		2		Interface, front	Both sub components have the same state	Yes/No	AOZ	13.02.2013	No	Not provided by the design
7	Function		2		Interface, front	The front interface have two states, closed and open	Yes/No	AOZ	13.02.2013	Yes	
8	Function	1			Interface, rear	The rear interface prevent a relative movement	Yes/No	AOZ	30.01.2013	Yes	Main function
9	Function		2		Interface, rear	The rear interface prevent relative movement through an active action	Yes/No	AOZ	13.02.2013	Yes	
10	Function		2		Interface, rear	The front interface, enables relative movement through an active movement	Yes/No	AOZ	13.02.2013	Yes	
11	Function	1			Interface, rear	Enable rotation through an cross axis (when integrated in tilt function)	Yes/No	AOZ	30.01.2013	Yes	
12	Function	1			Interface, rear	The rear interface have two sub components	Yes/No	AOZ	30.01.2013	Yes	
13	Function		2		Interface, rear	Both sub components have the same state	Yes/No	AOZ	13.02.2013	Yes	
14	Function		2		Interface, rear	The rear interface have two states, closed and open	Yes/No	AOZ	13.02.2013	Yes	
15	Function		2		Interface, rear	The closed state is only possible given a sufficient closed state front	Yes/No	AOZ	19.02.2013	Yes	Not validated by the prototype
16	Function	1			Interface module	The interface module holds for 100 kg load weight during a normal user case	Simulation/Test	AOZ/PDP	30.01.2013	No data	No simulation/test conducted
17	Function	1			Interface module	The interface is able to tilt through a cross axis so that the trunk lid can be closed/opended	Yes/No	AOZ/PDP	30.01.2013	Yes	Main function
18	Function		2		Interface module	The tilted position is fixed through a locking mechanism	Yes/No	AOZ/PDP	19.02.2013	Yes	
19	Function	1			Interface module	The interfaces works after dynamic long term loading	Dynamic testing	AOZ/PDP	30.01.2013	No data	No test conducted
20	Time to market	1				The product are launched 2016	Yes/No	PDP	19.02.2013	Yes	

21	Messures	1			Size	The add-on module can fit in the trunk of the current Q5	Yes/No	PDP	13.02.2013	Yes	
22	Messures		2		Size	The interface have the size of a briefcase	Yes/No	PDP	13.02.2013	Yes	
23	Messures			3	Size	The interface module's maximum measures are W x L x H = 420 x 500 x 100	Measure	PDP	19.02.2013	Fulfilled	410 x 490 x 60 mm
24	Messures		2		Size	The interface module have a minimum wieght	Yes/No	PDP	13.02.2013	Yes	
25	Messures			3	Size	The interface module wieght no more than 3 kg	Measure	AOZ	12.03.2013	Fulfilled	2,665 kg
26	Messures			3	Size	Any komplexity related to weight is concentrated in the add-on module part of the interface	Yes/No	AOZ	13.02.2013	Yes	
27	Messures	1			Compatibillity	The interface module are the same for any add-on module	Yes/No	PDP	13.02.2013	Yes	
28	Messures	1			Dimensioning	The four attachment points manage a force of 1000N (100kg)	Simulation	AOZ/PDP	30.01.2013	Fulfilled	
29	Cost	1				The manufacturing cost of the interface module are minimized	Yes/No	AOZ	30.01.2013	Yes	
30	Cost		2			The cost of manufcturing the components are maximum 50 €	Yes/No	AOZ	19.02.2013	Fulfilled	42,02 €
31	Cost		2			The tool cost are maximum 200 000 €	Yes/No	AOZ	19.02.2013	Fulfilled	148 200 €
32	Exclusitivity	1				The interface is unique for Audi Genuine Accessories	Design Rules	AOZ	30.01.2013	Fulfilled	
33	Exclusitivity		2			The interface is difficult for competitors to replicate	Feedback competitor	AOZ	30.01.2013	Fulfilled	
34	Exclusitivity		2			The interface, or part of it can be protected through a patent	Yes/No	AOZ	30.01.2013	Yes	Research from patent department at Audi
35	Exclusitivity	1				The exclusitivity in the interface module does not complicate the usability of the product	Customer evaluation	AOZ	07.03.2013	No data	No customer evaluation conducted
36	Ergonomic	1			Physical	The interface is easy to use	Customer evaluation	AOZ/PDP	07.03.2013	No data	No customer evaluation conducted
37	Ergonomic		2		Physical	The interface is through a one-hand-grip controlled.	Yes/No	PDP	12.03.2013	Yes	Main function
38	Ergonomic		2		Physical	The grip is positioned over the licence plate	Yes/No	PDP	12.03.2013	Yes	
39	Ergonomic		2		Cognitive	All grip have sufficient haptic	Yes/No	PDP	12.03.2013	Yes	
40	Ergonomic	1			Cognitive	Mishandling, or misuse is not possible	Yes/No	PDP	19.02.2013	Yes	Not validated by the prototype
41	Ergonomic		2		Cognitive	The interface have sufficient labelling	Yes/No	PDP	19.02.2013	No data	
42	Environment	1			Exposion	The interface works after exposion of dirt	Simulation/Test	AOZ	13.02.2013	No data	No simulation/test conducted
43	Environment	1			Exposion	The interface works after exposion of water and ice	Simulation/Test	PDP	13.02.2013	No data	No simulation/test conducted

44	Environment	1			Exposion	The interface works after manufacturing deviations	Yes/No	AOZ	13.02.2013	Yes	
45	Environment	1			Emissions	The material selcted for the interface does not emitt any dangerous emissions for the environment	Yes/No	AOZ	19.02.2013	No data	No analysis conducted
46	Environment	1			Emissions	Manufacturing methods are selected with the carbondioxide emission in mind	Yes/No	AOZ	30.01.2013	Yes	
47	Environment	1			Emissions	Materials are selected with the carbondioxide emission in mind	Yes/No	AOZ	30.01.2013	Yes	
48	Environment	1			Design	The product is designed according to DFE principles	Yes/No	AOZ	30.01.2013	Yes	
49	System impact	1				Any komplexity is concentrated in the add-on module	Yes/No	PDP	13.02.2013	Yes	
50	Protection	1			Theft	The interface module provide an antitheftsystem	Yes/No	AOZ	19.02.2013	Yes	Planned but not included in the design
51	Manufacturing	1				The interface module is manufactured with conventional manufacturing methods	Yes/No	AOZ	07.03.2013	Yes	
52	Manufacturing		2			The manufacturing methods are known by Audi	Yes/No	AOZ	07.03.2013	Yes	
53	Manufacturing		2			The manufacturing methods are known by suppliers to Audi	Yes/No	AOZ	07.03.2013	Yes	
54	Manufacturing	1			Design	The product is designed according to DFM principles	Yes/No	AOZ	30.01.2013	Yes	
55	Manufacturing	1			Design	The product is designed according to DFA principles	Yes/No	AOZ	30.01.2013	No	Not considered

Appendix V - The Pugh-matrices used in the concept screening

Concept screening - Interface, front				
Criterion	Without locking (with tilting)	ISOFIX	Cross-country ski binding	Without locking (without tilting)
Filfilment of the main function (prevent realtive movement)	0	-	-	+
Usability	0	-	-	+
Possibility to replicate	0	-	-	0
Ghost locking	0	0	-	0
Time to market	0	+	+	0
Complexity	0	-	0	+
Sensibility towards tolerances and dirt	0	+	0	-
Sum +	0	2	1	3
Sum -	0	4	4	1
Sum 0	7	1	2	3
Total:	0	-2	-3	2

Concept screening - Interface, front				
Criterion	ISOFIX	Cross-country ski binding	Without locking (with tilting)	Without locking (without tilting)
Filfilment of the main function (prevent realtive movement)	0	0	+	+
Usability	0	-	0	+
Possibility to replicate	0	0	+	+
Ghost locking	0	-	+	+
Time to market	0	0	0	0
Complexity	0	+	+	+
Sensibility towards tolerances and dirt	0	-	-	0
Sum +	0	1	4	5
Sum -	0	3	1	0
Sum 0	7	3	2	2
Total:	0	-2	3	5

Concept screening - Interface, front				
Criterion	Cross-country ski binding	Without locking (with tilting)	Without locking (without tilting)	ISOFIX
Filfilment of the main function (prevent realtive movement)	0	+	+	0
Usability	0	+	+	+
Possibility to replicate	0	+	+	0
Ghost locking	0	+	+	+
Time to market	0	0	0	0
Complexity	0	+	+	-
Sensibility towards tolerances and dirt	0	-	-	0
Sum +	0	5	5	2
Sum -	0	1	1	1
Sum 0	7	1	1	4
Total:	0	4	4	1

Concept screening - Interface, front				
Criterion	Without locking (without tilting)	Without locking (with tilting)	ISOFIX	Cross-country ski binding
Filfilment of the main function (prevent realtive movement)	0	0	-	-
Usability	0	-	-	-
Possibility to replicate	0	0	-	-
Ghost locking	0	0	-	-
Time to market	0	0	0	-
Complexity	0	-	-	-
Sensibility towards tolerances and dirt	0	0	+	-
Sum +	0	0	1	0
Sum -	0	2	5	7
Sum 0	7	5	1	0
Total:	0	-2	-4	-7

Concept screening - Interface, rear						
Criterion	Racing bike pedal	Seat belt bucket	Door lock	Two-cylinder system	TZ-system	Inverted two-cylinder system
Filfilment of the main function (prevent realtive movement)	0	-	-	+	0	+
Usability	0	+	+	+	0	+
Possibility to replicate	0	+	-	0	+	+
Ghost locking	0	+	+	-	+	0
Time to market	0	0	0	0	0	0
Complexity	0	-	+	-	-	-
Sensibility towards tolerances and dirt	0	-	0	-	-	-
Sum +	0	3	3	2	2	3
Sum -	0	3	2	3	2	2
Sum 0	7	1	2	2	3	2
Total:	0	0	1	-1	0	1

Concept screening - Interface, rear						
Criterion	Seat belt bucket	Door lock	Two-cylinder system	TZ-System	Inverted two-cylinder system	Racing bike pedal
Filfilment of the main function (prevent realtive movement)	0	0	0	0	0	+
Usability	0	+	+	0	+	-
Possibility to replicate	0	-	-	-	+	-
Ghost locking	0	+	0	0	0	-
Time to market	0	0	0	0	0	0
Complexity	0	+	0	0	+	+
Sensibility towards tolerances and dirt	0	+	+	+	-	+
Sum +	0	4	2	1	3	3
Sum -	0	1	1	1	1	3
Sum 0	7	2	4	5	3	1
Total:	0	3	1	0	2	0

Concept screening - Interface, rear						
Criterion	Door lock	Two-cylinder system	TZ-System	Inverted two-cylinder system	Racing bike pedal	Seat belt bucket
Filfilment of the main function (prevent realtive movement)	0	+	0	+	+	0
Usability	0	-	-	0	-	-
Possibility to replicate	0	-	-	+	+	+
Ghost locking	0	-	0	0	-	-
Time to market	0	0	0	0	0	0
Complexity	0	-	-	-	-	-
Sensibility towards tolerances and dirt	0	-	-	-	0	-
Sum +	0	1	0	2	2	1
Sum -	0	5	4	2	3	4
Sum 0	7	1	3	3	2	2
Total:	0	-4	-4	0	-1	-3

Concept screening - Interface, rear						
Criterion	Two-cylinder system	TZ-System	Inverted two-cylinder system	Racing bike pedal	Seat belt bucket	Door lock
Filfilment of the main function (prevent realtive movement)	0	0	0	-	0	-
Usability	0	0	+	-	-	+
Possibility to replicate	0	0	+	0	+	+
Ghost locking	0	+	0	+	0	+
Time to market	0	0	0	0	0	0
Complexity	0	+	-	+	0	+
Sensibility towards tolerances and dirt	0	-	0	+	-	+
Sum +	0	2	2	3	1	5
Sum -	0	1	1	2	2	1
Sum 0	7	4	4	2	4	1
Total:	0	1	1	1	-1	4

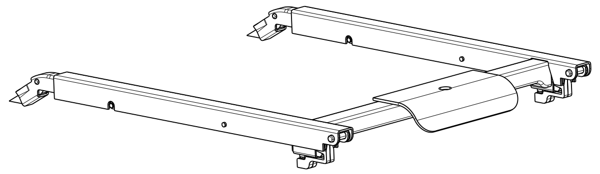
Concept screening - Interface, rear						
Criterion	TZ-System	Inverted two-cylinder system	Racing bike pedal	Seat belt bucket	Door lock	Two-cylinder system
Filfilment of the main function (prevent realtive movement)	0	+	0	0	0	0
Usability	0	+	0	0	+	0
Possibility to replicate	0	+	-	+	+	0
Ghost locking	0	+	-	0	0	-
Time to market	0	0	0	0	0	0
Complexity	0	-	+	0	+	-
Sensibility towards tolerances and dirt	0	-	+	-	+	+
Sum +	0	4	2	1	4	1
Sum -	0	2	2	1	0	2
Sum 0	7	1	3	5	3	4
Total:	0	2	0	0	4	-1

Concept screening - Interface, rear						
Criterion	Inverted two-cylinder system	Racing bike pedal	Seat belt bucket	Door lock	Two-cylinder system	TZ-System
Filfilment of the main function (prevent realtive movement)	0	-	0	-	0	-
Usability	0	-	-	0	-	-
Possibility to replicate	0	-	-	-	-	-
Ghost locking	0	0	0	0	0	-
Time to market	0	0	0	0	0	0
Complexity	0	+	-	+	+	+
Sensibility towards tolerances and dirt	0	+	+	+	0	+
Sum +	0	2	1	2	1	2
Sum -	0	3	3	2	2	4
Sum 0	7	2	3	3	4	1
Total:	0	-1	-2	0	-1	-2

