Design of A Modular Scania LowEntry Instep

Master's Thesis in the Master Degree Programme
Industrial Design Engineering

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ABSTRACT

This master's thesis concerns a new instep for the LowEntry truck segment of Scania. The current instep has major ergonomic, safety and aesthetic issues. The solution is manufactured by an external supplier and therefore it does not have a coherent design that matches the Scania brand.

Considering the problems, studies about the truck segment, the existing solutions within Scania and on the market were conducted. A user analysis was conducted and information was gathered about the standards and regulations of the truck business.

The set requirements acquired from the study have been used as a basis for the design proposals in the next phase. Different design concepts were proposed, on steps, step wells and finally on a new instep.

The last phase has been the development of the potential solutions, choosing the best set, designing it in details and progressing to a complete and tested prototype.

The report is written in English.

Keywords

LowEntry, Modular, Instep, Ergonomic, Design, Development, Scania CV AB.

Acknowledgements

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Notation

M	Moment
F	Force
σ	Stress
τ	Sheer stress
α	Step Gradient angle

Indices

t	Tensile Strength
s	Yield Strength

Abbreviations

QFD	Quality Function Development
APS	Air process system
LSV	Laxå Special vehicles
STD	Scania Specific Standard
PP	Painting with powder paint
FEM	Finite Element Method
STC	Scania Technical Centre

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Pre-Studies

Concept Design

Development

1. Introduction

The purpose of this chapter is to give the reader a background and the objectives for this master's thesis. This section also includes a brief description of the methods used to carry out the thesis along with a background introducing Scania.

1.1. Project background

LowEntry is a member of the Scania trucks family suited for applications requiring a low-entry boarding step. Recently the chassis of the model has been revised and created new opportunities for adapting the instep.

1.2. Objectives

Design a modular instep that can be used for LowEntry cabs with one or two insteps, depending on the height of the vehicle. The instep shall be designed to be safe, ergonomic and robust and give a high-quality impression. Since the instep is an exterior part of the cab's design, it is important that the design is integrated into the truck's exterior shape.

1.2.1. Clarifying objectives

To get a clear view of the projects' goals and desired result, the objectives are broken down with the "Objective tree" method. (1)

Modular
Use both as single and double instep
Fit both driver and co-driver side

Safe
Minimize risk of injuries

Ergonomic
Prevent abnormal and dangerous use

Robust and quality impression
Long life time
Resistant to external stresses

Integrated with the cab exterior
Follow the design line of the cab
Look like a product of Scania

1.2.1.1. Assignment directives from Scania CV AB

- *Study demands, standards and desires on instep for similar vehicles and compile a specification of requirements*
- *Obtain information and knowledge about insteps within Scania*
- *Study different solutions and evaluate different options*
- *Choose an option for detailed study*
- *Discuss options with ergonomics and styling departments within Scania as well as with Laxå Special Vehicles*
- *Provide drawings for the proposed solution*
- *Production adaption; tools, costs, inputs from suppliers*
- *Contacts with suppliers and customers is possible*
- *Visits to Laxå Special Vehicles*
- *Legislative demands, investigate legal requirements*
- *Generate CAD material*
- *Prototype modeling*
- *Cost analysis: parts and tools costs*
- *Presentation: written report and oral presentation*
- *If possible: cover the instep e.g. prolonging the door*

1.3. Method

The project is divided in three main phases; Pre-study, Concept design and Development. The Pre-study phase is aimed at analysing the existing design's function and exterior expressions. The concept design phase is aimed at generating many design solutions to find the best possible concepts. In the developing phase the concepts are developed to a complete design proposal.

The phases are carried out with the guidance from Ulrich and Eppingers´s Product Design and Development, (2) Nigel Cross´s Engineering Design Methods (1) and Fredy Olsson´s Principkonstruktion (3) and Primärkonstruktion (4).

1.4. Delimitations

- *A time limit of 20 weeks for the master's thesis.*
- *The LowEntry truck is a modification of a regular Scania truck, with several Scania standard parts. Due to the low sales volume of LowEntry trucks, major changes are difficult to make.*
- *Major changes that require investments in new production tools are hard to implement because of the high cost per unit.*
- *Limited drawing documentation is available.*
- *The existing 3D models have been modeled in the CAD software CATIA V4.*
- *The conversion to the currently in use version CATIA V5 is not editable, which makes it time-consuming to modify the existing parts.*
- *Due to that the LowEntry is an adaptation made by Laxå Special vehicles; there are a lot of accurate 3D models missing.*

1.5. Background of Scania

Scania was founded in 1891 and is now one of the world's leading manufacturers of heavy trucks and buses as well as industrial and marine engines. Unlike the other competitors Scania focuses only on the heavy transport segment. (5)

"Scania's objective is to deliver optimised heavy trucks and buses, engines and services, provide the best total operating economy for our customers, and thereby be the leading company in our industry. The foundation is our core values, our focus on methods and the dedicated people of Scania." (5)

The Scania's identity and strategy are reflected in their brand values: "Pride" and "Trust" and their core values: "Customer first", "Respect for the individual" and "Quality".
Scania communicates its philosophy as focusing on methods rather than results. "Results will come as a consequence of doing the right things right. In order to be successful it is essential to continuously work with improvements." (5)

Scania´s modular system gives the possibility of having a minimum number of parts and allows for many variations. This system provides a high degree of customization while keeping down the cost of product development and production as well as providing a global accessibility to parts and services. So tailoring each vehicle to specific transport needs and providing a better overall operating economy is the way Scania fulfills its core values. (6)

Pre-Studies

2. Theory

The theory chapter aims to give an understanding of LowEntry and analyse the existing instep solution to declare possible areas of improvement and to distinguish limitations and regulations.

2.1. Scania cab program

The existing Scania trucks are the 5th generation of cabs, with three different standard truck series; the P-, G- and R-series. The current total sales rate for Scania trucks is approximately 75.000 trucks a year. The series offers a range of different cab versions, short, day and sleeper. The sleeper cab version is available in different heights; Low, Normal, Highline and the R-series exclusive Topline height. See the different cab models in figure 2-1. (7)

Figure 2-1 Scania Cab program (8)

P-Series
The P-series are compact, lightweight, manoeuvrable and fuel-efficient trucks suited for applications such as regional and local distribution, short-range transportation and hectic construction sites. (7)

G-Series
The G- series offer more power, space and comfort compared to the P- series. The trucks are developed for national long-haulage, distribution and all types of construction applications. (7)

R-Series
The R-series are Scania's premium trucks. They are designed to meet the highest and toughest demands in the world regarding long-haulage and construction applications. (7)

2.2. LowEntry

The Scania LowEntry cab is part of the special vehicle program, and is suited for applications requiring a LowEntry step; where the crew frequently need to ingress and egress the cab throughout the workday. The main difference between a LowEntry and a regular truck is the lower height from the ground to the cab floor. In figure 2-2 a LowEntry cab is compared with a P-series cab.

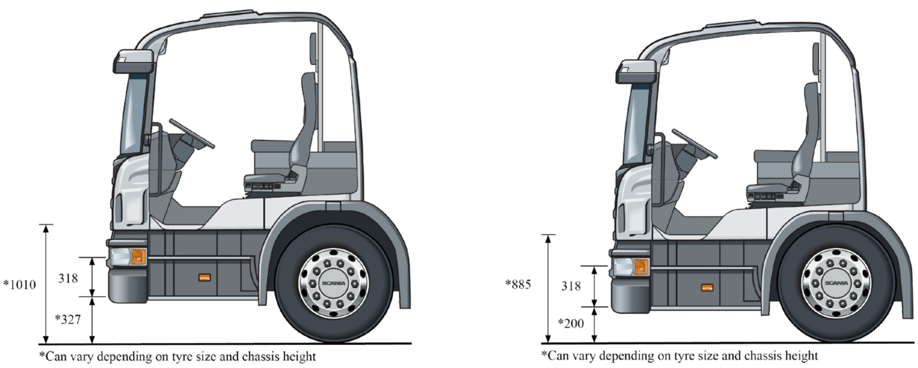
Figure 2-2 LowEntry compared with a regular P-series truck

The Scania LowEntry truck is a modification of the P-series, using the modular program from R and T-series, where the T-series are out of production. The cab front is taken from the P-series, the cab floor is from the R-series and the door is from the T-series. The cab is mounted 550 mm ahead of the front axle and the floor is lowered 450 mm compared to the R-Series. The configuration enables a LowEntry design with a wide instep. The truck has a kneeling function, which activates when the truck door opens if the parking brake is applied. This allows the cab to go lower. This process combined with a cab floor designed for cross-cab movement and the 90° opening door offers up to a four man crew an easy boarding from both sides of the truck. (9)

The LowEntry truck is intended for an urban and rural environment characterized by a hectic work schedule where there is a need for frequent, quick and convenient access to the cab. Examples of the suitable fields are refuse collectors, recycling transporters, multi-drop distribution and airside markets.
The annual current sales rate is approximately 50 LowEntry trucks a year.

2.2.1. Overview of the LowEntry

This subsection illustrates an overview of the LowEntry cab in driving and kneeling position.



Driving Position

Kneeling Position

Figure 2-3 Illustrated LowEntry overviews (8)

Specifications:

- *Kneeling function*
- *Double steps entry*
- *Total height from the ground to the cab floor 1010 mm**
- *Total height from the ground to the cab floor kneeled 885 mm**
- *The lower step's height from the ground 327 mm**
- *The lower step's height from the ground after kneeling 200 mm**
- *Instep width 810 mm*
- *90º opening door*
- *Overall cab width 2486 mm*

* Can vary depending on tire size and chassis height. The LowEntry truck is available in Normal and Low chassis heights, with a difference of 58 mm.

2.3. LowEntry background

Scania has been manufacturing the LowEntry cabs for three sequent truck generations. The principle of moving the cab forward, ahead of the front axle and lowering it down has been the same.

The first Scania LowEntry cab arose during the 1980's. The truck was named the Low-Liner and was based on Scania's 3rd cab generation. The cab had a single instep. See figure 2-4.

Figure 2-4 Scania Low-Liner (8)

The second LowEntry cab was based on the 4th generation of the Scania trucks launched in the mid-1990's. Similar to the current LowEntry model, the cab was higher than the earlier model. Therefore a double instep was necessary for accessing the cab. See figure 2-5.

Figure 2-5 Scania LowEntry 4th generation cab (8)

2.4. Product analysis

This section aims to clarify and define the instep's functions, relationship between parts and in order to give a general understanding of the existing instep.

2.4.1. Function

The instep's main function is to assist the driver to enter and exit the cab in a safe, quick and convenient way.

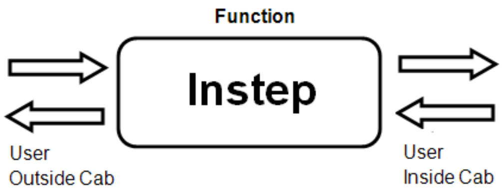


Figure 2-6 Process for an instep

2.4.2. Scania modular instep

The LowEntry instep is based on the standard Scania instep that is part of the Scania´s modular system. The modular system allows Scania to minimize the number of unique parts. All Scania truck series use the same design concept, except LowEntry since the cab is placed differently. See figure 2-7.