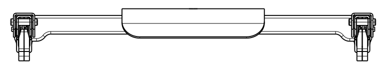
Appendix VI – Explosion drawings of the two concepts

This appendix contains explosion drawings of the final state for the two concepts.
The content is as follow:

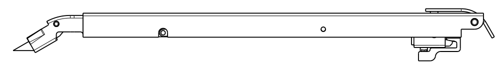
Unterlagen References	Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code
VW 01155	1		30.04.13	Granström		Created
VW 10500						
VW 91101						
VW 91102						
VW 01054						



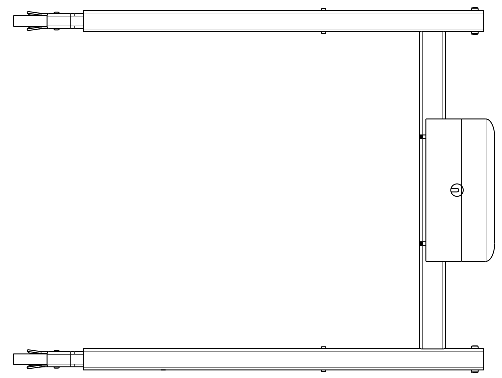
Isometric view
Scale: 1:3



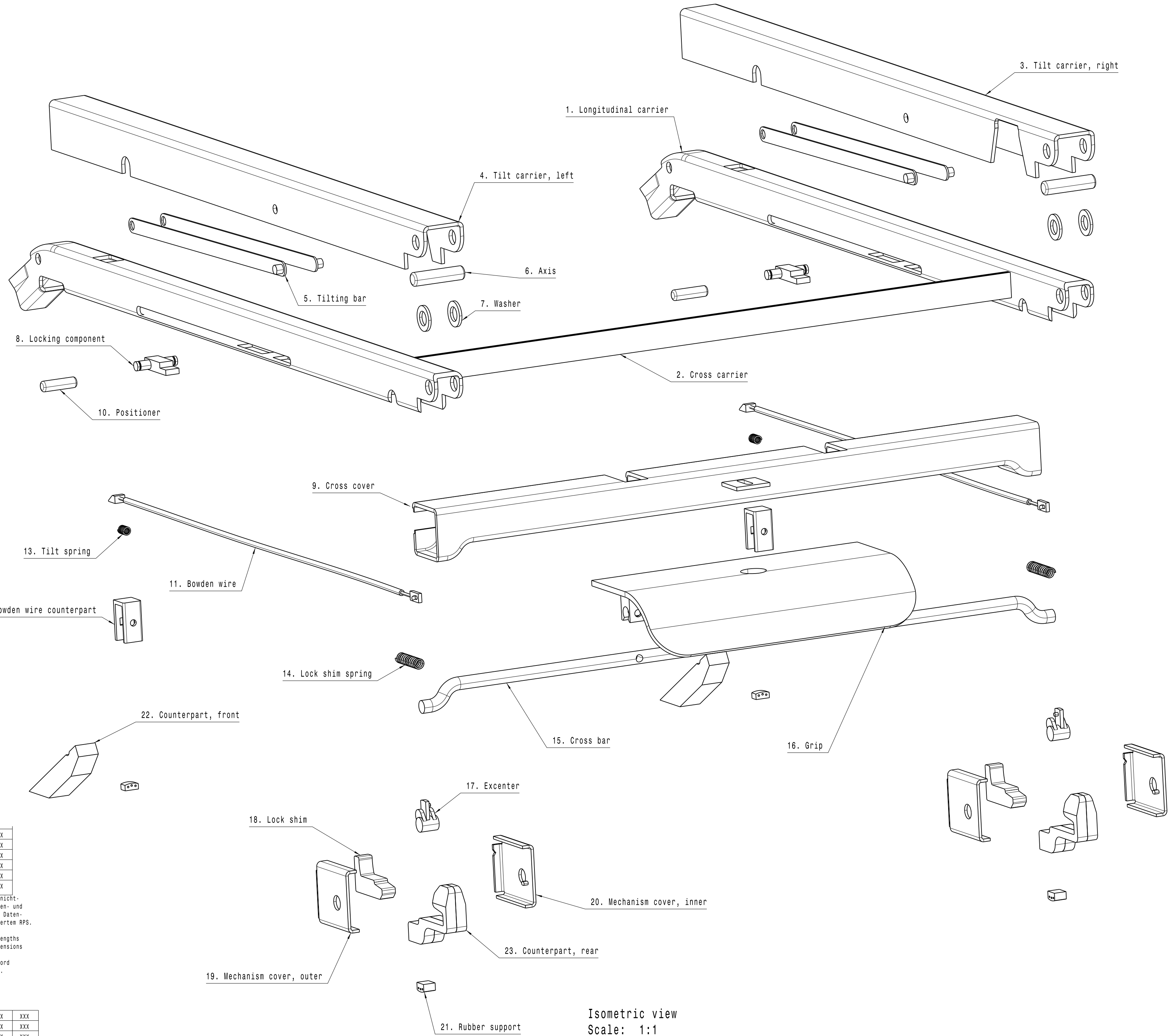
Right view
Scale: 1:3



Front view
Scale: 1:3



Top view
Scale: 1:3



Isometric view
Scale: 1:1

Nr.	Name	Number of items	Material
1	Longitudinal carrier	2	Steel
2	Cross carrier	1	Steel
3	Tilt carrier, right	1	Steel
4	Tilt carrier, left	1	Steel
5	Tilting bar	4	Steel
6	Axis	2	Steel
7	Washer	4	Steel
8	Locking component	2	PA.6.6
9	Cross cover	1	PA.6.6
10	Positioner	2	Steel
11	Bowden wire	2	---
12	Bowden wire counterpart	2	PA.6.6
13	Tilt spring	2	Springsteel
14	Lock shim spring	2	Springsteel
15	Cross bar	1	Steel
16	Grip	1	ASA
17	Excenter	2	Grivory - 55%GF
18	Lock shim	2	Aluminium
19	Mechanism cover, outer	2	Steel
20	Mechanism cover, inner	2	Steel
21	Rubber support	4	TPE
22	Counterpart, front	2	Steel
23	Counterpart, rear	4	Steel

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

	fertig finished	roh raw
>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Form FE 509 02.11 ( ) Bezugsmasz Ref. dim. [ ] Kontrollmasz Control dim. < > Vorrichtungsmasz Fixture dim. Ausfallmasz Temporary dim. Pruefmasz Test dim. Pruefmasz mit Bewertung Dim. to be checked Theoretisches Masz Basic dim. > < Werkstoff-Kennzeichnung Material marking

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr Type-appr.-doc. and type approval number	CAD-System und Verwaltungssystem-Schluessel CAD system and administration code Catia V5
Werkstoff/ Material See Table	Konst.-Verantwortg. Doc resp.
Werkstoffbehandlung/ Material treatment	Name/ Name Granström
Halbzeug/ Semi-finished product	Abt./Dept. I/EG-57
Oberflaechenschutz Surface protection VW 13750 Ofl-	Telefon/Phone +49 841-89 48733

Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.	Gez./Drawn
. . . .	2 655 g			

Sicherh.-Dok. Safety doc.

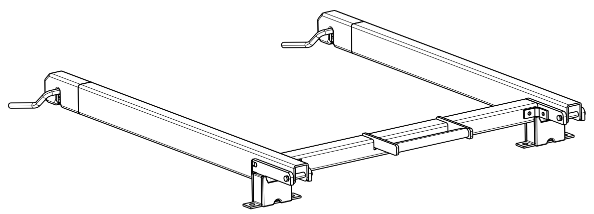
Benennung
Concept 1

Title
Exploded assembly drawing

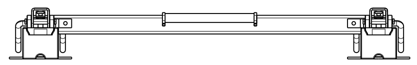
Maszstab/Scale	Teil-Nr. Part-no.	
1:1 1:3	. . . .	Format D.Size A0 Blatt Sheet 1 von of 1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

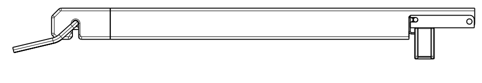
Unterlagen References	Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code
VW 01155	1		30.04.13	Granström		Created
VW 10500						
VW 91101						
VW 91102						
VW 01054						



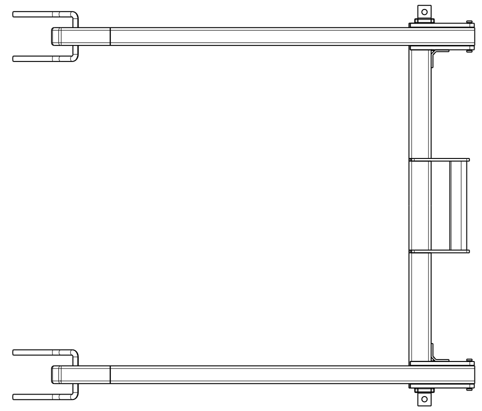
Isometric view
Scale: 1:3



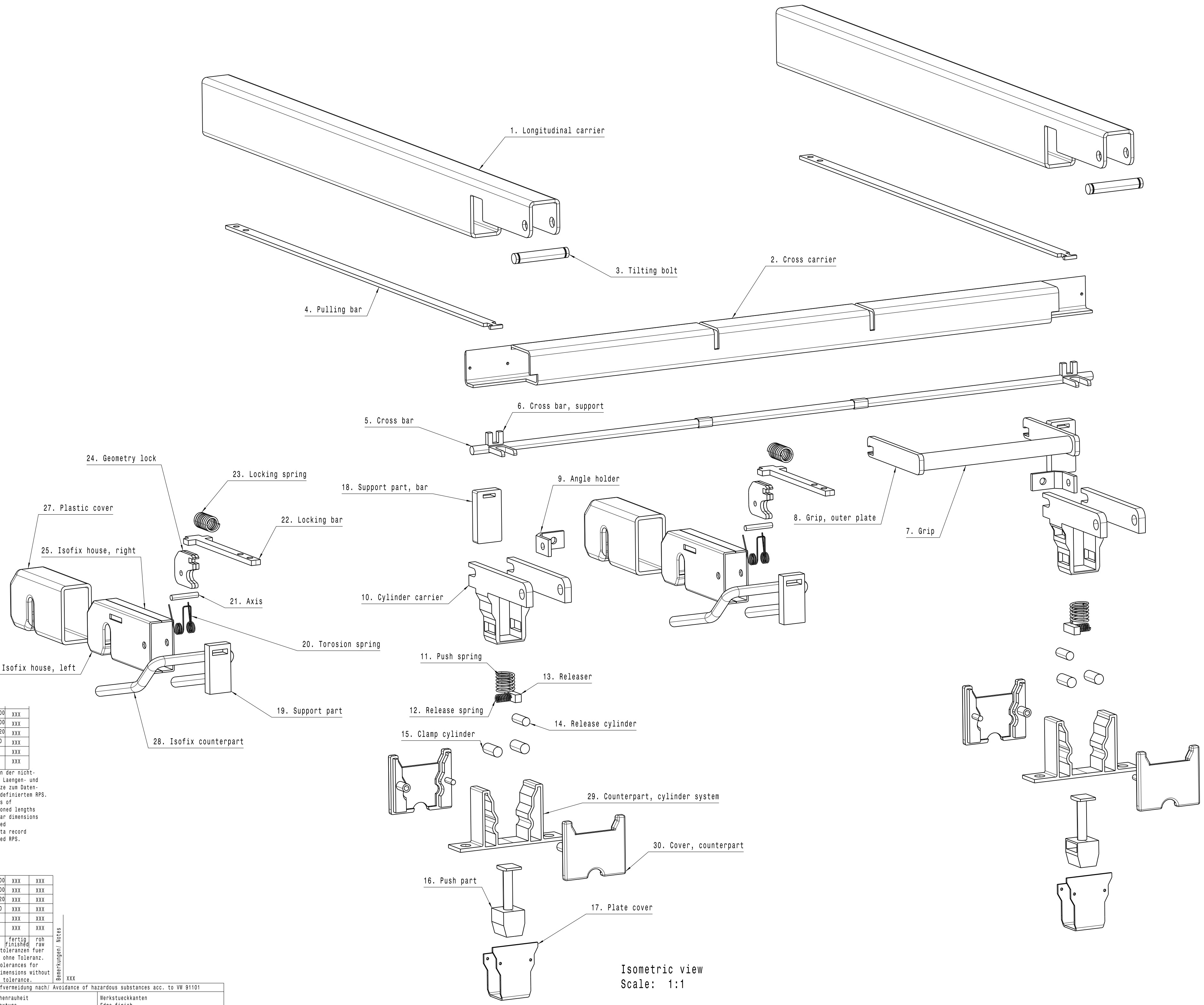
Right view
Scale: 1:3



Front view
Scale: 1:3



Top view
Scale: 1:3



Isometric view
Scale: 1:1

Nr.	Name	Number of items	Material
1	Longitudinal carrier	2	Steel
2	Cross carrier	1	Steel
3	Tilting bolt	2	Steel
4	Pulling bar	2	Steel
5	Cross bar	1	Steel
6	Cross bar, support	2	Aluminium
7	Grip	1	PA.6.6
8	Grip, outer plate	2	Steel
9	Angle holder	2	Steel
10	Cylinder carrier	2	PA.6.6 - 30%GF
11	Push spring	2	Springsteel
12	Release spring	2	Springsteel
13	Releaser	2	Steel
14	Release cylinder	2	Steel
15	Clamp cylinder	4	Steel
16	Push part	2	PA.6.6
17	Plate cover	2	Steel
18	Support part, bar	2	PA.6
19	Support part	2	PA.6
20	Torosion spring	2	Spingsteel
21	Axis	2	Steel
22	Locking bar	2	Steel
23	Locking spring	2	Springsteel
24	Geometry lock	4	Steel
25	Isofix house, right	2	Steel
26	Isofix house, left	2	Steel
27	Plastic cover	2	PA.6.6
28	Isofix counterpart	2	Steel
29	Counterpart, cylinder system	2	Aluminium
30	Cover, counterpart	4	PA.6.6