Figure 2-7 Standard modular insteps (8)

Regular truck instep specifications:

- *The steps are symmetrical, fits both left and right side*
- *The design has anti-slip texture*
- *The steps let dirt through the structure*
- *The steps are mounted directly on the step well*
- *The step well is integrated with the surrounding environment using plastic covers*

2.4.3. LowEntry instep

The current instep's main parts are the step well, the steps and a support frame. See figure 2-8. (3)

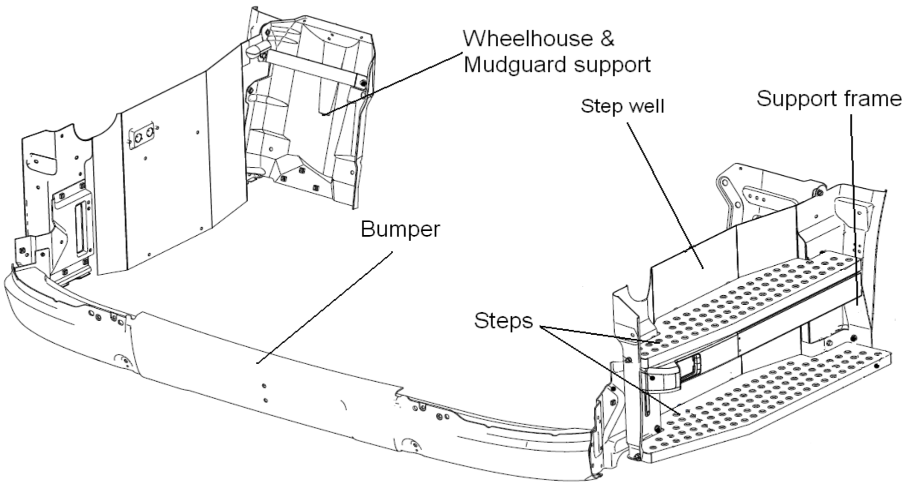


Figure 2-8 Instep overviews (10)

2.4.3.1. The step well

The LowEntry step well is a modification of the standard Scania step well. The step well has been cut into two mounting brackets that are separated, extended and offset from each other in longitude direction with a sheet metal to fit the existing standard assembly points. Since the standard brackets are designed for different height and placement, they do not fit the LowEntry trucks. The adjustment results in a step well with non-symmetric edges, bumps and holes. See figure 2-9 and 2-10

The general dimension of the house is 1065 x 520 mm, the thickness of the sheet metal is 1.5 mm and the mounting-brackets are 1.75 mm thick. The parts are irregular for the left and right side of the truck, the left side needs cuts for the nozzle with the level indicator for the anti-freeze liquid. The right side step well has cuts for the engine and the compartment heater plugs. See figure 2-9 and 2-10.

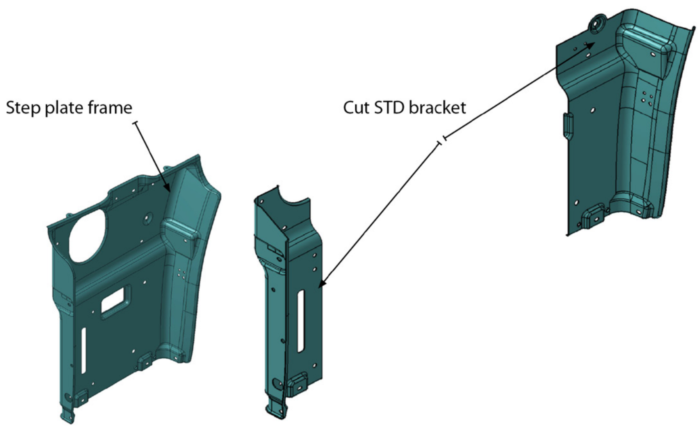


Figure 2-9 Cut standard brackets

The step well's functions are to:

- *Mount the steps to the cab*
- *Connect bumper with the wheelhouse and mudguards*
- *Mount internal brackets*
- *Cover internal parts like radiator, heaters, controllers, cabling, etc.*

The internal standard parts that the step well is mounted on are shaped after the bump on the cut standard mounting brackets. See figure 2-8. The internal parts limit the depth of the instep.

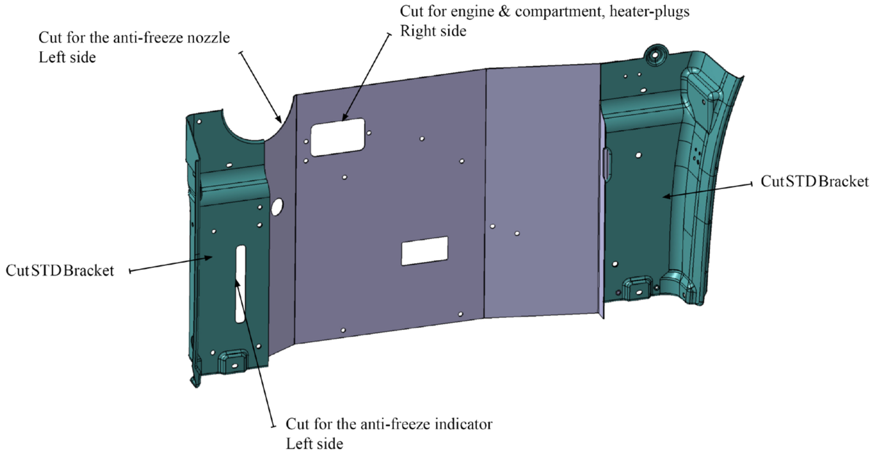


Figure 2-10 Step wells with left and right cuts (10)

2.4.3.2. *The steps and support frame*

The current steps are made of 2 mm thick sheet metal that is folded around a steel frame. The frame supports the steps and is mounted on the step well. See figure 2-11. The reason a frame is used to support the steps is the asymmetrical placement of the cut standard brackets. This causes the bumps and the screw holes' position out of place which makes it difficult to mount the steps directly on the step well in a good way.

- *The lower step is 965 mm wide with a maximum depth of 250 mm*
- *The upper step is 920 mm wide with a maximum depth of 200 mm*
- *The distance between the steps are 318 mm.*
- *Step gradient angle α 81°*
- *The steps are asymmetric, which means that each cab needs four unique steps, two for the right side and two for the left side of the cab.*
- *The edges have no anti-slip protection*
- *Texture of the topside doesn't give a good foothold*

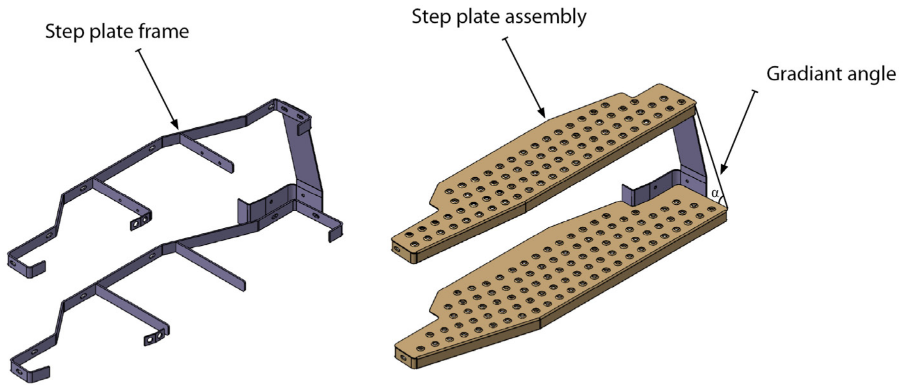


Figure 2-11 Support frame without and with steps

Figure 2-12 Existing insteps

2.4.3.3. *The cab floor*

In the regular Scania truck, the gap between the cab floor and the instep is covered with a plastic cover which follows the line from the bumper all the way to the mudguard. The solution is not applicable in the LowEntry trucks due to the lower cab placement. The plastic cover would clash with the cab floor because of the cab movement while driving. Therefore the current LowEntry instep has an elastic rubber sheet mounted from the cab to cover the gap and hide the inner parts. See figure 2-12.

2.4.3.4. *The washer fluid container*

The washer fluid container is located in front of the left side of the truck, where the container's pipe neck continues above the step well edge. The pipe does not perfectly fit the LowEntry instep; because the LowEntry instep has a shorter step well compared to the regular Scania trucks. See figure 2-12.

2.4.3.5. *The mudguard lock*

The wheel-house mudguards are connected to the step well with a spring lock fixed on the outer side of the rear cut standard bracket. The purpose of the step frame is to avoid the spring lock. See figure 2-12.

2.4.3.6. *Pipe guiding rail*

The Pipe guiding rail is a unique LowEntry part. The rail is mounted on the driver side step well and the part's function is to support and guide the cables due to the 550 mm cab extension. See figure 2-13.

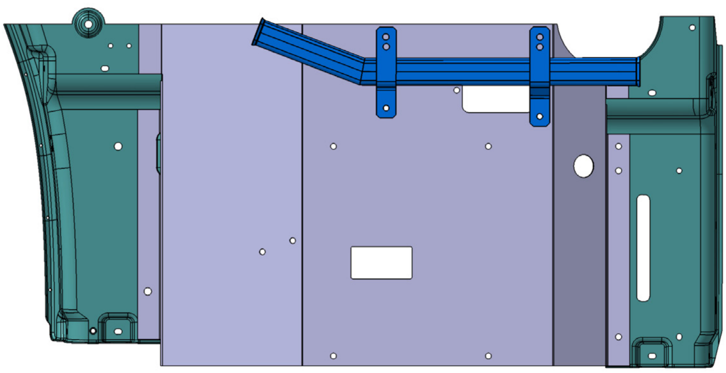


Figure 2-13 Pipe guiding rail

2.4.4. Manufacturing and costs

The existing LowEntry instep is designed by Laxå Special Vehicles AB. The company has developed and manufactured special vehicles for Scania since the 1960's.

Most of the standard Scania parts on the LowEntry chassis are assembled on the Scania´s production line in Södertälje and then delivered to Laxå Special Vehicles. Their production of the LowEntry includes:

- *Modification of the cab*
- *Modification of the chassis*
- *Docking the cab to the chassis*

Laxå Special Vehicles AB is a part of Scania's production system for the LowEntry and Crew-cab trucks. (11)

The manufacturing costs for a single complete existing instep is approximately 3000 SEK including the steps, frames and step well for each side of the cab.

2.5. Ergonomic guidelines

Transport-related activities involving manual handling on and off trucks are a major contributor to workplace injuries. Egression and ingression is often associated with poor steps, handholds and slipping risk. It is important that getting in and out of the cab is carried out in an easy and safe way.

There are a number of factors that are necessary for ease of ingress and egress in trucks. They are also required for avoiding potential accidents. These factors are presented in appendix A1.

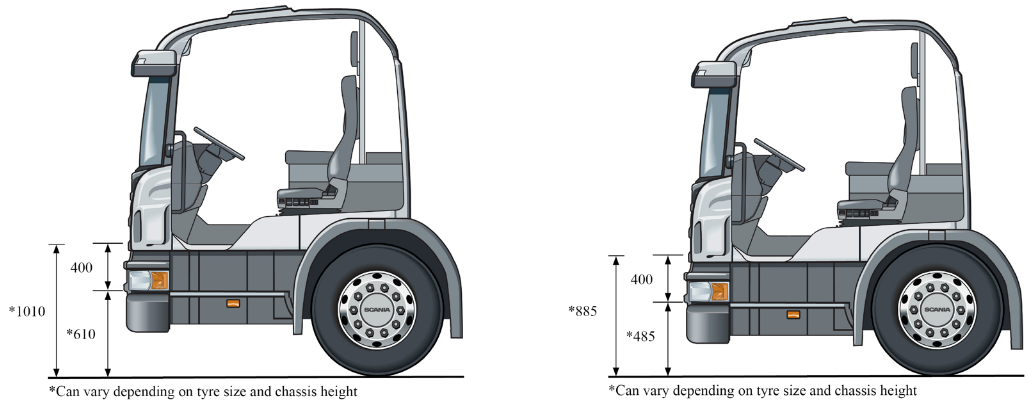
2.6. Standards

There are standards and legislations for how a truck instep should be designed. It is important that the design fulfills the necessary standards and legislations. The LowEntry truck has a broad range of applications, and needs to fulfill a range of different standards. A summary of the general access, refuse collectors and rescue service vehicles standards are available in appendix A2.

2.7. Single instep

One of the project's objectives is to design a modular instep that can be used as both a single and double instep. It is difficult to have a single instep on the existing LowEntry truck because of the height of the cab floor.

The cab floor height from the ground in driving position is approximately 1010 mm and 885 mm in kneeling position. According to the European Directive 70/387/EEC available in appendix A2 the maximum distance allowed between steps for a truck instep is 400 mm, which results in a step placement as in figure 2-14.



Driving Position

Kneeling Position

Figure 2-14 Single Step heights in driving and kneeling position (8)

According to the Swedish standard SS-EN 1501-1 available in appendix A2, the maximum allowed height to the first step from the ground in driving position for a regular truck is 600 mm (550 mm for fire fighter truck). For a refuse collector the maximum approved height to the first step from the ground is 450 mm (no specification on driving position).

To be able to design an approved single instep the truck needs to be lowered at least 10 mm (60 mm for fire fighters) in driving position and 35 mm kneeling position. A good single instep design requires the truck to be lowered so the cab floor height in kneeling position is maximum 800 mm.

The engine´s location and its size set restrictions on lowering the cab height in driving position and the minimum clearance between the ground and the bumper limits the kneeling height.

3. Exterior design elements

Products can be designed to carry explicit and implicit references (or simply called as explicit and implicit design cues) (12) Explicit visual references are embedded in the design features that designers implement with the intention to be immediately perceived and recognised. (13)

The exterior of the current Scania trucks was analysed with an element break down to find strong design cues that are present in the truck design.
The analysis identified the most important design elements used by Scania.

The LowEntry's front is taken from the P-Series cab. There are minor changes in the chassis, the doors and the instep (lower part) but the explicit design identity of Scania remains the same.

Figure 3-1 Scania P- Series truck (8)

3.1. Exterior element break down

The explicit design cues of the Scania exterior were listed to be used in order to integrate the new instep with the rest of the truck.

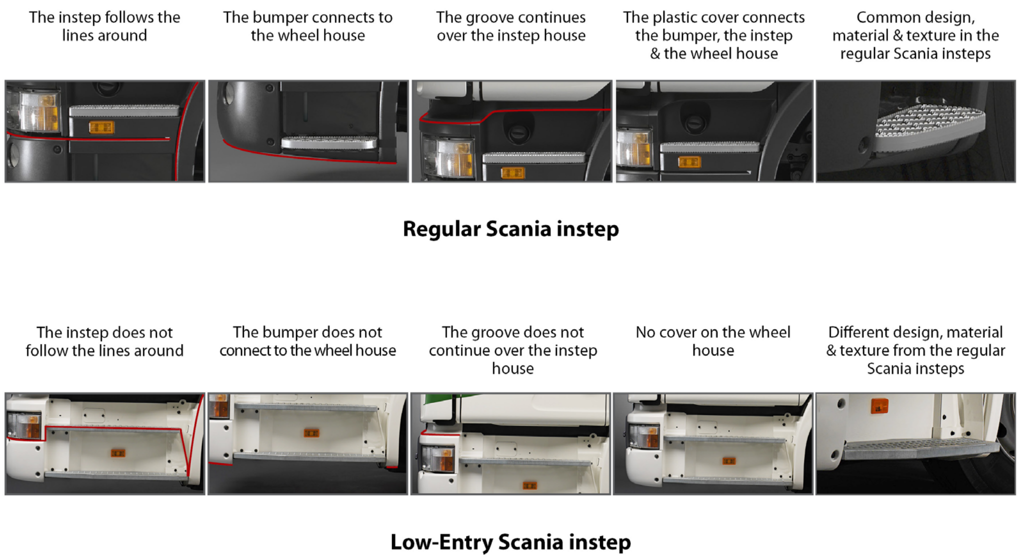
Some design elements are more applicable to designing an instep while there are some others that are explicit but less relevant to this project.

In this part the focus is on the relevant design elements and some less related ones are briefly mentioned. See figure 3-2.

Figure 3-2 Scania exterior element (8)

3.2. Scania modular instep VS. LowEntry instep

A comparison between the regular modular instep and the LowEntry instep has been carried out. The comparison shows that despite that there is a design thought behind the regular insteps in order to make them connected visually with the rest of the truck, the LowEntry insteps follow



none of the directions and it is totally different. See figure 3-3.

Figure 3-3 Comparison of the regular and LowEntry instep (8)

4. Competitor analysis

This chapter's aim is to get a general understanding of possible solutions for a new instep and find additional requirements. See the requirements from other manufacturers' point of view reflected on their design solutions. Therefore a market analysis on five LowEntry truck manufactures is carried out. The analysis focused on the latest solutions in the market for each brand.

4.1. Volvo

Volvo is a Swedish supplier of commercial transport solutions providing products such as trucks, buses, construction equipment, engines and drive systems for boats and industrial applications as well as aircraft engine components. (14)

4.1.1. FE low-entry cab (LEC)

Volvo FE Low Entry Cab (LEC) launched in 2010, is aimed at the waste collection and recycling sector in both urban and rural environments. It is especially designed for the UK and the Irish market. The Volvo LEC is built on the standard FE truck chassis, mounted 600 mm ahead of the front axle and lowered 200mm. (15)

"LEC" Specifications:

- *Four men crew cab*
- *Overall cab width of 2300 mm*
- *Flat floor*
- *Single step entry*
- *The lower step's height from the ground 550 mm at the both sides*
- *Available with air suspension (with the option of kneeling function)*
- *The first instep's height after kneeling function, 440 mm*
- *90º opening door*

Figure 4-1 Volvo LEC (15)

4.2. Dennis Eagle

Dennis Eagle is a manufacturer of refuse collection trucks based in the UK. The company focuses on the complete recycling solutions. (16)

4.2.1. Olympus

The Olympus low-entry cab is based on the Pheonix2 body, an earlier low-entry cab from Dennis Eagle. (17)

"Olympus" specifications:

- *Four to six men crew cab*
- *Overall cab width of 2500 mm*
- *The cab floor's height from the ground 790 mm*
- *Single step entry*
- *The first step's height from the ground 435 mm*

Figure 4-2 Dennis Eagle Olympus (17)

4.3. MAN

MAN is a German supplier of commercial vehicles, diesel engines, turbo machinery and related services in Europe. (18)

4.3.1. TGA low-entry

The MAN TGA low-entry was produced from 2005 to 2008. The cab was bought from Dennis Eagle in the UK. (19)

"TGA" specifications:

- *Four men crew cab*
- *The entry width of 750 mm on the co-driver's side*
- *The cab floor's height from the ground 700 mm*
- *Pivoting door used on buses at the co-driver's side*

- *The first step's height from the ground 345 mm*
- *Air suspension function*

Figure 4-3 TGA low-entry (19)

4.4. Mercedes-Benz

Mercedes-Benz is a German manufacturer of automobiles, buses, coaches and trucks.

4.4.1. Econic II

The second Mercedes-Benz's low-entry truck (Econic I/1998) introduced in 2006 is a municipal, collection and distribution vehicle. The cab is available with a low and high roof. (20)

Econic II specifications:

- *Four men crew cab*
- *Overall cab width of 2032 mm*
- *Entry width of 620 mm*
- *Flat cab floor*
- *The cab floor's height from the ground 795 mm*
- *Folding door at the co-driver side*
- *The first step's height from the ground 450 mm*
- *The standing height in the cab 1930 mm in high cab*
- *Air suspension with kneeling function*

Figure 4-4 Mercedes Econic (20)

Figure 4-5 Air Suspension (20)

4.4.2. Renault

Renault is a French automaker producing cars, vans, buses, tractors, trucks and in the past auto rail vehicles.

4.4.3. Access

Renault Trucks new low-entry cab named "Access" added to Renault's distribution range in 2010. The truck is mainly designed for refuse collection. The cab is mounted on a Dennis Eagle Elite2 chassis at the Dennis Eagle manufacturing site badged with the Renault brand, initially launched for the French market. (21)

"Access" specifications:

- *Three men crew cab*
- *Flat cab floor*
- *Single step entry*
- *The first step's height from the ground 435 mm*
- *The standing height in the cab 2000 mm*

Figure 4-6 Renault Access (21)

4.4.4. Puncher

The "Puncher" model was a common project from both Renault Trucks and PVI (Ponticelli Vehicles Industrials). When launched (2004), the Puncher introduced the highest payload capacity on the existing refuse market, while also having a very low access. The "Puncher" low-entry cab is especially suited to household refuse collection, street cleaning and urban delivery in European cities. The series is out of production since 2007. (22) (23)

Figure 4-7 Puncher (23)

4.5. BMC

BMC is one of the largest commercial vehicle manufacturers in Turkey. It was founded 1964 by Ergün Özakat in partnership with the British Motor Corporation in Izmir. BMC's product range consists of light commercial vehicles, heavy commercial vehicles, buses and coaches. (24)

4.5.1. BMC Professional 628 low-entry cab truck

The BMC Professional 628 Low entry truck is designed to ease the access of the cab by emphasizing the step height and door opening. (24)

BMC Low Entry specifications:

- *Four men cab*
- *Overall cab width of 1850mm*
- *Flat cab floor*
- *Low frame*
- *Single step entry*
- *The cab floor's height from the ground ~800mm*

Figure 4-8 BMC Professional 628 (24)

4.6. Summary

According to the analysis, providing a low access and an easy ingress/egress without obstacles are the most manoeuvrable features in new low-entry trucks. By combining some of the elements from buses and trucks, especially for refuse collectors results in an easy and fast access.

			Low-Entry	LEC	Econic II	TGA	Olympus	628 UHX	Puncher	Access
Kneeling function			●	●	●	—	—	—	—	—
Flat cab floor			—	●	●	●	●	●	●	●
Single step entry			—	●	●	●	●	●	●	●
Folding door			—	—	●	●	—	—	●	—
Chassis		*	T	T	B	B	B	B	B	B
Floor height from the ground		**	1009 / 875	~950 / ~840	890 / 795	700	790	~800	—	790
Lower step from the ground			390 / 195	550 / 440	450	345	435	450	—	435
Upper step to the floor			365	~400	440	355	355	~350	—	355

* T=Truck , B=Bus
** Heights are measured before and after kneeling.

Figure 4-9 Competitor Comparison

4.6.1. Kneeling function

Kneeling function lowers the cab with air suspension. Since Scania LowEntry trucks are mounted on a truck chassis, the kneeling function is needed to lower the cab down as much as possible for a lower access. While it's an added value to Econic II to become even lower.

4.6.2. Bus chassis

Lower level of bus chassis offers easy and convenient access in and out. The disadvantage in comparison with the truck chassis is less driving comfort.

4.6.3. Folding doors

Positioned low, bus doors provide a convenient and easy way in and out. One of the disadvantages of folding doors is the higher noise level in the cab.

4.6.4. Single instep

It provides lower access, easy and safe ingress and egress. Scania LowEntry trucks are the highest from the ground and the only one with double steps.

4.6.5. Flat floors

Flat floor allows the cab-crew to get in and out on both sides - a very practical feature when cars or walls restrict access to the vehicle. Scania has a flat floor with a bump in between and that's because of the engine tunnel.