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS. Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz. General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr Type-appr.-doc. and type approval number	CAD-System und Verwaltungssystem-Schluessel CAD system and administration code: Catia V5
Werkstoff/ Material: See Table	Konst.-Verantwortg. Doc resp.
Werkstoffbehandlung/ Material treatment	Name/ Name: Granström
Halbzeug/ Semi-finished product	Abt./Dept.: I/EG-57
Oberflaechenschutz Surface protection: VW 13750 Ofl-	Telefon/Phone: +49 841-89 48733

Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.	Gez./Drawn
	2 333 g			

Sicherh.-Dok. Safety doc. XXX	Benennung: Concept 2
	Title: Exploded assembly drawing
Maszstab/Scale: 1:1, 1:3	Teil-Nr. Part-no.
Format D.Size	A0
Blatt Sheet	1
von of	1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

Form FE 509 02.11 ( ) Bezugsmasz Ref. dim. [ ] Kontrollmasz Control dim. < > Vorrichtungsmasz Fixture dim. Ausfallmasz Temporary dim. Pruefmasz Test dim. Pruefmasz mit Bewertung Dim. to be checked. Theoretisches Masz Basic dim. > < Werkstoff-Kennzeichnung Material marking

Appendix VII - Cost Calculation

Concept 1

Number	Component	Number of items	Material	Weight (g)	Manufacturing step	Manufacturing method	Time/cykle (s)	Price / component	Items / cycle	Labour level	Machine level	Cost of machine / hour	Labour cost / hour
1	Longitudinal carrier	2	Steel	486	I	Cutted	15,00		1	a	a	30	28
		2			II	Bended (1 cycle)	10,00		1	a	a	30	28
		2			III	Milled	120,00		1	b	b	60	35
2	Cross carrier	1	Steel	107	I	Cutted	15,00		1	a	a	30	28
	Tilt carrier, basic palte	2	Steel	488,5	I	Stamped (2 cycles)	20,00		1	a	c	80	28
3	Tilt carrier, right	1	Steel		II	Bended (1 cycle)	10,00		1	a	c	80	28
4	Tilt carrier, left	1	Steel		II	Bended (1 cycle)	10,00		1	a	c	80	28
5	Tilting bar	4	Steel	12,25	I	Stamped (1 cycle)	10,00		1	a	c	80	28
		4			II	Compressed	10,00		1	b	c	80	35
6	Axis	2	Steel	10,5	I	Bulk component	-	0,05	1	-	-		
7	Washer	4	Steel	1	I	Bulk component	-	0,05	1	-	-		
8	Locking component	2	PA.6.6	2	I	Injection-moulded	-	0,25	2	-	-		
9	Cross cover	1	PA.6.6	68	I	Injection-moulded	-	0,72	1	-	-		
10	Positioner	2	Steel		I	Bulk component	-	0,05	1	-	-		
11	Bowden wire	2	---		I	360 mm long	-	1	1	-	-		
12	Bowden wire counterpart	2	PA.6.6	1	I	Injection-moulded	-	0,17	2	-	-		
13	Tilt spring	2	Spring steel	1	I	Bulk component	-	0,1	1	-	-		
14	Lock shim spring	2	Spring steel	1	I	Bulk component	-	0,1	1	-	-		
15	Cross bar	1	Steel	117	I	Bended (1 cycle)	10,00	0,7	1	a	c	80	28
16	Grip	1	ASA	55	I	Injection-moulded	-	0,78	2	-	-		
17	Excenter	2	Grivory - 55%GF	1	I	Injection-moulded	-	0,08	4	-	-		
18	Lock shim	2	Aluminium	7	I	Extruded	-	0,055	1	-	-		
		2			II	Cutted	15,00		1	a	a	30	28
		2			III	Surface (corrosion resistance)	-	0,70	1	b	-		35
19	Mechanism cover, outer	2	Steel	19	I	Stamped and bended (5 cycles)	50,00		1	a	c	80	28
20	Mechanism cover, inner	2	Steel	19	I	Stamped and bended (5 cycles)	-		1	a	c	80	28
21	Rubber support	4	TPE	1	I	Injection-moulded	-	0,52	12	-	-		
22	Counterpart, front	2	Steel	61,5	I	Cutted	15,00		1	a	a	30	28
		2			II	Milled	60,00		1	b	b	60	35
23	Counterpart, rear	2	Steel	50	I	Laser cutted	20,00		0,5	a	d	90	28
		2			II	Welded	60,00		1	b	c	80	35
		2			III	Milled	60,00		1	b	b	60	35

Labour costs, levels (€/h)	
a	28
b	35
Machine cost, levels (€/h)	
a	30
b	60
c	80
d	90

Component difference:
Bulk component
Plastic components, price given
Component manufactures

Concept 1

Number	Component	Total material weight (kg)	Material add-on (125 %)	Material price (€/kg)	Material cost	Manufacturing costs - Labour	Manufacturing costs - Machine	Manufacturing cost add-on (120 %)	Tool cost	Cost for components / delivered product
1	Longitudinal carrier	0,972	1,215	1	0,972	0,117	0,125	0,290	1000,00	1,552
						0,078	0,083	0,193	1000,00	0,387
						1,167	2,000	3,800	1000,00	7,600
2	Cross carrier	0,107	0,134	1	0,107	0,117	0,125	0,290	1000,00	0,397
	Tilt carrier, basic palte					0,156	0,444	0,720	10000,00	1,440
3	Tilt carrier, right					0,078	0,222	0,360	5000,00	0,360
4	Tilt carrier, left					0,078	0,222	0,360	5000,00	0,360
5	Tilting bar	0,049	0,061	1	0,049	0,078	0,222	0,360	10000,00	1,489
						0,097	0,222	0,383	5000,00	1,533
6	Axis							0,000		0,100
7	Washer							0,000		0,200
8	Locking component							0,000	4800,00	0,250
9	Cross cover							0,000	35000,00	0,720
10	Positioner							0,000		0,100
11	Bowden wire							0,000		2,000
12	Bowden wire counterpart							0,000	4300,00	0,170
13	Tilt spring							0,000		0,200
14	Lock shim spring							0,000		0,200
15	Cross bar	0,117	0,146	1	0,117	0,078	0,222	0,360	1000,00	0,477
16	Grip							0,000	26000,00	0,390
17	Excenter							0,000	4800,00	0,040
18	Lock shim	0,014	0,018					0,000	3500,00	0,110
						0,117	0,125	0,290	1000,00	0,580
								0,000	0,00	1,400
19	Mechanism cover, outer	0,038	0,048	1	0,038	0,389	1,111	1,800	10000,00	3,638
20	Mechanism cover, inner	0,038	0,048	1	0,038			0,000	10000,00	0,000
21	Rubber support							0,000	3800,00	0,173
22	Counterpart, front	0,123	0,154	1	0,123	0,117	0,125	0,290	1000,00	0,703
						0,583	1,000	1,900	1000,00	3,800
23	Counterpart, rear	0,100	0,125	1	0,100	0,156	0,500	0,787	1000,00	3,247
						0,583	1,333	2,300	1000,00	4,600
						0,583	1,000	1,900	1000,00	3,800
									148 200,00 €	**42,02 €**

Concept 2

Number	Component	Number of items	Material	Weight (g)	Manufacturing step	Manufacturing method	Time/cycle (s)	Price/component	Items / cycle	Labour level	Machine level	Cost of machine / hour	Labour cost / hour
1	Longitudinal carrier	2	Steel	581	I	Cutted	15,00		1	a	a	30	28
		2		0	II	Milled	60,00		1	b	b	60	35
2	Cross carrier	1	Steel	353	I	Cutted	15,00		1	a	a	30	28
		1		0	II	Milled	120,00		1	b	b	60	35
3	Tilting bolt	2	Steel	7	I	Bulk component	-	0,05	1	-	-		
4	Pulling bar	2	Steel	41	I	Stamped (1 cycle)	10,00		1	a	c	80	28
5	Cross bar	1	Steel	11	I	Cutted	15,00		1	a	a	30	28
6	Cross bar, support	2	Aluminium	0	II	Casted	60,00		1	a	b	60	28
7	Grip	1	PA.6.6	8	I	Injection molded	-	0,15	2	-	-		
8	Grip, outer plate	2	Steel	10	I	Stamped (1 cycle)	10,00		1	a	c	80	28
9	Angle holder	2	Steel	5	I	Bulk component	-	0,10	1	-	-		
10	Cylinder carrier	2	PA.6.6 - 30%GF	14	I	Injection molded	-	0,26	2	-	-		
11	Push spring	2	Spring steel	2	I	Bulk component	-	0,10	1	-	-		
12	Release spring	2	Spring steel	1	I	Bulk component	-	0,10	1	-	-		
13	Releaser	2	Steel	1	I	Bulk component	-	0,05	1	-	-		
14	Release cylinder	2	Steel	2,5	I	Bulk component	-	0,05	1	-	-		
15	Clamp cylinder	4	Steel	2,5	I	Bulk component	-	0,05	1	-	-		
16	Push part	2	PA.6 - 15%GF	3,5	I	Injection molded	-	0,11	4	-	-		
17	Plate cover	2	Steel	12	I	Stamped (2 cycles)	20,00		1	a	c	80	28
		2		0	II	Bended (1 cycle)	10,00		1	a	c	80	28
18	Support part, bar	2	PA.6	3,5	I	Injection molded	-	0,12	4	-	-		
19	Support part	2	PA.6	3	I	Injection molded	-	0,12	4	-	-		
20	Torosion spring	2	Spring steel	2	I	Bulk component	-	0,10	1	-	-		
21	Axis	2	Steel	1	I	Bulk component	-	0,10	1	-	-		
22	Locking bar	2	Steel	12,5	I	Stamped (1 cycle)	10,00		1	a	c	80	28
23	Locking spring	2	Spring steel	1	I	Bulk component	-	0,10	1	-	-		
24	Geometry lock	4	Steel	5,5	I	Stamped (1 cycle)	10,00		2	a	c	80	28
	Isofix house, basic plate	2	Steel	5	I	Stamped (3 cycles)	30,00		1	a	c	80	28
25	Isofix house, right	2	Steel	0	II	Bended (3 cycles)	30,00		0,5	a	c	80	28
26	Isofix house, left	2	Steel	0	II	Bended (3 cycles)	0,00		0,5	a	c	80	28
27	Plastic cover	2	PA.6.6	15	I	Injection molded	-	0,26	4	-	-		
28	Isofix counter part	2	Steel	45	I	Bended (1 cycle)	10,00		1	a	c	80	28
29	Counterpart, cylinder system	2	Aluminium	13,5	I	Extruded	-	0,10	1	-	-		35
		2		0	II	Cutted	15,00		1	a	a	30	28
		2		0	III	Surface (corrosion protection)	0,00	0,7	1	b	-		35
30	Cover, counterpart	4	PA.6.6	5	I	Injection molded	-	0,21	2	-	-		

Labour costs, levels (€/h)	
a	28
b	35
Machine cost, levels (€/h)	
a	30
b	60
c	80
d	90

Component difference:
Bulk component
Plastic components, price given
Component manufactures

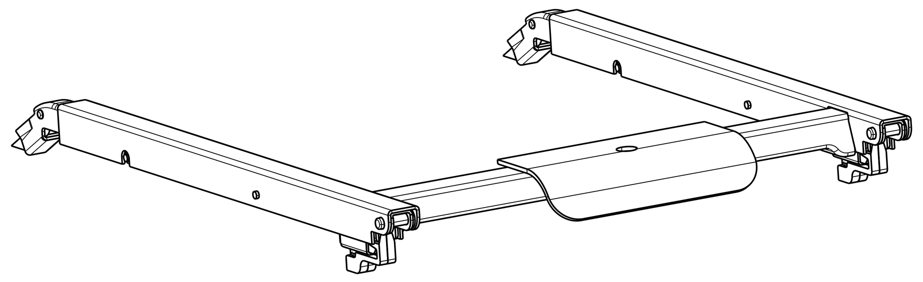
Concept 2

Number	Component	Total material weight (kg)	Material add-on (125%)	Material price (€/kg)	Material costs	Manufacturing costs - Labour	Manufacturing costs - Machine	Manufacturing add-on (120%)	Tool cost	Cost for components / delivered product
1	Longitudinal carrier	1,162	1,453	1	1,453	0,117	0,125	0,290	1000,00	2,033
						0,583	1,000	1,900	1000,00	3,800
2	Cross carrier	0,353	0,441	1	0,441	0,117	0,125	0,290	1000,00	0,731
						1,167	2,000	3,800	1000,00	3,800
3	Tilting bolt									0,100
4	Pulling bar	0,082	0,103	1	0,103	0,078	0,222	0,360	10000,00	0,823
5	Cross bar	0,011	0,014	1	0,014	0,117	0,125	0,290	1000,00	0,304
6	Cross bar, support			1		0,467	1,000	1,760	10000,00	3,520
7	Grip								5600,00	0,075
8	Grip, outer plate	0,020	0,025	1	0,025	0,078	0,222	0,360	10000,00	0,745
9	Angle holder									0,200
10	Cylinder carrier								25000,00	0,260
11	Push spring									0,200
12	Release spring									0,200
13	Releaser									0,100
14	Release cylinder									0,100
15	Clamp cylinder									0,200
16	Push part								4800,00	0,055
17	Plate cover	0,024	0,030	1	0,030	0,156	0,444	0,720	10000,00	1,470
				1		0,078	0,222	0,360	5000,00	0,720
18	Support part, bar								4800,00	0,060
19	Support part								4800,00	0,060
20	Torosion spring									0,200
21	Axis									0,200
22	Locking bar	0,025	0,031	1	0,031	0,078	0,222	0,360	5000,00	0,751
23	Locking spring									0,200
24	Geometry lock	0,022	0,028	1	0,028	0,078	0,222	0,360	5000,00	0,748
	Isofix house, basic plate	0,010	0,013	1	0,013	0,233	0,667	1,080	10000,00	2,173
25	Isofix house, right			1		0,233	0,667	1,080	5000,00	4,320
26	Isofix house, left			1		0,000	0,000	0,000		0,000
27	Plastic cover								11200,00	0,130
28	Isofix counter part	0,090	0,113	1	0,113	0,078	0,222	0,360	5000,00	0,833
29	Counterpart, cylinder system	0,027	0,034	-					5000,00	0,200
				-		0,117	0,125	0,290	1000,00	0,580
										1,400
30	Cover, counterpart								6800,00	0,420
									149 000,00 €	**31,71 €**