4.6.6. Floor height from the ground
Lower floor height provides ease of entry and exit. Scania LowEntry trucks are the highest from the ground in the market.

4.6.7. Lower step from the ground
Lower floor height provides ease of entry and exit. Scania has the lowest first step level only because it has double steps entry.

4.6.8. Upper step to the floor
An evenly distributed distance from the ground/upper step to the floor eases the cab access.

5. User Analysis

The user analysis aims to clarify the users' needs and recognise their behaviour as well as identifying the opportunities to satisfy the users' requirements. (2) (1)

To be able to clarify the needs and behaviours, three visits has been carried out at different refuse collector companies and at one storage distributor, where observations, recordings, interviews and user tests of the existing LowEntry instep have been done. The outcome is presented in different user scenarios based on the visits. See appendix A3 with correlated media files in appendix A10 for more details.

5.1. User scenarios

A user scenario includes a well-defined hypothetical user and storyline about the user, using the product. The purpose of the scenarios is to present a feeling about how and in what environment the product is used, and reveal the opportunity for improvement. (1)

5.1.1. Fredrik the refuse collector

Fredrik is 42 years old and has been working in a refuse collector company for more than 5 years. He drives a Scania LowEntry truck with a sweeper and fraction for collecting household wastes.

The refuse collection field characteristics are very hectic; Fredrik has to collect all the households in his district during one workday. Customers follow a schedule for when the bins should be placed at the road for the refuse collector to pick them up. His daily collecting tour has about 300 collection stops. It means that Fredrik has to step in and out of the cab more than 300 times during a working day and he has started to get problems with his knees because of the repetitive strain that the continuous ingress and egress causes in the knees.

Fredrik needs to hurry to be able to finish his daily round, and then get home. But the truck's instep doesn't fit his needs very well. The steps are placed like a ladder; he can't see the lower step. In addition the steps are very slippery.

Despite being very cautious, he has fallen several times from the instep and hurt his shinbone. Due to him avoiding a fall and putting strain on the knees, he never jumps or skips any steps. Instead he uses both steps and climbs in and out carefully, gripping the door handle and the steering wheel. Especially in winter when the steps and his shoes collect snow and mud and it gets even more slippery.

Fredrik needs a better positioned instep in which he can step in and out instead of climbing. He wants non-slippery steps for safe access. He wants the steps not to collect dirt and water or snow.

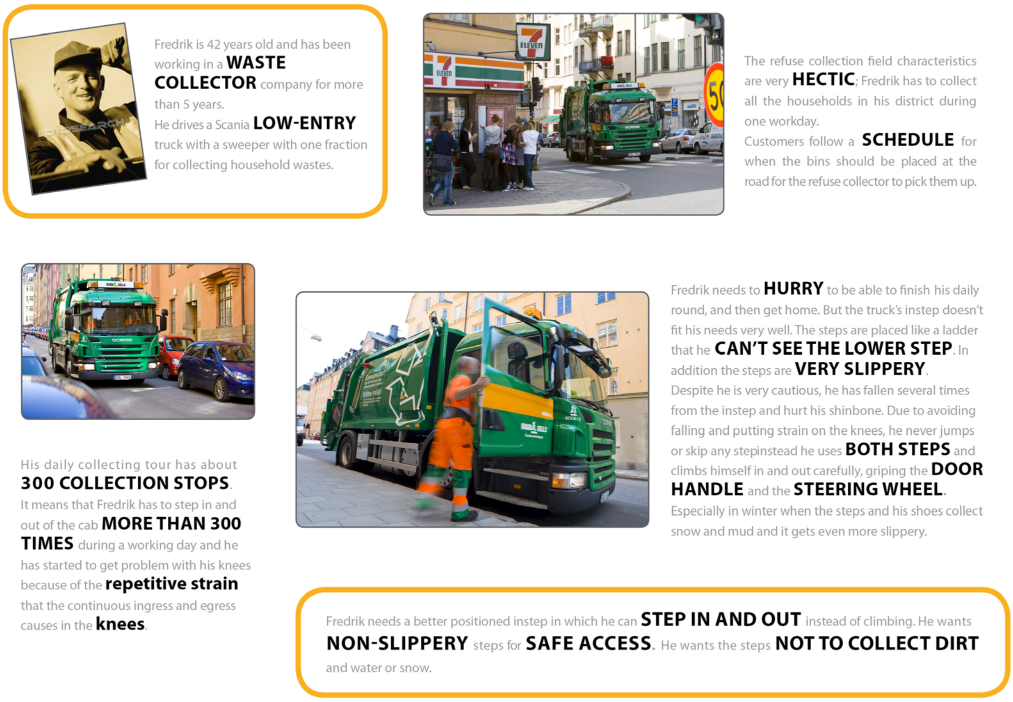


Figure 5-1 Fredrik the refuse collector

5.1.2. Mark the storage distributor

Mark is 28 and has been working as storage distributor in IKEA for 2 years. He drives a Scania LowEntry truck with a kneeling function and distributes containers to different warehouses inside the storage area. He usually works together with another colleague. They divide the driving task between them during the day, but both exit the truck for the delivery and loading process.

They have a tight schedule of delivering 4 to 5 containers every hour. Each load and delivery requires 5 to 6 exits and entries in order to be able to connect and disconnect the container on the truck. During an 8 hour work day, they ingress and egress at least 200 times.

Mark always approaches the cab entrance from the back of the truck, he opens the door and the cab kneels. He grabs the door handle and reaches for the steering wheel and lift himself up using both steps, long before the cab has fully kneeled. If the truck is already in kneeling position, he sometimes uses only the upper step because he feels the lower step is placed too low. But the upper step is too high to always be used as a single entry step.

In order to be fast, Mark needs to step in and out instead of climbing the stairs. But the lower step is hard to reach in a fast pace. Most of the times he just touches the steps' edges with his foot paw. Because of the steps position and the slippery steps, there is a risk of falling. Mark has slipped on the steps several times and feels unsecure exiting the cab, so he often jumps off from the upper step. He is aware that the frequent jumps put a lot of strain on his knees and in the long term he will get problems with his knees, like his elder colleagues.

Mark needs an instep with a stair feeling, easy to reach without gripping the door and steering wheel with a good anti-slip texture.

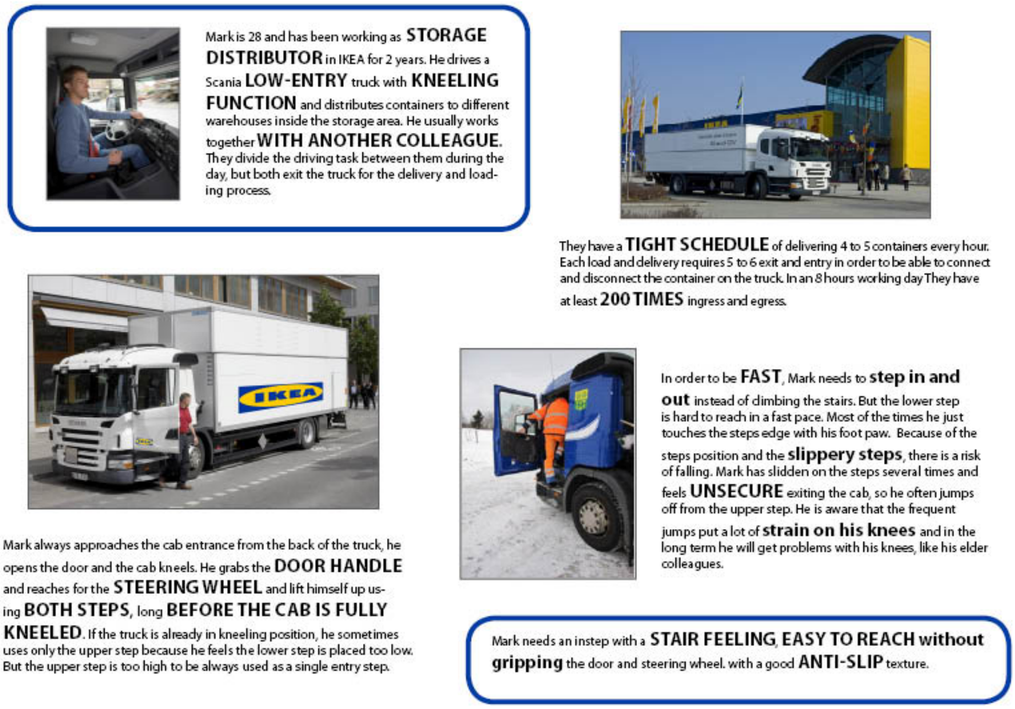


Figure 5-2 Mark the storage distributor

5.2. Conclusions

The user analysis displays that the user desires an instep with a stair feeling, which enables the user to walk in and out of the cab instead of climbing. The defied areas of improvement are:

- *The steps are slippery*
- *The steps collect water, dirt and snow*
- *The lower step is hidden under the upper step and hard to reach*
- *The kneeling function is too slow*
- *The steps are not robust enough*

6. Setting requirements

The purpose of setting the requirements is to make an accurate specification of the performance required for the design solution that consists of both demands (D) and wishes (W). The specification defines the required performance, and not the required product.

The requirements for the instep are developed together with Scania's Special Vehicles department.

6.1. Requirements

General function

- *Assist the user's entry and exit of the cab (D)*

Safety

- *Anti-slip function (D)*
- *Safety labels/notations (W)*
- *Fulfill ergonomic guidelines (W)*

Design

- *Modular, adjusted for different range of use (D)*
- *Fit on the truck (D)*
- *Adjustable instep heights (W)*
- *Use the existing step well (W)*
- *Use standard parts (W)*
- *Single instep (W)*
- *Hide instep by the door (W)*
- *Convey the Scania identity (D)*

Technical

- *Carry static load of 1800 N (D)*
- *Temperature range (-30) – (+80)°C (D)*
- *Last 75000 design load cycles (D)*
- *No visible corrosion for the first 3 years (D)*
- *No visible corrosion for the first 5 years (W)*

Standards and legislations

- *Fulfill the standard for general insteps (D)*
- *Fulfill the standard for refuse collectors (D)*
- *Fulfill the standard for fire and rescue service vehicles (D)*
- *Fulfill the general standards regarding truck measurements (D)*
- *Fulfill general Scania standards (D)*

Costs

- *Price of the final product should be proportional with the existing solution (D)*

Manufacturing

- *Possible to assemble by Laxå Special Vehicles AB (D)*
- *Possible to be sourced by Scania CV AB (D)*

Environment

- *Recyclable (D)*
- *Designed for disassemble (W)*
- *Environmental friendly materials and surface treatment (W)*

6.2. Quality Function Deployment

The aim of the Quality Function Deployment (QFD) method is to set and weigh the engineering characteristics of the product against the customer demands and to clarify the relationship between them. The customer demands in the QFD are the project objectives.

The QFD chart shows that the step placement, distance between the steps and the shape of the steps are the main engineering criteria for an ergonomic instep design. See appendix A4.

Concept Design

7. Concept generation

To find a solution which meets the set requirements, demands and wishes, four weeks of concept design is carried out. The aim has been to generate as many ideas as possible in order to find the feasible concepts according to the limitations and develop them further to come across the best solution. (2)

The approach has been to find basic principal solutions that are essential for the instep. Then make different variations of the principles to explore different shapes, connections and integration. The concept generation are separated in step concept and step well concepts, which later are combined with a morphological chart for further development.

Pencil and paper are the main tools used for the design phase. To be able to determine the concepts' functionality, simple wooden prototypes are made and tested in an instep model rig.