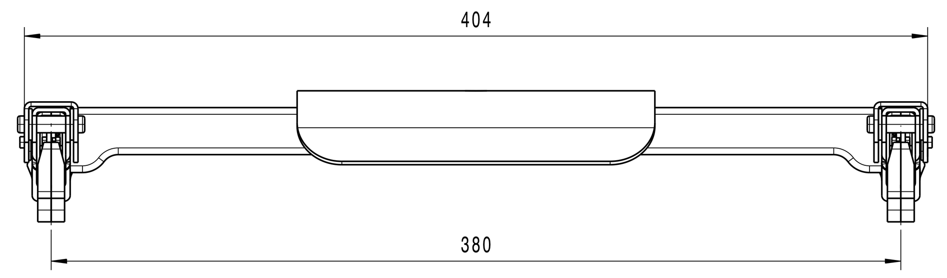
Appendix VIII – Drawing of the final solution

This appendix contains a drawing of the final solution. The content is as follow:

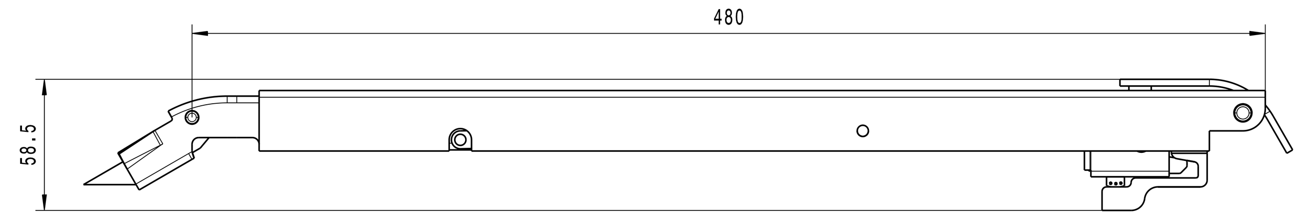
Unterlagen References	Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code
VW 01155	1		08.05.13	Granström		Drawing created
VW 10500						
VW 91101						
VW 91102						
VW 01054						