Based on the test results and consultation with advisors at the special vehicles, the ergonomics and styling departments the concepts are screened and the concepts with the most potential are further developed.

7.1. Step concepts

The generated step shapes are categorized into 6 main concept principles. See figure 7-1. Each concept group consists of several shape and form variations of the same basic principle. The concepts' sketches are presented in table 7-1, a part of a developed morphological chart section.

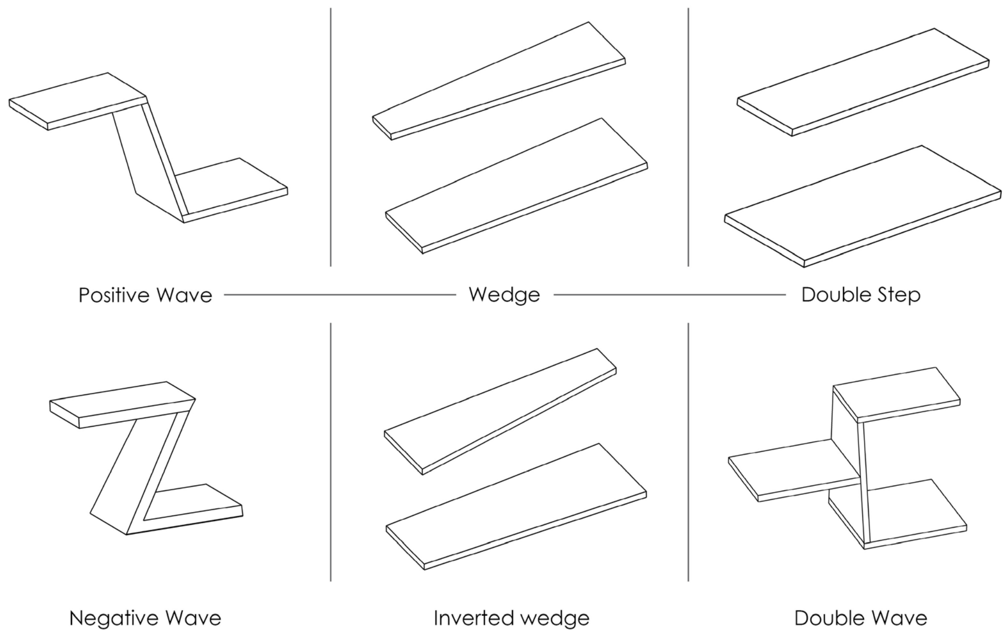


Figure 7-1 Step concepts

7.1.1. Concept 1 “Positive wave”
The aim with this principle is to have an instep with a stair feeling that allows the user to walk in and out of the cab with good comfort and good visibility of the steps. The idea is based on the users’ tendency to approach the truck from the back side so offering a stair from the side. The Step is intended to be a single part step in different levels, resulting in a double step as well.

7.1.2. Concept 2 “Negative wave”
The design principle behind concept 2 is similar to concept 1. The only difference is the reverse angle. The “Wave” has a gradient towards the rear of the instep, allowing for a wider upper step.

7.1.3. Concept 3 “Wedge”
The concept principle is that the steps are shaped like a Wedge. The purpose is to get a comfortable stair feeling for both ingress and egress of the cab.

7.1.4. Concept 4 “Inverted wedge”
The Inverted Wedge is the same principle as the Wedge. The difference is that the upper step is inverted for more shin clearance while getting out.

7.1.5. Concept 5 “Double step”
Concept 5 is a regular double step solution similar to the existing solution but with different depth of the steps to obtain a better “walk-in-and-out” feeling.

7.1.6. Concept 6 “Double wave”
The principle behind the concept 6 is to have the possibility of both single and double steps in the same design. The concepts are supposed to be used as both single, double or a combination of steps depending on the user’s length.

7.1.7. Concept X “Mix”
Concept X is consisting of random concepts with irregular shapes that are not practical or functional. More sketches are available in the media appendix A10.

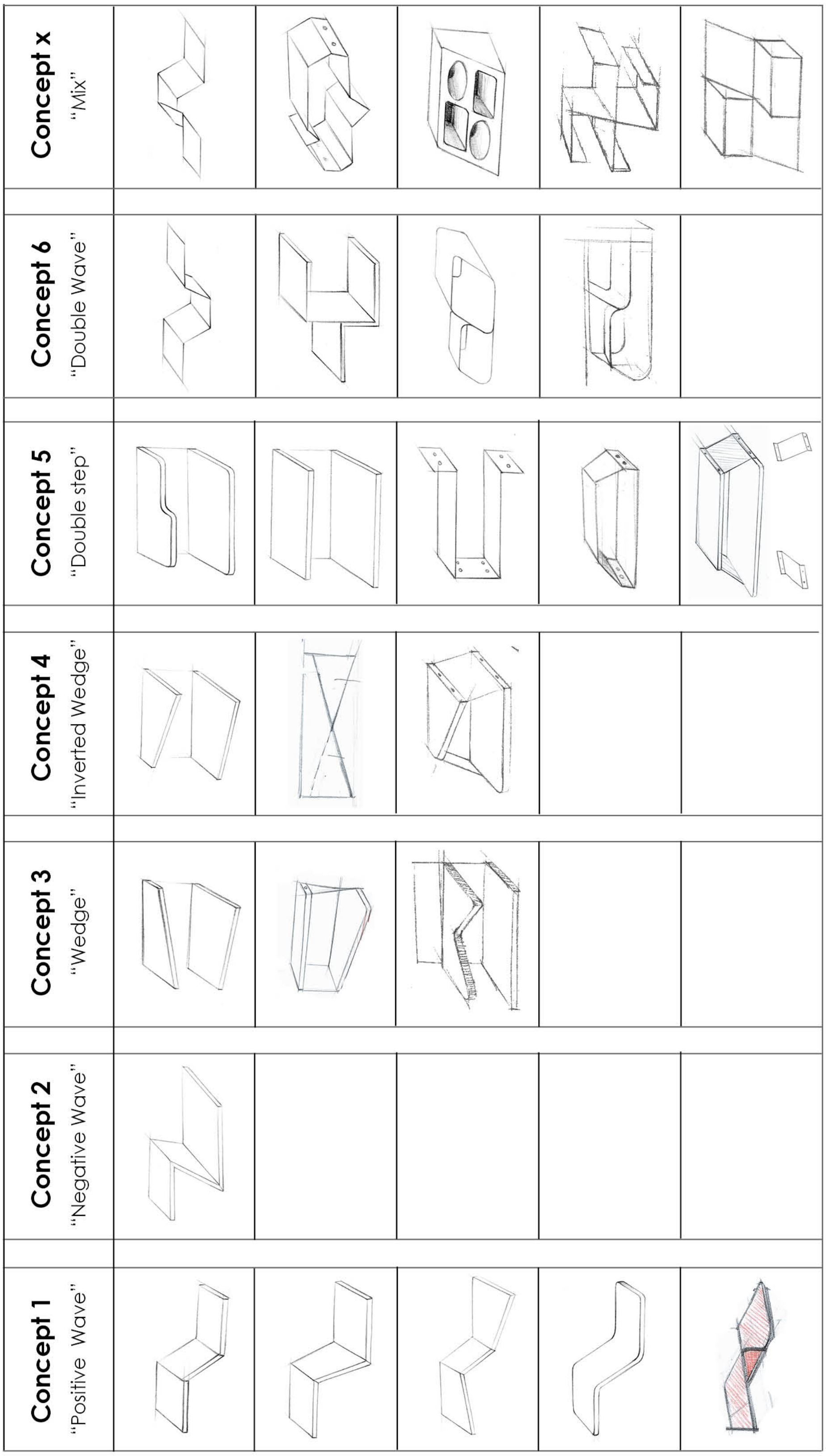


Table 7-1 Morphological chart steps

7.2. Step concept test analysis

The test analysis aims to evaluate the ergonomics of the principal concepts and determine the best height placement of the steps. The principle shapes of the steps are manufactured in wood and tested at different heights in an instep model rig at the Scania´s model workshop.

The different concepts are tested with 7 participants, including 3 vehicle ergonomists from Scania R&D. The test includes both kneeling and driving position. The summary of the tests are available in appendix 5 and the video recordings of the test are available in the media appendix A10.

7.2.1. Single instep test

A test with a single instep demonstrates that a single instep is a bad ergonomic solution with the current cab floor height of 885 mm in kneeling position. The height obliges the user to put a lot of extra strain on knees and hips. The test concludes that the floor height for a good ergonomic single instep is maximum 800 mm.

7.2.2. Step test conclusions

The tests conclude that "The Inverted Wedge" and "The double step" concepts are the safest and most ergonomic step concepts.

According to the test, an equal spaced distance between the steps from 300 to 340 mm and a maximum step gradient α of 75°offers good ergonomic when entering and exiting from the cab. See figure 7-2, 7-3 and table 7-2.

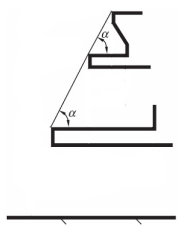


Figure 7-2 Step gradient α (25)

Step placement	Concept placements						Existing placement
Upper step to the floor	A	300	310	320	330	340	365
Distance between steps	B	300	310	320	330	340	318
Lower step from the ground	C	410*	390*	370*	350*	330*	327*
Lower step from the ground kneeling position	D	285*	265*	245*	225*	205*	200*
Upper step from the ground in kneeling position	B+D	585*	575*	565*	555*	545*	520*

*Figure 7-3 Step heights

Table 7-2 Step placement

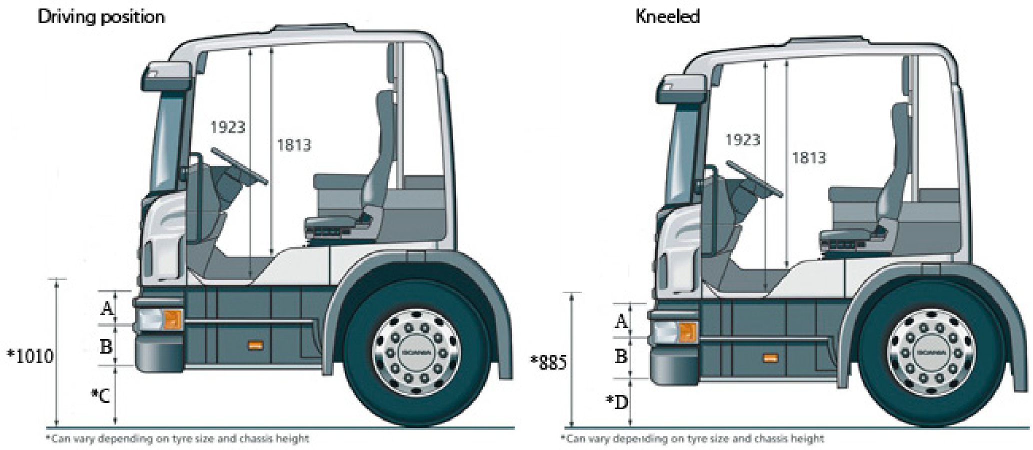


Figure 7-3 Step heights (8)

7.2.3. Step well concepts

The generated step well designs are categorized in 3 main concepts principles. Each concept group consists of several shape and form variations of the same basic principle. See table 7-3.

The main design idea is to cover the asymmetrical uneven instep brackets as well as the non-effective ingress and egress area of the steps. Early concept sketches are available in the media appendix A10.