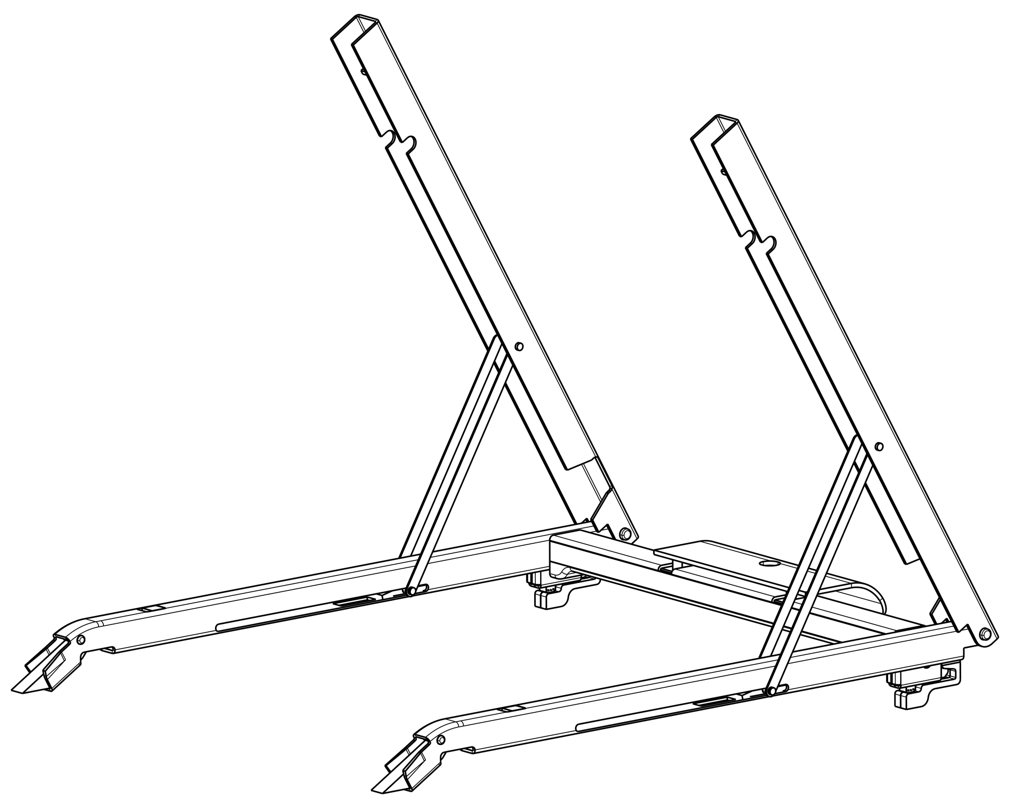
Isometric view
Scale: 1:3



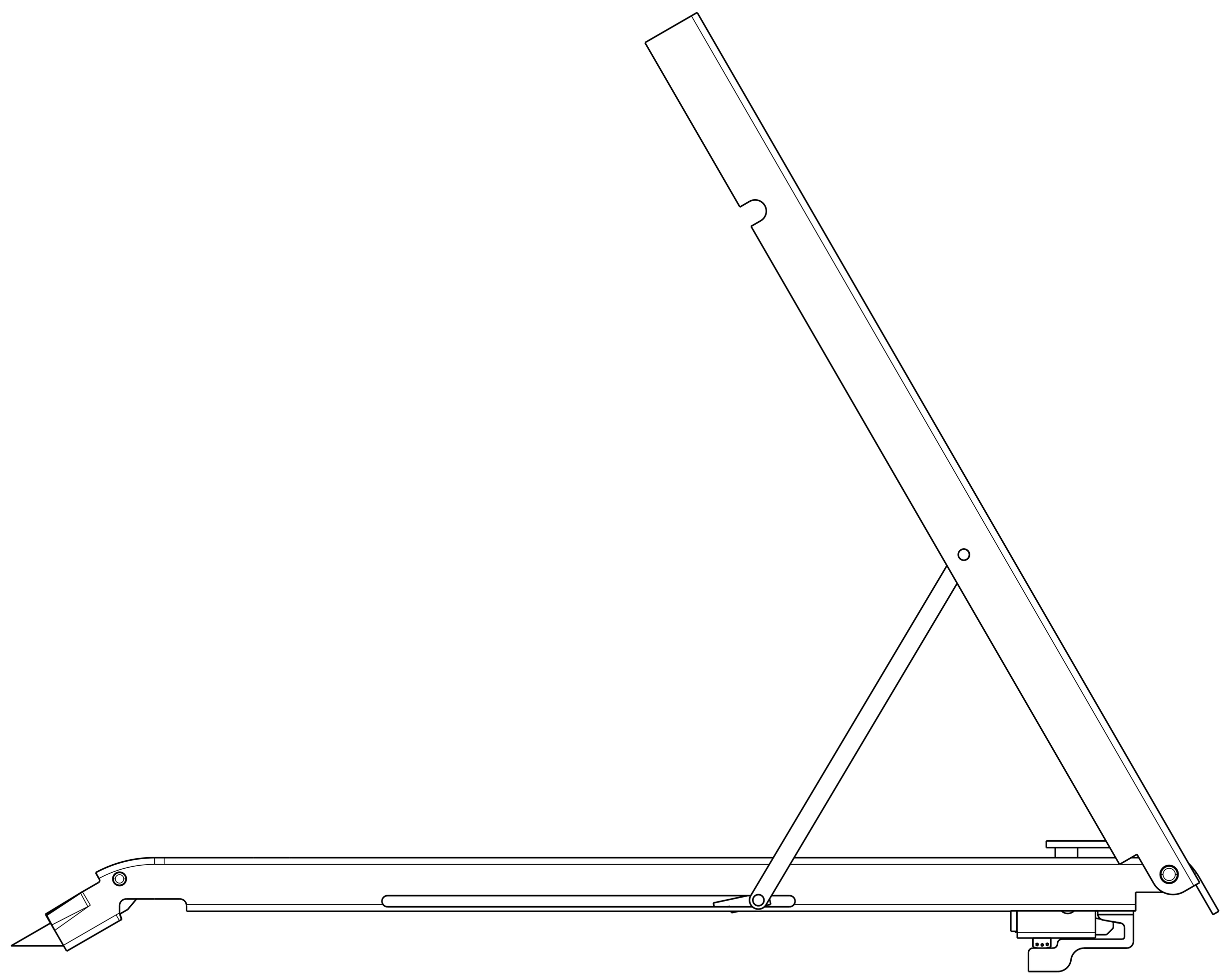
Right view
Scale: 1:2



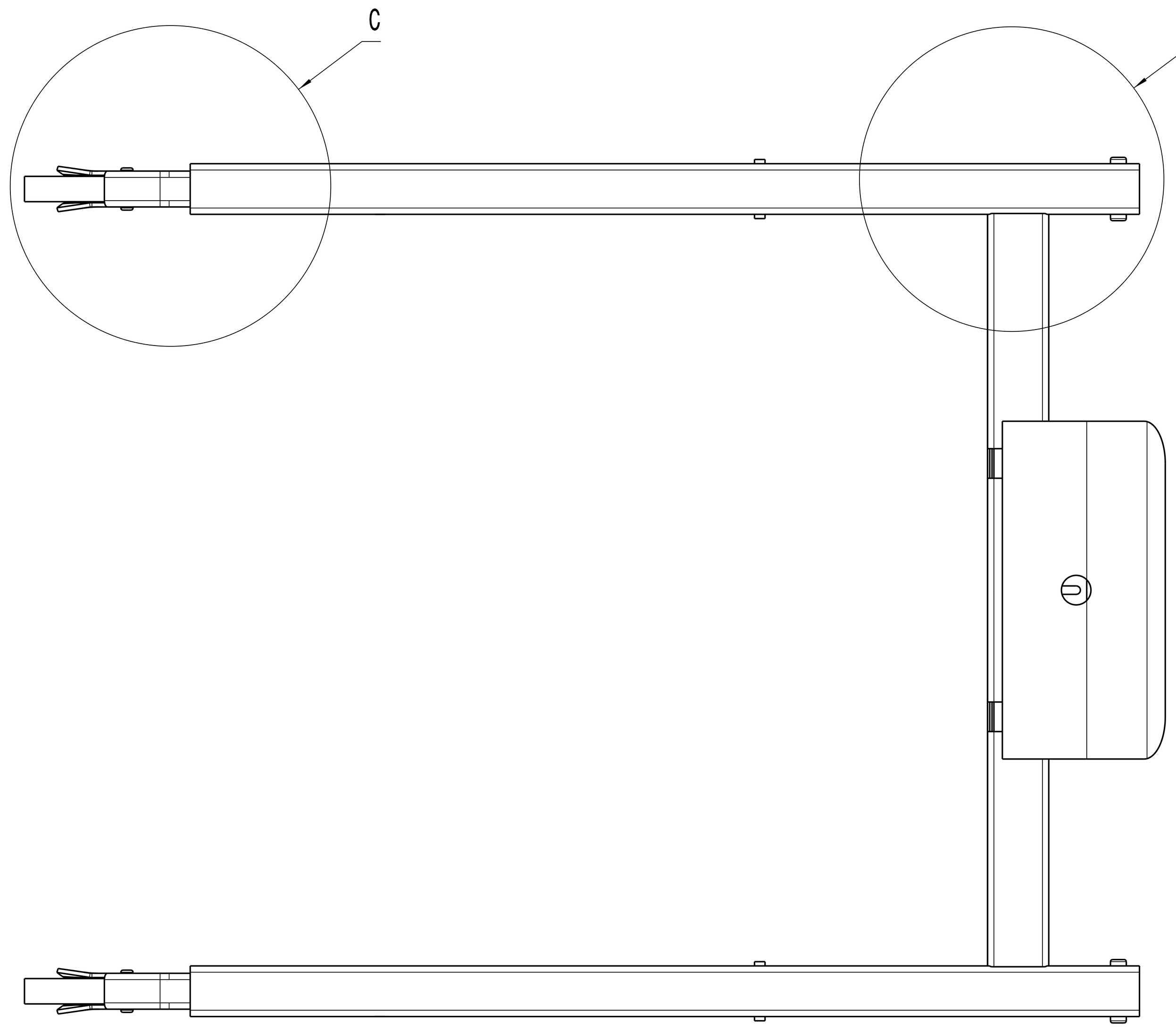
Front view
Scale: 1:2



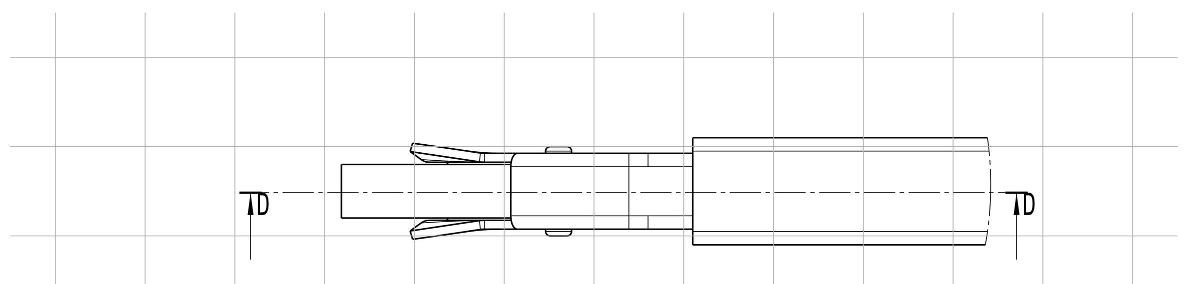
Isometric view
Scale: 1:3



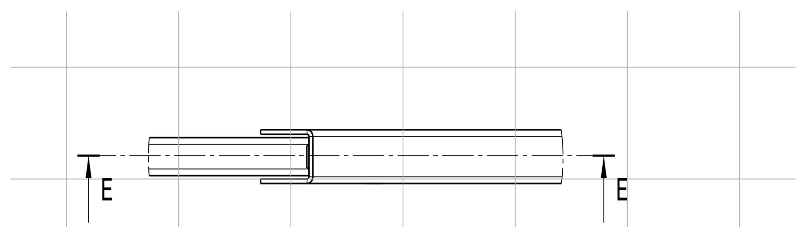
Front view
Scale: 1:2



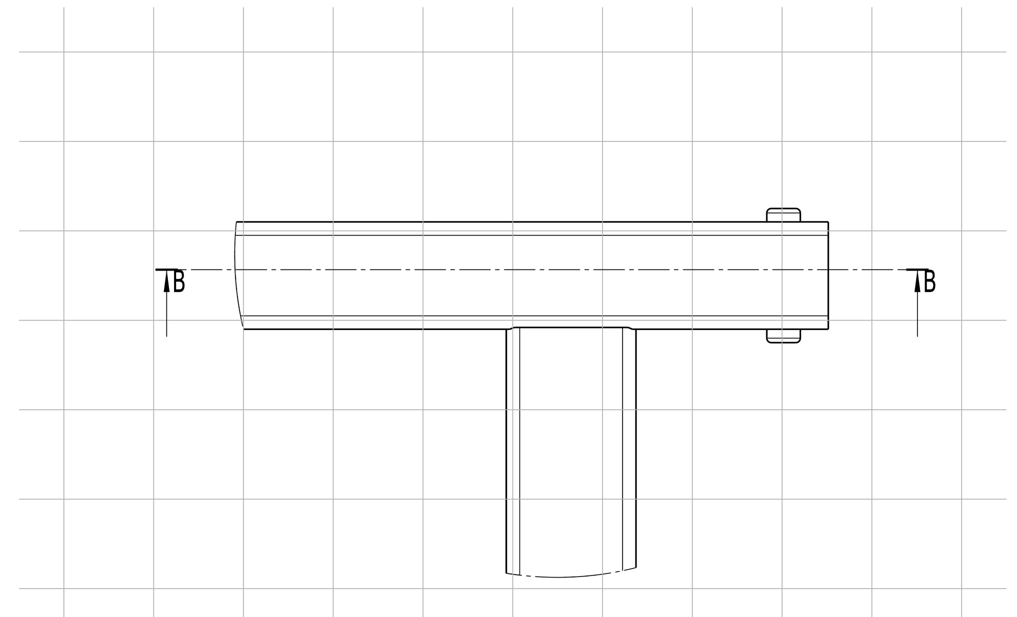
Top view
Scale: 1:2



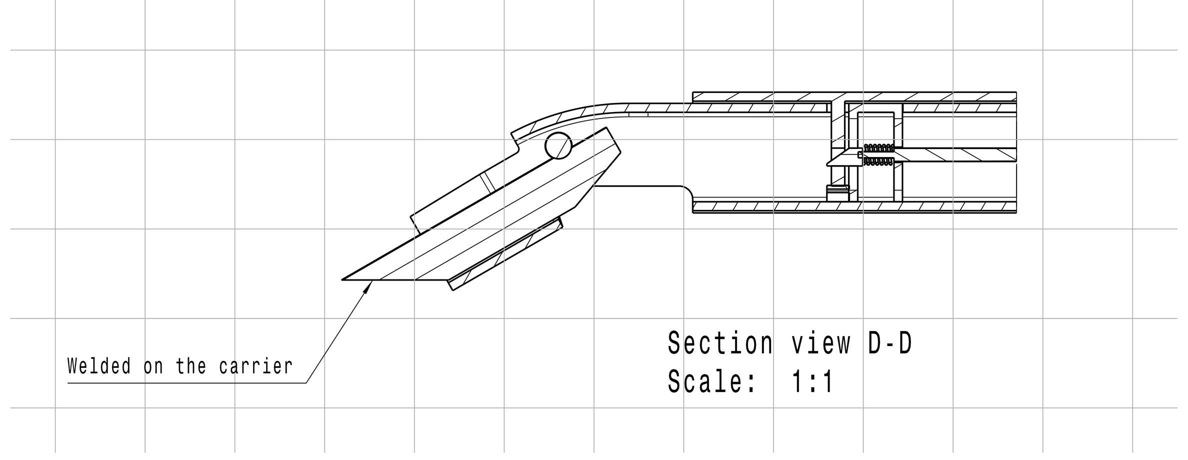
Detail C
Scale: 1:1



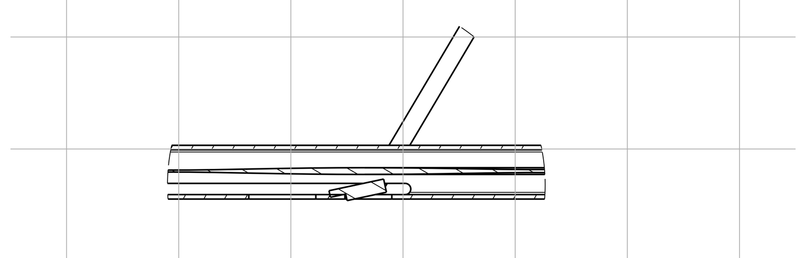
Top view
Scale: 1:2



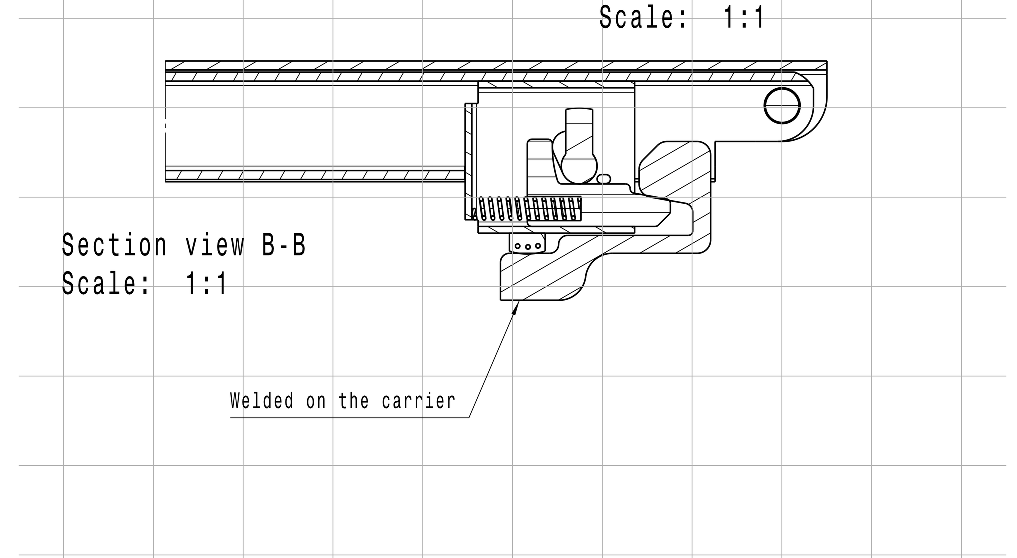
Detail A
Scale: 1:1



Section view D-D
Scale: 1:1



Section view E-E
Scale: 1:2



Section view B-B
Scale: 1:1

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nichtbemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr Type-appr.-doc. and type approval number

CAD-System und Verwaltungssystem-Schluessel
CAD system and administration code
Catia V5

Werkstoff/ Material: See separate table	Konst.-Verantwortg. Doc resp.
Werkstoffbehandlung/ Material treatment: See separate table	Name/ Name: Granström
Halbzeug/ Semi-finished product	Abt./Dept.: I/EG-57
Oberflaechenschutz Surface protection: VW 13750 Ofl-	Telefon/Phone: +49 841-89 48733

Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.	Gez./Drawn
2 665				

Sicherh.-Dok. Safety doc.

Benennung
Description of Final Solution

Title

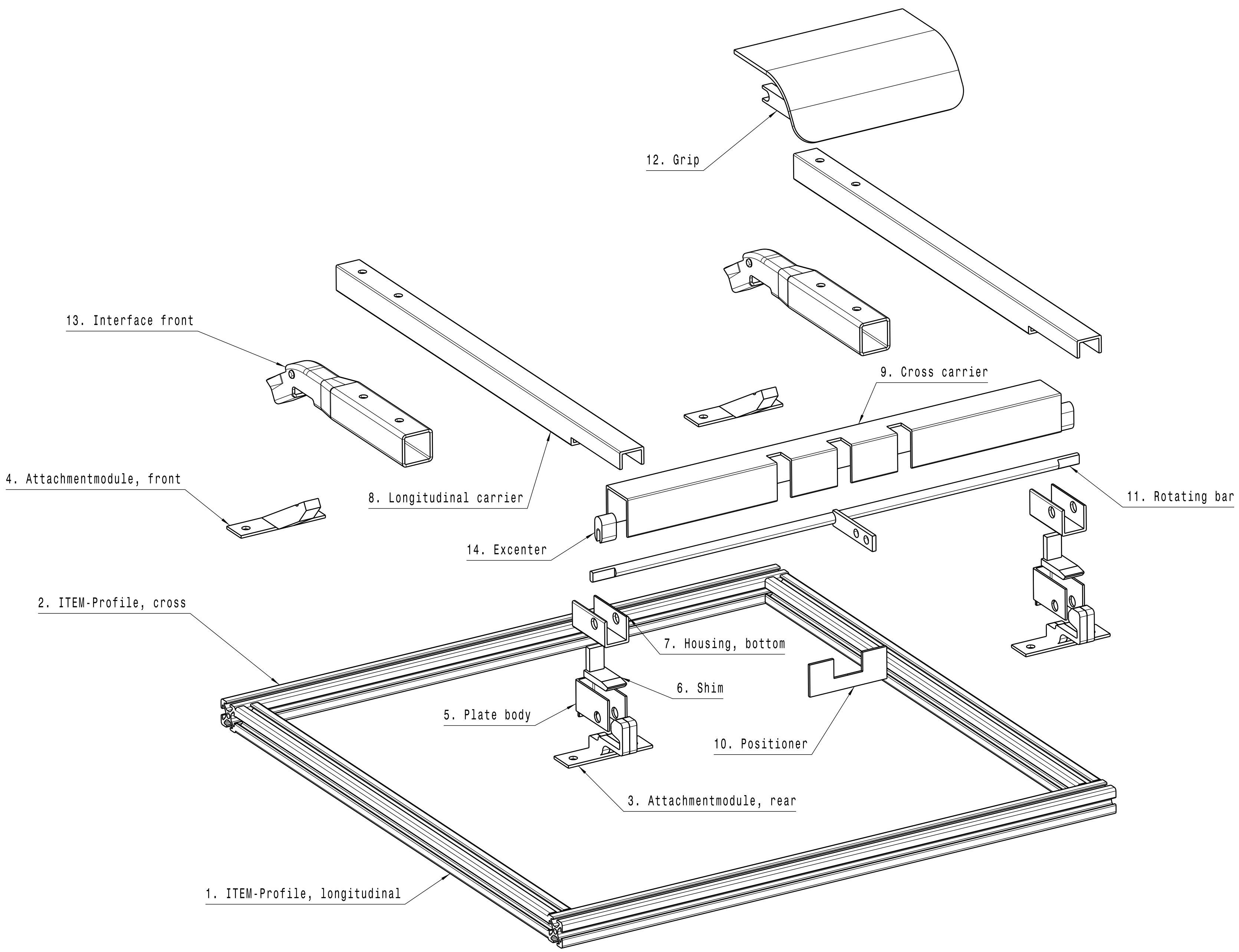
Maszstab/Scale	Teil-Nr. Part-no.	Format D.Size	A0
1:2 1:1	. . . .	Blatt Sheet	1
		von of	1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

Appendix IX – Drawings of the Prototype

This appendix contains drawings of the components in the prototype.
The content is as follow:

Unterlagen References	Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code
VW 01155						
VW 10500						
VW 91101						
VW 91102						
VW 01054						



Isometric view
Scale: 1:2

Nr.	Name	Items	Material	Comment
1.	ITEM-Profile, longitudinal	2	Aluminium	435 mm
2.	ITEM-Profile, cross	2	Aluminium	460 mm
3.	Attachmentmodule, rear	2	Steel	Contains of 3 parts, see drawing "3. Befestugungsmodule, hinten"
4.	Attachmentmodule, front	2	Steel	Contains of 2 parts, see drawing "4. Befestigungsmodule, vorne"
5.	Plate body	2	Steel	See drawing "5. Blechkörper"
6.	Shim	2	Steel	See drawing "6. Klemmkeil"
7.	Houseing, bottom	2	Aluminium	See drawing "7. Gehäuser, unten"
8.	Longitudinal carrier	2	Aluminium	See drawing "8. Längsträger"
9.	Cross carrier	1	Aluminium	See drawing "9. Querträger"
10.	Positioner	1	Steel	See drawing "10. Positionshalter"
11.	Rotating bar	1	Steel	Contains of 2 parts, see drawing "11. Drehstange"
12.	Grip	1	ABS	Rapid prototype part
13.	Interface front	2	ABS	Rapid prototype part
14.	Excenter	2	Aluminium	See drawing "14. Excenter"

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

	fertig finished	roh raw
>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Form FE 508 02.11 ( ) Bezugsmasz Ref. dim. [ ] Kontrollmasz Control dim. < > Vorrichtungsmasz Fixture dim. Ausfallmasz Temporary dim. Pruefmasz Test dim. Pruefmasz mit Bewertung Dim. to be checked Theoretisches Masz Basic dim. > < Werkstoff-Kennzeichnung Material marking

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr Type-appr.-doc. and type approval number

CAD-System und Verwaltungssystem-Schluessel CAD system and administration code: Catia V5

Werkstoff/ Material: See Table

Konst.-Verantwortg. Doc resp.