7.2.4. Delimitation

Very early in the design phase, limitations were revealed that not many changes are possible in order to refine the design. These limitations affected and limited the idea generation process. Some of the limitations are listed below:

- *Scania's modular system restricts use of new parts*
- *Some of the standard parts are altered in Laxå Special Vehicles in order to fit the LowEntry*
- *Lack of resources restricts possible solutions*

7.2.5. Concept 1 "Remake"

The "Remake" principle is a complete new step well that is more integrated with the exterior design of the LowEntry truck. The design concepts focus on following the design lines from the side view of the cab.

The remake concept requires altering of the internal standard Scania parts to fit the new step.

7.2.6. Concept 2 "Instep add-on"

The "instep add-on" concepts are based on the existing cut standard bracket. The brackets are intended to mount a bent sheet metal that offer a smooth and clean surface for the whole step well. That allows for an easy mount of the steps directly on the step well wall in a clean way.

7.2.7. Concept 3 "Edge covers"

The "Edge covers" principle is based on the existing instep. The steps are mounted with a frame. The frame and the bracket edges are covered in different variations.

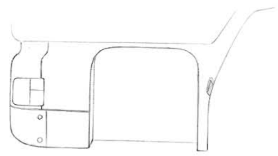
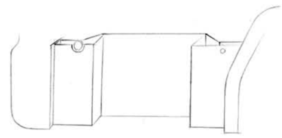
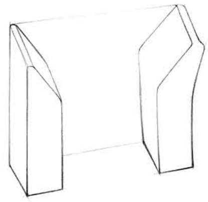
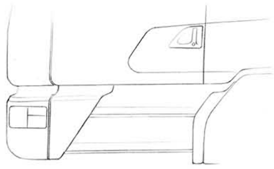
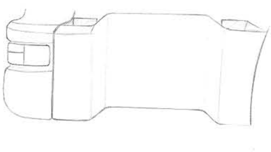
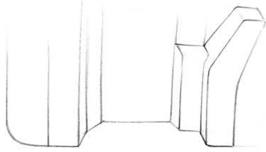
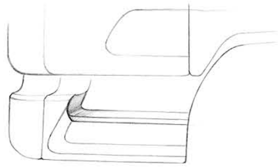
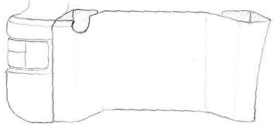
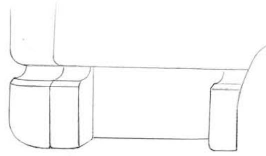
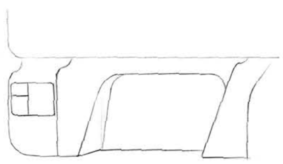
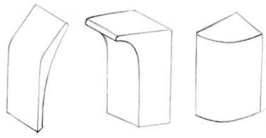
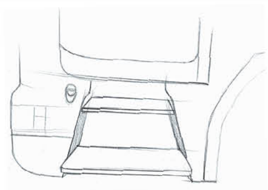
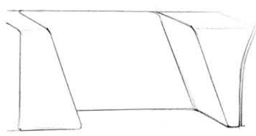
Concept 1 "Remake"	**Concept 2** "Instep add-on"	**Concept 3** "Edge Covers"
		
		
		
		
		

Table 7-3 Morphological chart step wells

7.3. The morphological chart

The Morphological chart lists the possible features and functions that are essential for a complete instep. The chart displays a large number of possible design combinations. (1)

The intention of this chart is to combine the variations of the step and the step well concepts presented in previous sections with features to be able to generate complete concepts proposals.

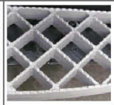
Step Concept	Positive Wave	Negative Wave	Double Step	Wedge	Inverted Wedge	Double Wave	Single Step
Step texture							
Instep house Concept	Remake	Instep add-on	Edge Covers				
Enable step height adustment	Rails	Diffrent postion of holes	No				
Mount of steps Instep house	Direct on instep house	 Console	 Frame	 Bracket	From cab floor		
Material	Plastic	Steel	Carbon fiber	Aluminium	Fiberglass		
Assembly	Screws & bolts	Welding	Glue	Pop rivet			

Table 7-4 Morphological Chart Features

7.4. Concept selection

The concepts are screened with a two-stage concept selections method. The two stages are concept screening followed by concept scoring. Each stage is supported by a decision matrix which is used to rate, rank and select the best concept(s). The concept screening is a quick and approximate evaluation that aims to introduce a few viable alternatives. The concept scoring is a more detailed analysis and evaluation of these relative few concepts. Highly scored concepts will be developed further. (2 pp. 124-129)

Both stages follow a six-step process:

- *Prepare the selection matrix*
- *Rate the concept*
- *Rank the concept*
- *Combine and improve the concepts*
- *Select one or more concepts*
- *Reflect on the result and the process*

7.4.1. Concept screening

Concept screening is based on a method called the Pugh concept selection. The aim of this stage is to narrow down the concept quickly and to improve them before the final selection. The process is done systematically through the six-step mentioned above. (2 pp. 130-133)

The selection matrix criteria are based on the main relevant objectives set of Scania for the master's thesis, where each criterion is given an equal weight at this stage. The screening process focuses on the step and the step well concepts, which are screened separately. See table 7-6 and 7-7. The design concepts are benchmarked relatively against a reference, in this case the existing LowEntry instep design. The relative grading system is presented in Table 7-5.

Rating	Relative Preformence
+	Better than reference
0	Same as reference
-	Worse than reference

Table 7-5 Relative screening grading

7.4.2. Step selection

The step concept selection is based on the concept test and evaluations made with responsible advisors at the special vehicles department at Scania that made it obvious to identify the more promising concepts. See table 7-6.

Selection Criteria Steps	Existing solution	Concept 1 "Positive Wave"	Concept 2 "Negative Wave"	Concept 3 "Wedge"	Concept 4 "Inverted Wedge"	Concept 5 "Double step"	Concept 6 "Double Wave"
Modular	0	0	0	+	+	+	-
Safety	0	0	-	+	+	+	-
Robust	0	0	0	0	0	0	-
Ergonomic	0	+	-	0	+	+	-
Manufacturing	0	0	0	+	+	+	0
Cost	0	-	-	+	+	+	0
Sum +´s	0	1	0	4	5	5	0
Sum 0´s	5	4	3	2	1	1	2
Sum -´s	0	1	3	0	0	0	4
Net Score	0	0	-3	+4	+5	+5	-4
Rank	3	0	4	1	1	1	5
Continue	No	No	No	No	Yes	Yes	No

Table 7-6 Step Concept Screening

The concepts principle "Inverted Wedge" and the "Double Step" are selected to be improved further. The ergonomic design was the main criteria when choosing the concepts to be further developed.

7.4.3. Step well selection

The step well concept selection is carried out as well together with responsible advisors at special vehicles department.

Selection Criteria Instep house	Existing solution	Concept 1 "Remake"	Concept 2 "Edge covers"	Concept 3 "Instep add-on"
Modular	0	+	0	+
Robust	0	+	0	+
Intergraded exterior design	0	+	+	+
Manufacturing	0	0	-	+
Sum +´s **Sum 0´s** **Sum -´s**	0 7 0	3 0 0	1 2 1	4 0 0
Net Score **Rank**	0 3	+3 2	0 3	+4 1
Continue	No	No	No	Yes

Table 7-7 Step well Concept Screening

The concept "instep add-on" is selected to be improved further because the concept provides a clean surface, which makes the mounting of the steps easy and without any expensive investments in tools.

The new instep design faces a lot of limitations especially regarding investment costs because of the low sales volume of the LowEntry truck. (~50 vs. 75,000 trucks)

Encountering these restrictions, the possible solutions have been narrowed down to a few options which can be adapted to the existing parts. On the other hand Scania would like to have some suggestions regardless of the limitation that could be used for future application where the single step entry is feasible. Brief concepts description is available in appendix A6.

8. Concept improvement

The selected concepts are improved to get a resolution that will better differentiate the competing concepts. The concepts are drawn in CATIA V5 in order to inspect the form in interaction with the surrounding parts. This method helps to examine the general shape on a basic level.

The section includes a description of an improved step concept together with 3 compatible step well concepts. All of them are labelled under the "instep add-on" category.

8.1. Step concept X "Combined"

Based on the conclusions from the test, a new step concept is generated. The advantages from the "Positive Wave" and the "Inverted Wedge" are combined in order to develop a solution which has the required strength points.

The concept utilizes the "Wave" concepts stair feeling with a longitude offset of the upper step relative to the lower step. The step has an angle that allows an ergonomic "attack angle" entering the cab and the step clearance gotten from the "Inverted Wedge" concept, comfortable for exiting the cab. See the basic shape in figure 8-1.
The tests summaries are available in appendix A5 and in the media appendix A10.

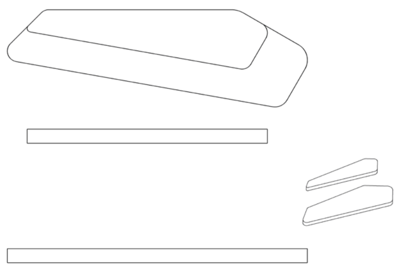


Figure 8-1 Concept X "Combined"

The steps are intended to be of an open waved texture similar to the regular Scania steps. The symmetric texture provides a modular solution where the steps can be flipped and used both on the driver and co-driver side. See figure 8-2

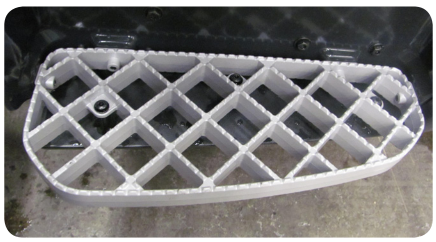


Figure 8-2 Step texture

8.2. Instep concept 1 "add-on 90°"

The concept consists of a variety of the "add-on" step well and the "Double step" concept.

The add-on concept is going to be fully done in sheet metal with the help of folding and bending techniques in order to avoid tooling costs.

8.2.1. Step well

The "add-on 90°" offers a smooth and clean surface that covers the asymmetric standard brackets. The design has a wide instep and the covered parts do not affect the functionality of the instep, since they are not the effective parts used in ingress and egress the truck. See figure 8-3. The step well is supposed to be mounted with brackets on the edges of the cut standard brackets.

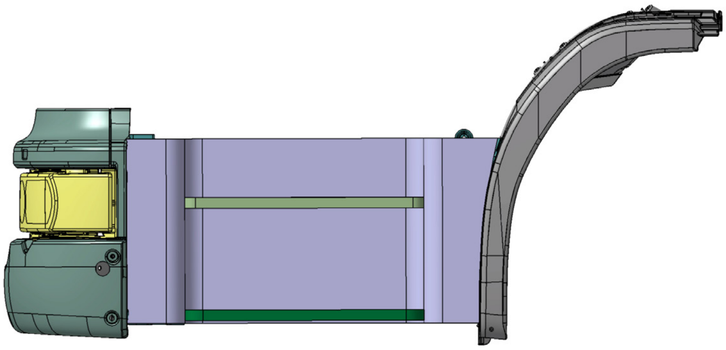


Figure 8-3 "Add-on 90°" Side view

The concept is a sheet metal bent at 90° both in the front and rear bracket. The sheet metal follows the bumper and the wheel house. See figure 8-4.