Name/ Name: Granström

Werkstoffbehandlung/ Material treatment

Abt./Dept.: I/EG-57

Halbzeug/ Semi-finished product

Telefon/Phone: +49 841-89 48733

Oberflaechenschutz Surface protection: VW 13750 Ofl-

Gewicht Weight (g) | errechnet calculated | Ent.-Nr. Draft no. | EA-Nr. Eng.proj.no. | Gez./Drawn

Sicherh.-Dok. Safety doc.: XXX

Benennung: Interface Prototype

Title: Exploded assembly drawing

Maszstab/Scale: 1:2

Teil-Nr. Part-no.

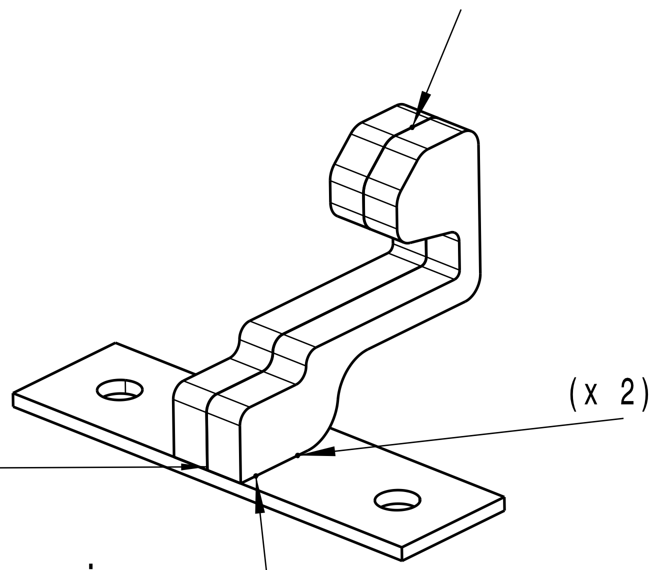
Format D.Size: A1
Blatt Sheet: 1
von of: 1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

Unterlagen References	Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code
VW 01155						
VW 10500						
VW 91101						
VW 91102						
VW 01054						

Baugrupp (gegenteil, hinten)
ist zentriert geschweißt,
vorne aber Rand gegen Rand

(x 2)



(x 2)

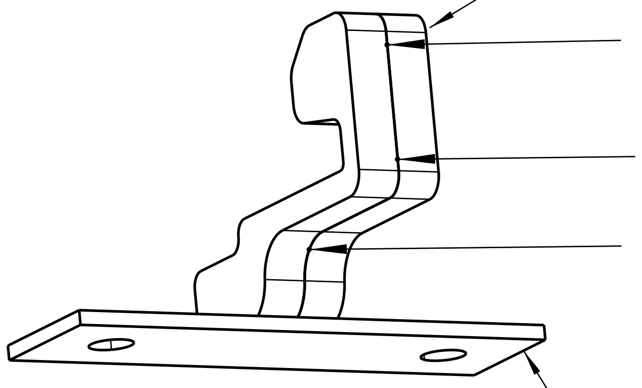
Isometric view
Scale: 1:1

→ Schweißpunkt

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

Gegenteil hinten, 2 pro Baugruppe
Gelasert, von 6 mm Stahlblech



Befsestigungsblech
Siehe Zeichnung "Befestigungsblech"

Isometric view
Scale: 1:1

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Stückzahl: 2

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr Type-appr.-doc. and type approval number: XXX.xxx.XXX.zz
CAD-System und Verwaltungssystem-Schluessel CAD system and administration code: XXX

Werkstoff/ Material
Werkstoffbehandlung/ Material treatment
Halbzeug/ Semi-finished product
Oberflaechenschutz Surface protection VW 13750 Ofl-

Konst.-Verantwortg. Doc resp.
Name/ Name: Granström
Abt./Dept.: I/EG-57
Telefon/Phone: 48733

Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.	Gez./Drawn
. . . . /	XXX / XXX	XXX	XXX	XXX

Sicherh.-Dok. Safety doc. XXX

Benennung: 3. Befestigungsmodule, hinten

Title: Prototypen Schnittstelle

Maszstab/Scale: 1:1

Teil-Nr. Part-no. . . . . / . . . .

Format D.Size A3
Blatt Sheet 1
von of 1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

Form FE 506 02.11

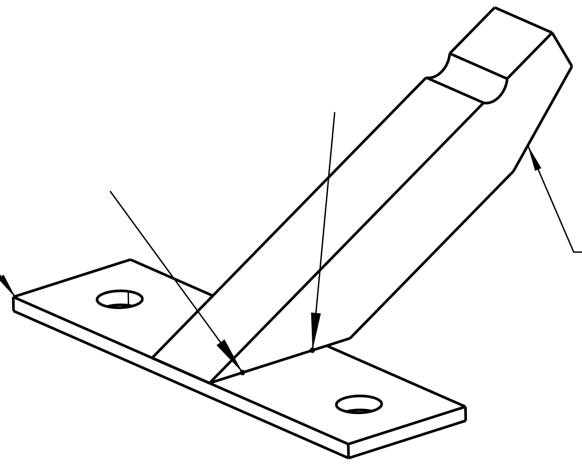
( ) Bezugsmasz Ref. dim. — [ ] Kontrollmasz Control dim. — < > Vorrichtungsmasz Fixture dim. — Ausfallmasz Temporary dim. — Pruefmasz Test dim. — Pruefmasz mit Bewertung Dim. to be checked — Theoretisches Masz Basic dim. — > < Werkstoff-Kennzeichnung Material marking

Unterlagen References	Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code
VW 01155 VW 10500 VW 91101 VW 91102 VW 01054						

Isometric view
Scale: 1:1

Befestigungsblech
Siehe Zeichnung "Befestigungsblech"

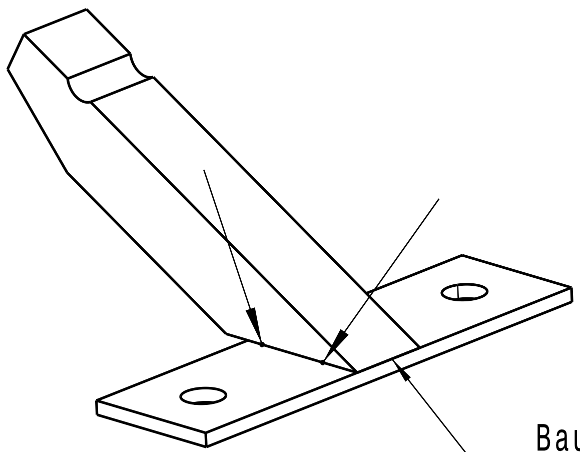
Schon gemachtes Teil



Schweißpunkt

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.



Bauteil zentriert geschweißt, hinten aber Rand gegen Rand

Isometric view
Scale: 1:1

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Stückzahl: 2

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr / Type-appr.-doc. and type approval number: XXX.xxx.XXX.zz

CAD-System und Verwaltungssystem-Schluessel / CAD system and administration code: XXX

Werkstoff/ Material

Werkstoffbehandlung/ Material treatment

Halbzeug/ Semi-finished product

Oberflaechenschutz / Surface protection: VW 13750 Ofl-

Konst.-Verantwortg. / Doc resp.
Name/ Name: Granström
Abt./Dept.: I/EG-57
Telefon/Phone: 48733
Gez./Drawn: XXX

Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.
. . . .	XXX XXX	XXX	XXX

Sicherh.-Dok. / Safety doc.: XXX

Benennung: 4. Befestigungsmodule, vorne

Title: Prototypen Schnittstelle

Maszstab/Scale: 1:1

Teil-Nr. / Part-no.: . . . .

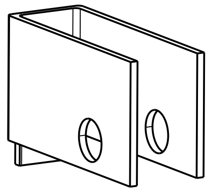
Format D.Size: A3
Blatt Sheet: 1
von of: 1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

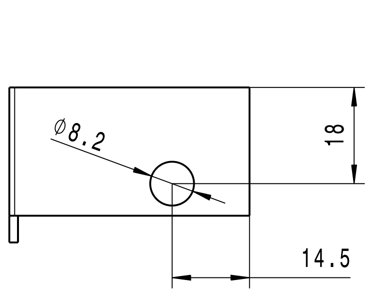
( ) Bezugsmasz Ref. dim. | [ ] Kontrollmasz Control dim. | < > Vorrichtungsmasz Fixture dim. | Ausfallmasz Temporary dim. | Pruefmasz Test dim. | Pruefmasz mit Bewertung Dim. to be checked | Theoretisches Masz Basic dim. | > < Werkstoff-Kennzeichnung Material marking

Unterlagen References
VW 01155
VW 10500
VW 91101
VW 91102
VW 01054

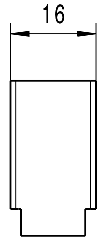
Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code



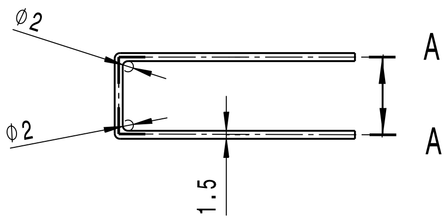
Isometric view
Scale: 1:1



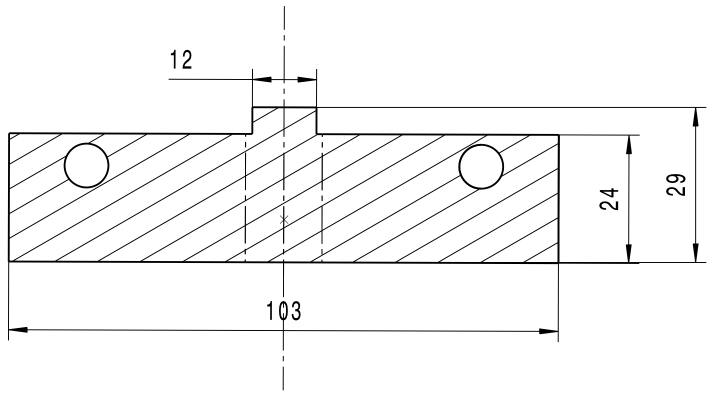
Front view
Scale: 1:1



Left view
Scale: 1:1



Top view
Scale: 1:1



Section view A-A
Scale: 1:1

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Stückzahl: 2

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr Type-appr.-doc. and type approval number	CAD-System und Verwaltungssystem-Schluessel CAD system and administration code
XXX.xxx.XXX.zz	XXX

Werkstoff/ Material: Stahl	Konst.-Verantwortg. Doc resp.
	Name/ Name: Granström
Werkstoffbehandlung/ Material treatment: XXX	Abt./Dept.: I/EG-57
Halbzeug/ Semi-finished product: XXX	Telefon/Phone: 48733
Oberflaechenschutz Surface protection: VW 13750 Ofl-	

Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.	Gez./Drawn
. . . .	28 g	XXX	XXX	XXX

Sicherh.-Dok. Safety doc.: XXX	Benennung: 5. Blechkörper XXX
	Title: Prototypen Schnittstelle
Maszstab/Scale: 1:1	Teil-Nr. Part-no.: . . . .

Format D.Size A2
Blatt Sheet 1
von of 1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

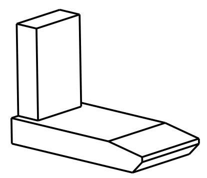
Form FE 507 02.11

( )	Bezugsmasz Ref. dim.
[ ]	Kontrollmasz Control dim.
< >	Vorrichtungsmasz Fixture dim.
	Ausfallmasz Temporary dim.
	Pruefmasz Test dim.
	Pruefmasz mit Bewertung Dim. to be checked
	Theoretisches Masz Basic dim.
> <	Werkstoff-Kennzeichnung Material marking

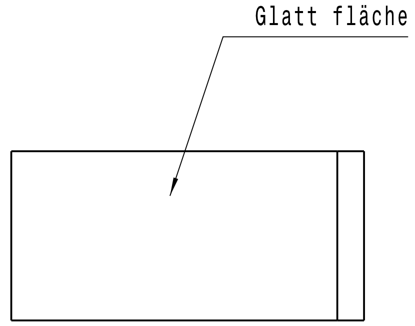
1	2	3	4	5	6	7	8

Unterlagen References
VW 01155
VW 10500
VW 91101
VW 91102
VW 01054

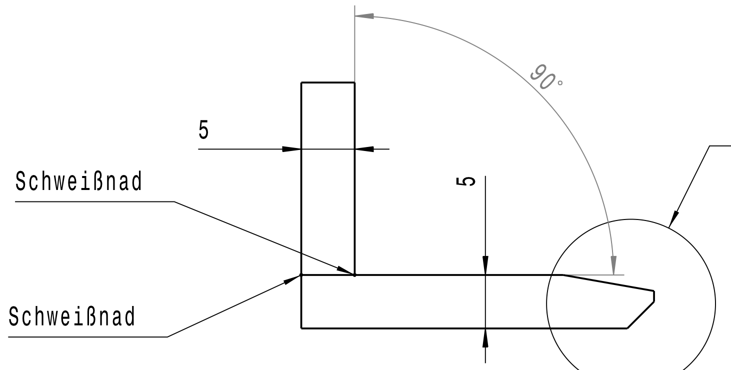
Nr. No.	Feld Section	Datum Date	Geaendert Changed	Geneh-migt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code



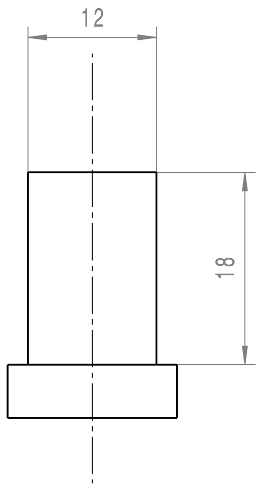
Isometric view
Scale: 1:1



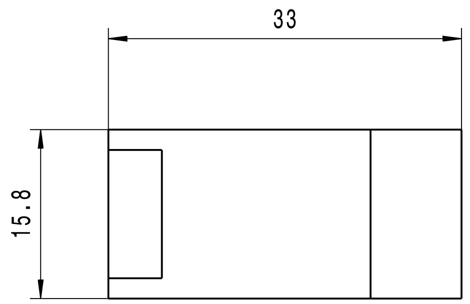
Bottom view
Scale: 2:1



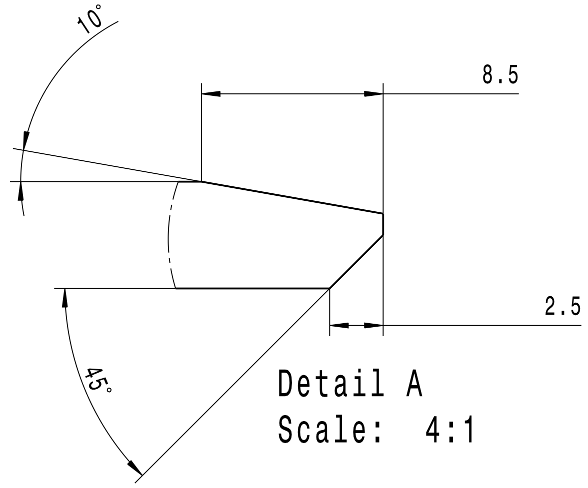
Front view
Scale: 2:1



Left view
Scale: 2:1



Top view
Scale: 2:1



Detail A
Scale: 4:1

Stückzahl: 2

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr Type-appr.-doc. and type approval number	CAD-System und Verwaltungssystem-Schluessel CAD system and administration code
XXX.xxx.XXX.zz	XXX

Werkstoff/ Material: Stahl	Konst.-Verantwortg. Doc resp.
	Name/ Name: Granström
Werkstoffbehandlung/ Material treatment: XXX	Abt./Dept.: I/EG-57
Halbzeug/ Semi-finished product: XXX	Telefon/Phone: 48733
Oberflaechenschutz Surface protection: VW 13750 Ofl-	Gez./Drawn: XXX

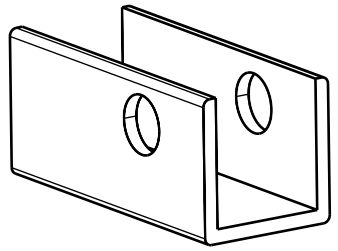
Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.
. . . .	28 g	XXX	XXX

Sicherh.-Dok. Safety doc.	Benennung
XXX	6. Klemmkeil XXX
	Title: Prototypen Schnittstelle

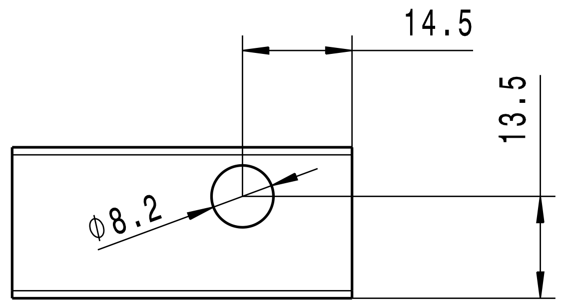
Maszstab/Scale	Teil-Nr. Part-no.	Format D.Size	A2
1:1	. . . .	Blatt Sheet	1
		von of	1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

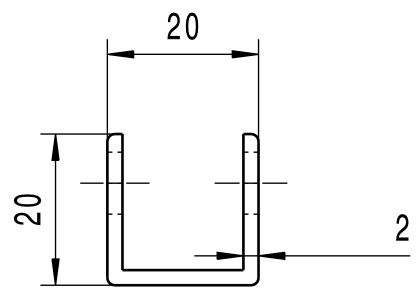
Form FE 507 02.11 ( ) Bezugsmasz Ref. dim. [ ] Kontrollmasz Control dim. < > Vorrichtungsmasz Fixture dim. Ausfallmasz Temporary dim. Pruefmasz Test dim. Pruefmasz mit Bewertung Dim. to be checked Theoretisches Masz Basic dim. > < Werkstoff-Kennzeichnung Material marking



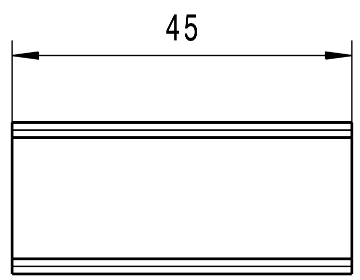
Isometric view
Scale: 1:1



Front view
Scale: 1:1



Left view
Scale: 1:1



Top view
Scale: 1:1

Unterlagen References
VW 01155
VW 10500
VW 91101
VW 91102
VW 01054

Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Stückzahl: 2

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr / Type-appr.-doc. and type approval number: XXX.xxx.XXX.zz

CAD-System und Verwaltungssystem-Schluessel / CAD system and administration code: XXX

Werkstoff/ Material: Aluminium

Konst.-Verantwortg. Doc resp.

Name/ Name: Granström

Werkstoffbehandlung/ Material treatment: XXX

Abt./Dept.: I/EG-57

Halbzeug/ Semi-finished product: XXX

Telefon/Phone: 48733

Oberflaechenschutz Surface protection: VW 13750 Ofl-

Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.	Gez./Drawn
. . . .	13 g	XXX	XXX	XXX

Sicherh.-Dok. Safety doc.: XXX

Benennung: 7. Gehäuser, unten
XXX

Title: Prototypen Schnittstelle

Maszstab/Scale: 1:1

Teil-Nr. Part-no.: . . . .
. . . .

Format D.Size: A3
Blatt Sheet: 1
von of: 1

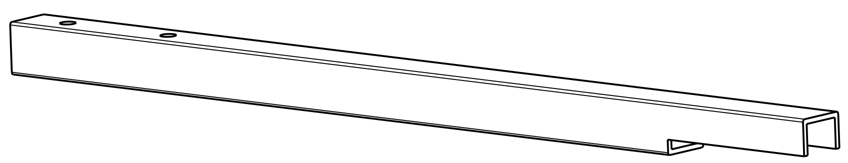
Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

Form FE 506 02.11

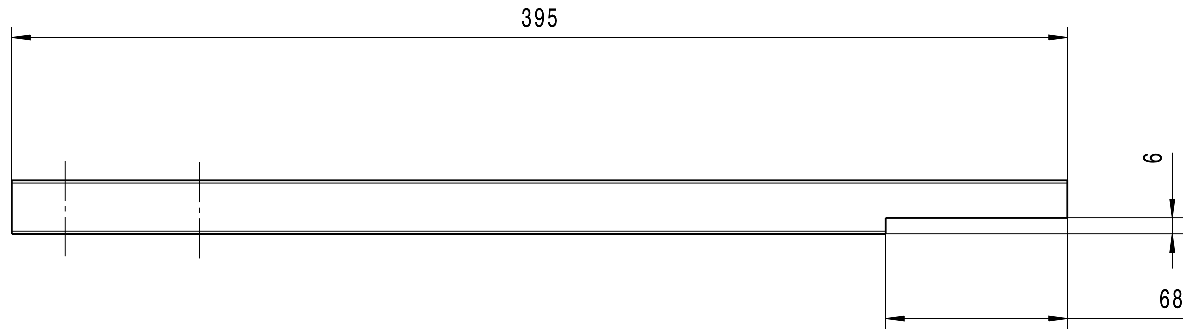
( ) Bezugsmasz Ref. dim. | [ ] Kontrollmasz Control dim. | < > Vorrichtungsmasz Fixture dim. | Ausfallmasz Temporary dim. | Pruefmasz Test dim. | Pruefmasz mit Bewertung Dim. to be checked | Theoretisches Masz Basic dim. | > < Werkstoff-Kennzeichnung Material marking

Unterlagen References
VW 01155
VW 10500
VW 91101
VW 91102
VW 01054

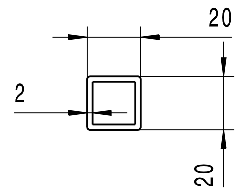
Nr. No.	Feld Section	Datum Date	Geaendert Changed	Geneh-migt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code



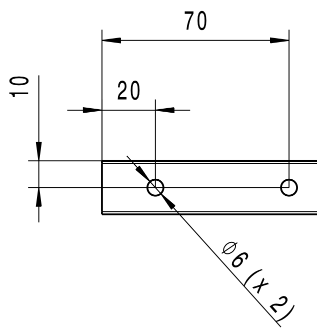
Isometric view
Scale: 1:2



Front view
Scale: 1:2



Left view
Scale: 1:2



Top view
Scale: 1:2

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes: XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Stückzahl: 2

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr Type-appr.-doc. and type approval number: XXX.xxx.XXX.zz	CAD-System und Verwaltungssystem-Schluessel CAD system and administration code: XXX
Werkstoff/ Material: Aluminium	Konst.-Verantwortg. Doc resp. — Name/ Name: Granström
Werkstoffbehandlung/ Material treatment: XXX	Abt./Dept.: I/EG-57
Halbzeug/ Semi-finished product: XXX	Telefon/Phone: 48733
Oberflaechenschutz Surface protection: VW 13750 Ofl-	

Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.	Gez./Drawn
. . . .	142 g	XXX	XXX	XXX

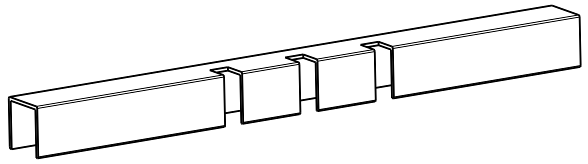
Sicherh.-Dok. Safety doc.: XXX	Benennung: 8. Längsträger XXX
	Title: Prototypen Schnittstelle
Maszstab/Scale: 1:2	Teil-Nr. Part-no.: . . . . / . . . .

Format D.Size	A2
Blatt Sheet	1
von of	1

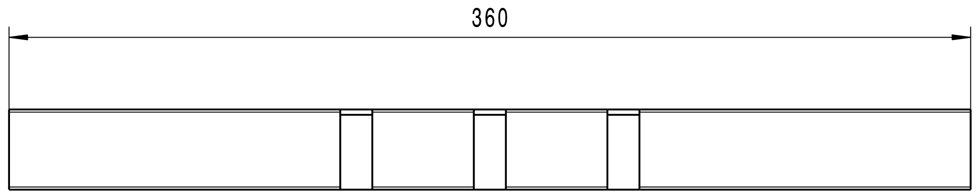
Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

Form FE 507 02.11 | ( ) Bezugsmasz Ref. dim. | [ ] Kontrollmasz Control dim. | < > Vorrichtungsmasz Fixture dim. | Ausfallmasz Temporary dim. | Pruefmasz Test dim. | Pruefmasz mit Bewertung Dim. to be checked | Theoretisches Masz Basic dim. | > < Werkstoff-Kennzeichnung Material marking

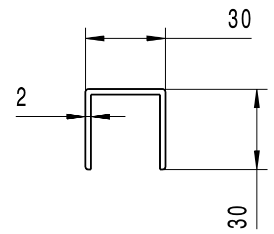
	1	2	3	4	5	6	7	8



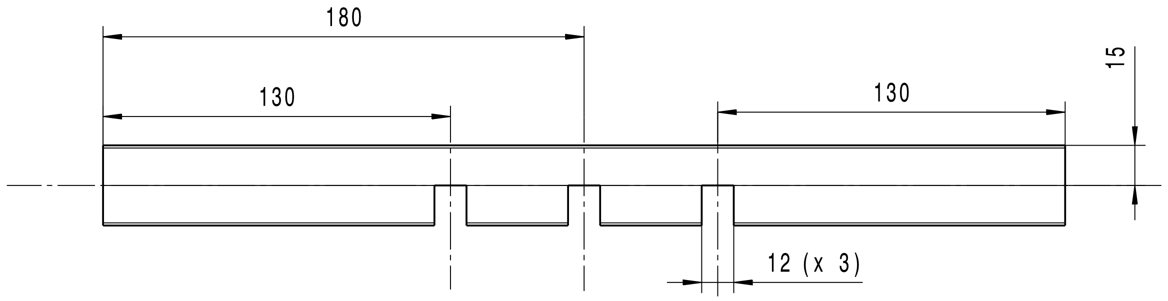
Isometric view
Scale: 1:3



Front view
Scale: 1:2



Left view
Scale: 1:2



Top view
Scale: 1:2

Stückzahl: 1

Unterlagen References
VW 01155
VW 10500
VW 91101
VW 91102
VW 01054

Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes: XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr / Type-appr.-doc. and type approval number: XXX.xxx.XXX.zz
CAD-System und Verwaltungssystem-Schluessel / CAD system and administration code: XXX

Werkstoff/ Material: Aluminium
Werkstoffbehandlung/ Material treatment: XXX
Halbzeug/ Semi-finished product: XXX
Oberflaechenschutz / Surface protection: VW 13750 Ofl-

Konst.-Verantwortg. / Doc resp.
Name/ Name: Granström
Abt./Dept.: I/EG-57
Telefon/Phone: 48733
Gez./Drawn: XXX