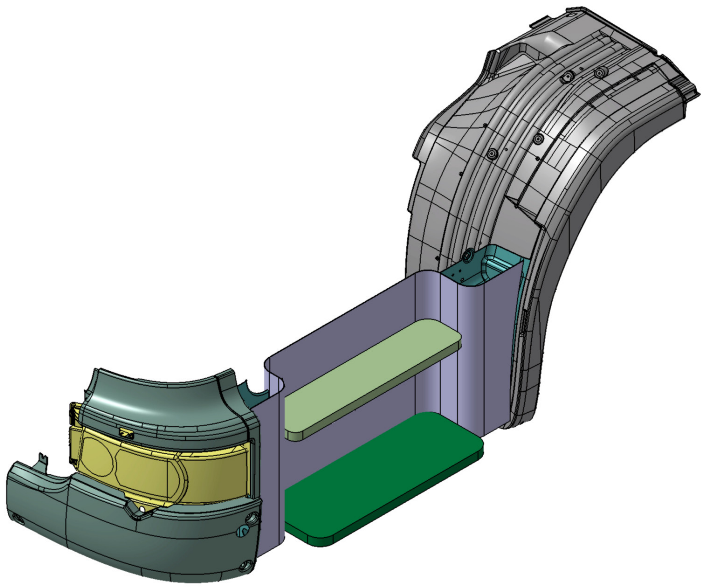


Figure 8-4 "add-on 90°" ISO view

8.2.2. Steps

The suggested step for this step well is bent 90º with a stair like "Double step" at its maximum width in the lower step parallel to minimum depth at the upper one, which provides an ergonomic stair feeling both entering and exiting. Figure 8-5 illustrates a top view of the basic shape of the steps.

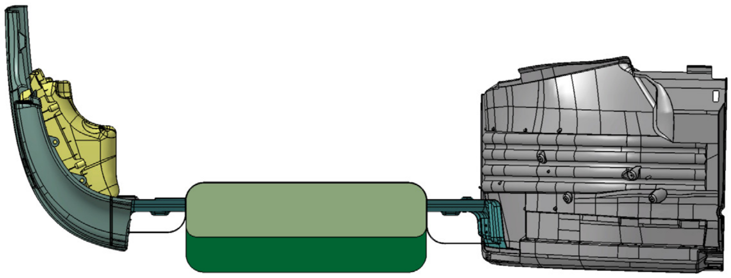


Figure 8-5 Steps - "add-on 90°" Top view

The lower step exceeds outside the wheelhouse, which gives a slight attack angle for the foot entering the cab. See figure 8-6

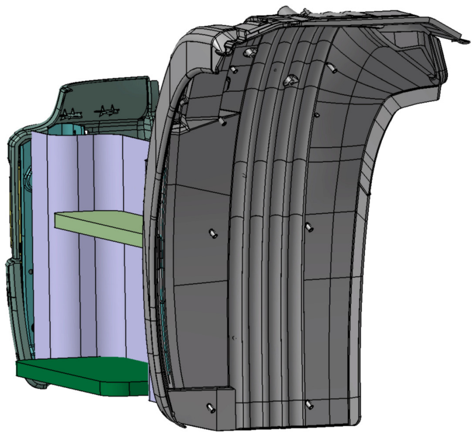


Figure 8-6 "add-on 90°" attack angle

8.2.2.1. Disadvantages

- *Wide areas of plane sheet metal without any function.*
- *The required depth of the step well doesn't fit the Air Process System cooling coil mounted on the wheelhouse bracket that is connected to the chassis.*

8.3. Instep concept 2 "Add-on 45°"

This concept consists of a variant of the "add-on" step well and the "Combined" step concept.

The "add-on 45°" offers a smooth and clean surface suitable for placing the steps.

8.3.1. Step well

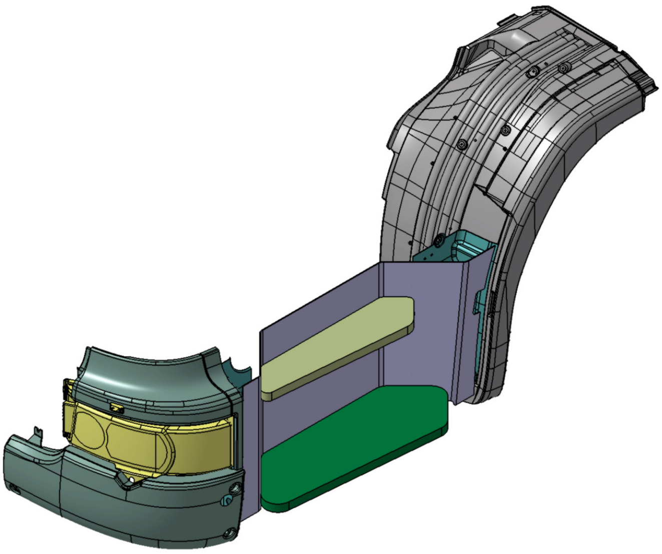


Figure 8-7 Instep "add-on 45°" ISO view

The step well Add-on 45° concept is a sheet metal bent 45º in the front and the rear bracket. The straight surface makes it easy to mount the steps directly on the step well. The symmetric angles form a wide and welcoming instep. See figure 8-7 and 8-8.

The step well is supposed to be mounted with brackets on the edges of the cut standard brackets.

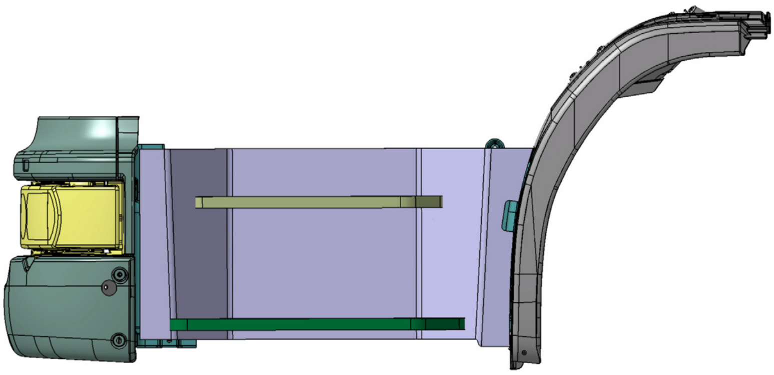


Figure 8-8 Instep "add-on 45°" Side view

8.3.2. Steps

The suggested step for this concept is the combined "Wave" and "Inverted Wedge" step concept with 45º angle on sides. See figure 8-9.

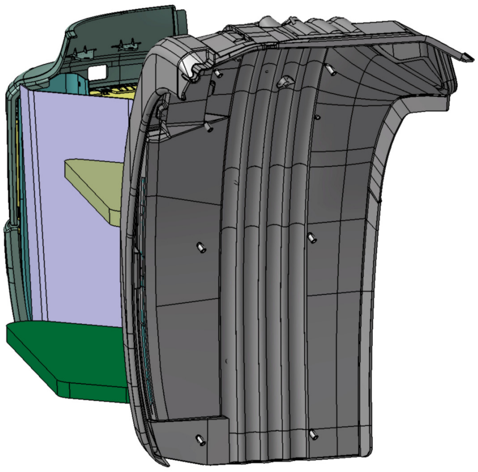


Figure 8-9 Attack angle "add-on 45"

The wedge angle allows a good step gradient for exiting the cab. From the top view the step shape represents a variation of the eagle beak shape used often in the truck's exterior. The 45° angle on the step well plate allows for a deep step that results in a good step gradient. See figure 8-10.

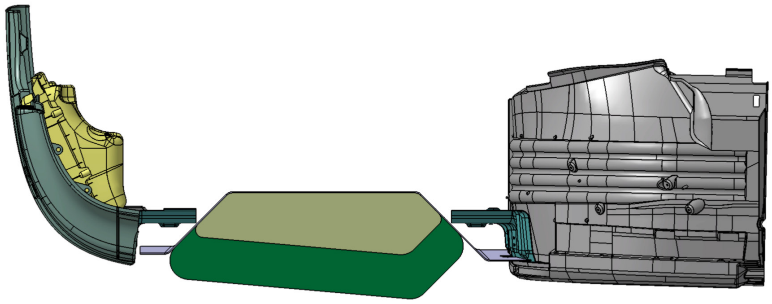


Figure 8-10 Steps -"add-on 45" Top view

8.3.2.1. Disadvantages

The angle in the front interferes with the nozzle neck of the washer fluid container.

8.4. Instep concept 3"Add-on 30°"

The concept is similar variant of the "add-on 45°" concept with the "Combined" step concept.

The "add-on 30°" offers a smooth and clean surface in the same way as the "add-on 45" concept.

8.4.1. Step well

The step well Add-on 30° concept is a sheet metal bent at 30° in the rear and 45° in the front. The angles grant a wide and welcoming instep. See figure 8-11 and 8-12.

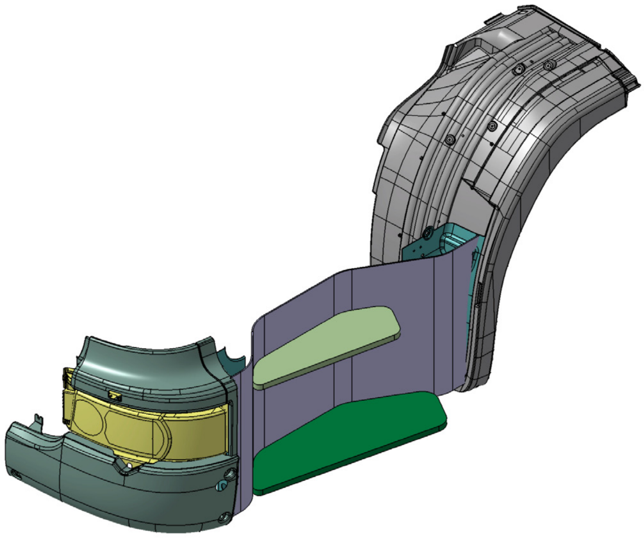


Figure 8-11 Instep "add-on 30°" ISO view

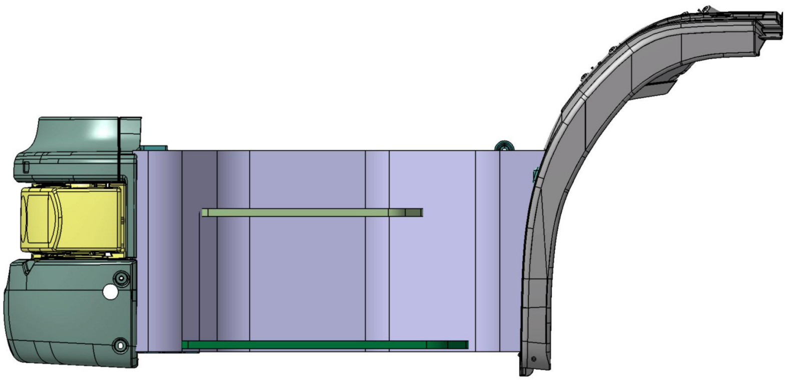


Figure 8-12 Instep "add-on 30°" Side view

8.4.2. Steps

The combined "Wave" and "Inverted Wedge" step concept offers a stair feeling with a good shin clearance with 30 ° angles on the sides. See figure 8-13.

Figure 8-13 Attack angle "add-on 30"

The wedge angle allows a good step gradient for exiting the cab and the offset upper step offers a good stair feeling entering the cab. The step shape represents a variation of the eagle beak shape from the top view. The design thought for the 30º angle in the rear is to amplify an ergonomic walk angle suited to place the user foot approaching the cab from the rear. See figure 8-14.