Gewicht Weight (g)	errechnet calculated	Ent.-Nr. Draft no.	EA-Nr. Eng.proj.no.
. . . .	159 g	XXX	XXX

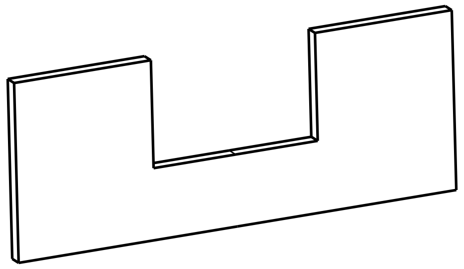
Sicherh.-Dok. / Safety doc.: XXX
Benennung: 9. Querträger
XXX
Title: Prototypen Schnittstelle

Maszstab/Scale: 1:2
Teil-Nr. / Part-no.: . . . . / . . . .
Format D.Size: A2
Blatt Sheet: 1
von of: 1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

Form FE 507 02.11 ( ) Bezugsmasz Ref. dim. [ ] Kontrollmasz Control dim. < > Vorrichtungsmasz Fixture dim. Ausfallmasz Temporary dim. Pruefmasz Test dim. Pruefmasz mit Bewertung Dim. to be checked Theoretisches Masz Basic dim. > < Werkstoff-Kennzeichnung Material marking

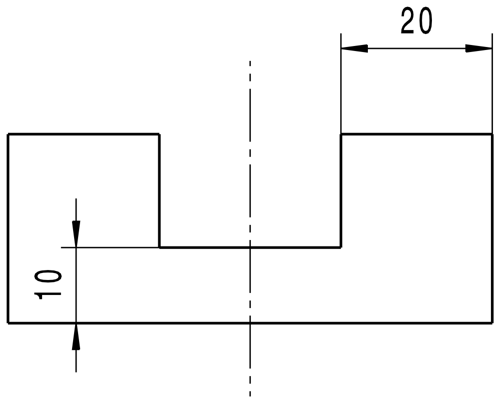
Unterlagen References	Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code
VW 01155						
VW 10500						
VW 91101						
VW 91102						
VW 01054						



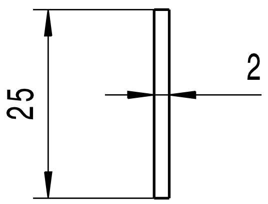
Isometric view
Scale: 1:1

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

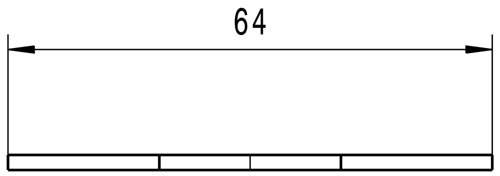
Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.



Front view
Scale: 1:1



Left view
Scale: 1:1



Top view
Scale: 1:1

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Stückzahl: 1

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr Type-appr.-doc. and type approval number: XXX.xxx.XXX.zz

CAD-System und Verwaltungssystem-Schluessel CAD system and administration code: XXX

Werkstoff/ Material: Stahl

Werkstoffbehandlung/ Material treatment: XXX

Halbzeug/ Semi-finished product: XXX

Oberflaechenschutz Surface protection: VW 13750 Ofl-

Konst.-Verantwortg. Doc resp.
Name/ Name: Granström
Abt./Dept.: I/EG-57
Telefon/Phone: 48733
Gez./Drawn: XXX

Gewicht Weight (g): . . . . / . . . .
errechnet calculated: 19 g
Ent.-Nr. Draft no.: XXX
EA-Nr. Eng.proj.no.: XXX

Sicherh.-Dok. Safety doc.: XXX

Benennung: 10. Positionshalter

Title: Prototypen Schnittstelle

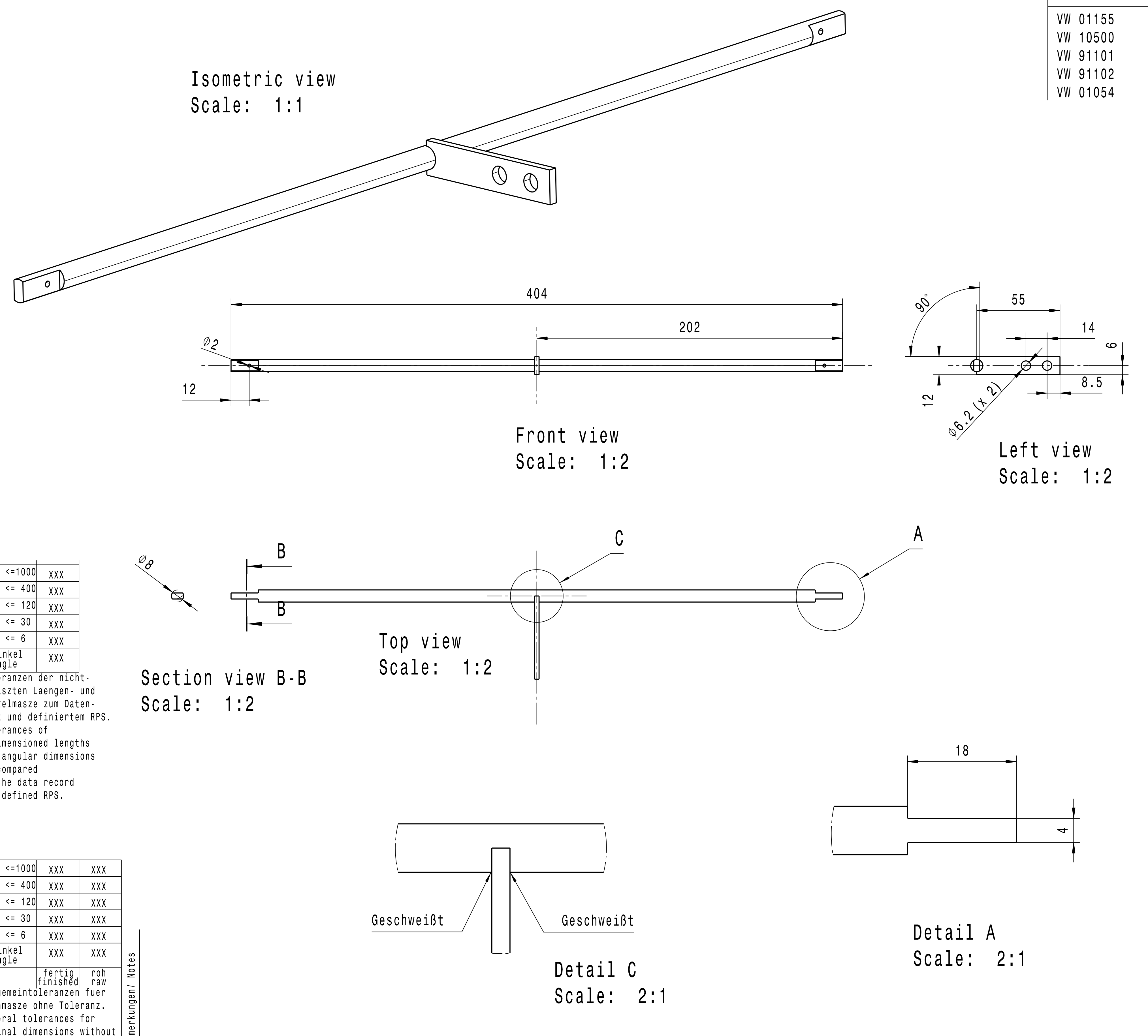
Maszstab/Scale: 1:1 XXX

Teil-Nr. Part-no.: . . . . / . . . .

Format D.Size: A3
Blatt Sheet: 1
von of: 1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

( ) Bezugsmasz Ref. dim. | [ ] Kontrollmasz Control dim. | < > Vorrichtungsmasz Fixture dim. | Ausfallmasz Temporary dim. | Pruefmasz Test dim. | Pruefmasz mit Bewertung Dim. to be checked | Theoretisches Masz Basic dim. | > < Werkstoff-Kennzeichnung Material marking



Stückzahl: 1

Unterlagen References
VW 01155
VW 10500
VW 91101
VW 91102
VW 01054

Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes: XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr / Type-appr.-doc. and type approval number: XXX.xxx.XXX.zz

CAD-System und Verwaltungssystem-Schluessel / CAD system and administration code: XXX

Werkstoff/ Material: Stahl

Werkstoffbehandlung/ Material treatment: XXX

Halbzeug/ Semi-finished product: XXX

Oberflaechenschutz / Surface protection: VW 13750 Ofl-

Konst.-Verantwortg. / Doc resp.
Name/ Name: Granström
Abt./Dept.: I/EG-57
Telefon/Phone: 48733
Gez./Drawn: XXX

Gewicht / Weight (g): . . . . / . . . .
errechnet / calculated: 168 g
Ent.-Nr. / Draft no.: XXX
EA-Nr. / Eng.proj.no.: XXX

Sicherh.-Dok. / Safety doc.: XXX

Benennung: 11. Drehstange
XXX

Title: Prototypen Schnittstelle

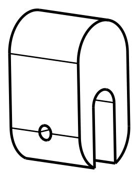
Maszstab/Scale: 1:1

Teil-Nr. / Part-no.: . . . . / . . . .

Format D.Size: A2
Blatt Sheet: 1
von of: 1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

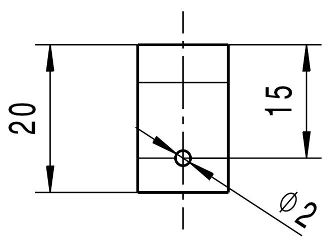
Form FE 507 02.11 — ( ) Bezugsmasz Ref. dim. — [ ] Kontrollmasz Control dim. — < > Vorrichtungsmasz Fixture dim. — Ausfallmasz Temporary dim. — Pruefmasz Test dim. — Pruefmasz mit Bewertung Dim. to be checked — Theoretisches Masz Basic dim. — > < Werkstoff-Kennzeichnung Material marking



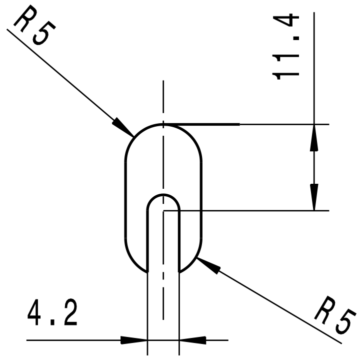
Isometric view
Scale: 1:1

>400 <=1000	XXX
>120 <= 400	XXX
> 30 <= 120	XXX
> 6 <= 30	XXX
<= 6	XXX
Winkel Angle	XXX

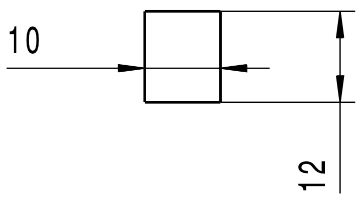
Toleranzen der nicht-bemaszten Laengen- und Winkelmasze zum Datensatz und definiertem RPS.
Tolerances of undimensioned lengths and angular dimensions as compared to the data record and defined RPS.



Right view
Scale: 1:1



Front view
Scale: 1:1



Top view
Scale: 1:1

>400 <=1000	XXX	XXX
>120 <= 400	XXX	XXX
> 30 <= 120	XXX	XXX
> 6 <= 30	XXX	XXX
<= 6	XXX	XXX
Winkel Angle	XXX	XXX
	fertig finished	roh raw

Allgemeintoleranzen fuer Nennmasze ohne Toleranz.
General tolerances for nominal dimensions without specified tolerance.

Bemerkungen/ Notes
XXX

Schadstoffvermeidung nach/ Avoidance of hazardous substances acc. to VW 91101

Oberflaechenrauheit Surface texture VW 13705	Werkstueckkanten Edge finish VW 01088

Alle Masze gelten fuer das Fertigteil einschliesslich Oberflaechenschutz.
All dimensions apply to the finished part including surface protection.

Stückzahl: 2

Unterlagen References
VW 01155
VW 10500
VW 91101
VW 91102
VW 01054

Nr. No.	Feld Section	Datum Date	Geaendert Changed	Genehmigt Appr.	Beschreibung der Aenderung und Aenderungsterminschluessel Revision Record and Change date code

Nur fuer Colorado-Projekt/ For Colorado project only

Typ-Pruef-Dok. und Typ-Pruef-Nr / Type-appr.-doc. and type approval number: XXX.xxx.XXX.zz
CAD-System und Verwaltungssystem-Schluessel / CAD system and administration code: XXX

Werkstoff/ Material: Stahl
Konst.-Verantwortg. Doc resp.
Name/ Name: Granström
Werkstoffbehandlung/ Material treatment
Abt./Dept.: I/EG-57
Halbzeug/ Semi-finished product
Telefon/Phone: 48733
Oberflaechenschutz Surface protection: VW 13750 Ofl-

Gewicht Weight (g): . . . . / . . . .
errechnet calculated: 13
Ent.-Nr. Draft no.: XXX
EA-Nr. Eng.proj.no.: XXX
Gez./Drawn: XXX

Sicherh.-Dok. Safety doc.: XXX
Benennung: 14. Excenter
XXX
Title: Prototypen Schnittstelle

Maszstab/Scale: XXX
XXX
Teil-Nr. Part-no.: . . . . / . . . .
Format D.Size: A3
Blatt Sheet: 1
von of: 1

Teilekennzeichnung nach VW 10500. Parts marking acc. to VW 10500.
Recyclinganforderungen nach VW 91102. Recycling requirements acc. to VW 91102.
Tolerancing principle acc. to VW 01054. Tolerancing principle acc. to VW 01054.

Form FE 506 02.11
( ) Bezugsmasz Ref. dim. | [ ] Kontrollmasz Control dim. | < > Vorrichtungsmasz Fixture dim. | Ausfallmasz Temporary dim. | Pruefmasz Test dim. | Pruefmasz mit Bewertung Dim. to be checked | Theoretisches Masz Basic dim. | > < Werkstoff-Kennzeichnung Material marking