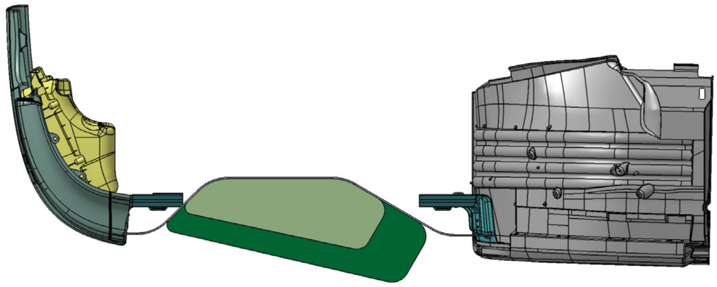


Figure 8-14 Steps -"add-on 30" Top view

8.4.2.1. *Disadvantages*

- *The 30º angle steals step depth.*
- *The angle results in a large gap between the standard bracket and the Step well.*
- *The angle in the front can cause problems when integrating the nozzle neck of the washer fluid container.*

8.5. Concept scoring

The concept scoring is a more detailed evaluation that aims to identify the best concept. The increased resolution of the concept due to a more detailed design will better differentiate the competing concepts.
In this stage the selection matrix criteria are more detailed compared to the screening matrix in table 7-8 and 7-9. The criteria are set based on the clarified objectives and the specification of the requirements set in the previous chapters.

The concept scoring rating system is a weighing system, with 100 percentage points allocated among the selection criteria in the matrix. A new reference system is used as a benchmark for all the criteria as in the previous stage. See table 8-1. Since the reference will be of average performance relative to all criteria, it will result in a "scale compression" from 5 to 3 levels for some of the criteria. Different references are points for various criteria among all the concepts. The reference points are designated by a bold font value in the scoring matrix shown in Table 8-2. The concepts are ranked from the sum of the weighted scores.

Rating	Relative Preformence
1	Much worse than reference
2	Worse than reference
3	Same as reference
4	Better than reference
5	Much better than reference

Table 8-1 Relative scoring grading

8.5.1. Instep scoring

The Concept scoring is prepared and carried out together with the responsible advisors at the special vehicles and market department to obtain different aspects on the improved concepts.

Selection Criteria	Weight	Concept 1 "Add-on 90"		Concept 2 "Add-on 45°"		Concept 3 "Add-on 30°"	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Modular design	12						
Enable Sing & double step	3	4	9	3	9	3	9
Fit both driver & co-driver side	5	3	15	3	20	3	20
Fit a rang of application	4	3	12	3	12	3	12
Safety	18						
Low risk of injuries	9	4	36	3	27	3	27
Non slippery	9	3	27	3	27	3	27
Intergrated exterior design	16						
Follow the design line of the cab	9	2	18	4	36	3	27
Look like a Scania product	7	2	14	4	28	3	21
Ergonomic	18						
Encourage normal, bal-anced movement	8	3	24	3	24	3	24
Minimize strain on the body	10	3	30	3	30	3	30
Manufacturing	18						
Low complexity	4	2	8	3	12	3	12
Possible to assemble by Laxå Special vehicles AB	7	3	21	3	21	3	21
Possible to source by Scania CV AB	7	3	21	3	21	3	21
Cost	18						
Low material cost	4	3	12	3	12	3	12
Avoid tool cost	10	3	30	3	30	3	30
Low time cost	4	3	12	3	12	3	12
Total Score			**289**		**321**		**305**
Rank			**3**		**1**		**2**
Continue			**No**		**Yes**		**No**

Table 8-2 Relative scoring grading

Concept 2 achieves the highest score from the evaluation and is ranked as number one.

8.5.2. Reflection

According to Ulrich and Eppinger it is essential to supplement the evaluation, done in the concept scoring with a discussion to ensure that the selected concept is the one with greatest potential for success (2 p. 137).

The concept scoring reflection is done with the responsible advisors and concerned managers at the market department. The concepts are reviewed, and it could conclude that the selected concept has the most potential. Because of the good ergonomic and integrated design regarding the delimitations discussed below.

8.5.2.1. Delimitations

- *The standard instep is part of the Scania's modular system. The cut standard brackets are shaped after standard internal parts that connect the instep to the chassis. Redesign of the step well to suit the LowEntry requires changes of several internal standard parts as well. This is not an option with the current sales rates.*
- *Since the tooling cost is very high and the LowEntry is a minor share of the company's market, using details that require investment in tools cannot be a reasonable option.*
- *The distance between the cab floor and the instep is different in the regular trucks. Therefore the similar integration covering solution on the top is hard to implement. Because of the cab movement, there needs to be a minimum tolerance of 50 mm between the cab floor and the step well.*
- *Lowering the cab more is difficult because of the existing engine size and the cab cannot kneel more because of the required clearance between the bumper and the ground.*

Development

9. Concept development

This section aims to describe the development phase of the selected design concept "add-on 45° with the "combined" step concept.

In this phase with the help of the 3D software AliasStudio and CATIA V5, shape explorations in details are carried out. The aim is to adapt the design practically to the interacting parts and to evaluate the connection with the exterior of the truck in relation to the new instep design.

9.1. New circumstances

The initial conditions for the step well are changed in this phase. The main changes are:

- *The Air Process System (APS) located on the wheelhouse mounting bracket*
- *A new bumper design.*

9.1.1. Air process system

The development of the "Add-on 45°" concept faced problems with the Air Process System (APS). The standard APS is located on the Wheel house bracket that is assembled to the chassis on the main production line in Södertälje. Laxå Special Vehicles rebuilds the Air Process System to fit the unique design of the LowEntry truck. This results in the "add-on 45°" concept that clashes with the new APS configuration. Scania special vehicles department were not aware of the rebuild Laxå Special Vehicle did to the APS since it wasn't available in any CAD models or drawings. The discovery of this forced the development to restart and adapt to the newly discovered problem. The development of the original "Add-on 45°" concept is briefly presented in Appendix A7.

9.1.2. Horn

The horn is originally placed on the wheelhouse mounting bracket, but the new rebuild of the APS requires the horn to be placed on the step well plate.

9.1.3. Bumper

The LowEntry truck will have an upgraded front that includes a new bumper called the Protruded bumper. It is a wider steel bumper with different connection types compared to the old bumper with plastic covers. See figure 9-1 and 9-2.

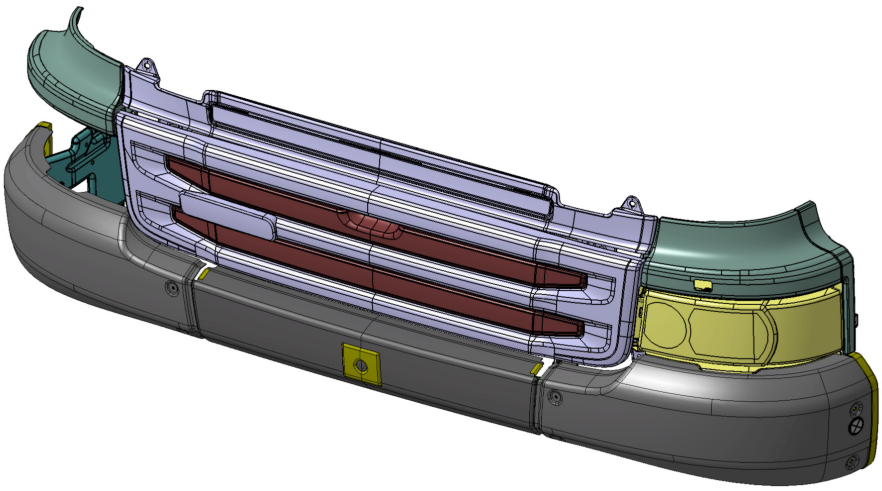


Figure 9-1 The Protruded bumper

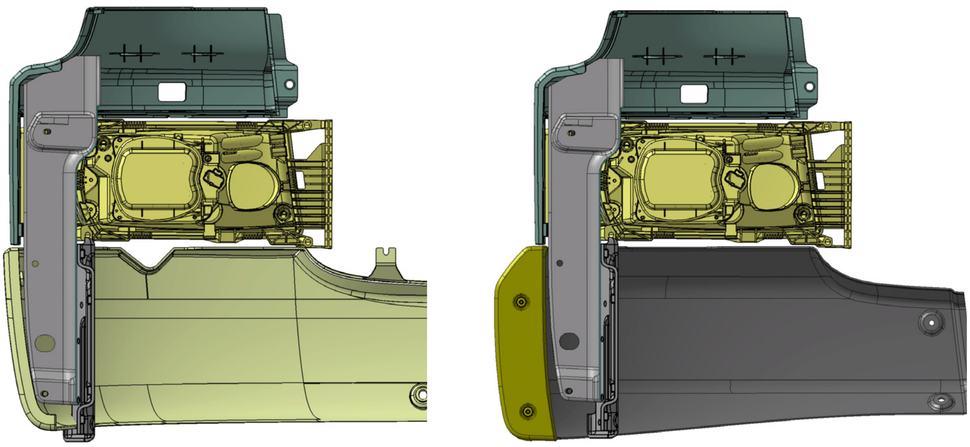


Figure 9-2 Bumper width comparison

9.2. Form exploration

In the following subsections a form exploration on the selected concept has been carried out. The examination has been performed with the aid of AliasStudio and CATIA V5. The purpose for using the CAD software is to do quick form variations, in combination with the interacting parts. This method helps to narrow down the possible solutions to the most feasible result.

9.2.1. 50º angle

The step well angles are modified from 45º to 50º in order to leave space for the LowEntry unique Air Process System (APS).

The alteration also provides more space for the top cover both for accessing the lock and the placement of the pipe, as it gets 5º wider.

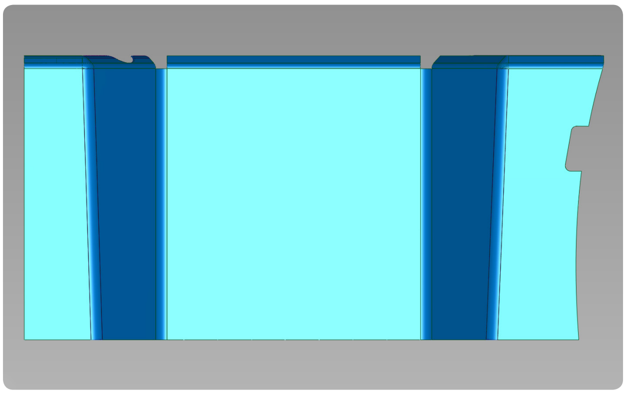


Figure 9-3 Tilted 45°

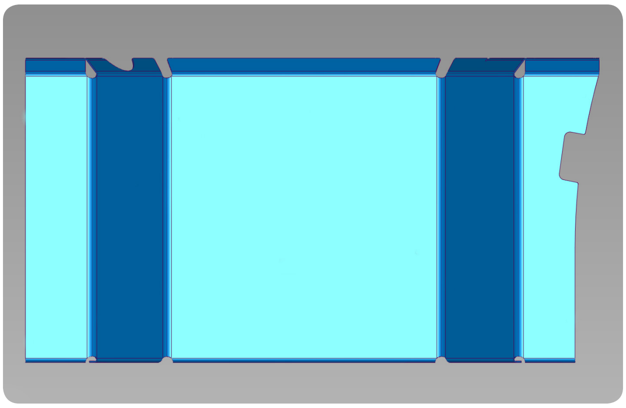


Figure 9-4 Straight 50°

9.2.2. Tilting angle

The 45° step well had a tilting angle on the sides in order to fit the bumper's shape and the cut standard brackets which are curved after the bumper and the wheel-house. The front surface was tilted 2° and the rear part was tilted 3° inwards. With changing the old bumper and emerging the Protruded bumper which is wider, the tilted angles were fixed to the straight angle surfaces.

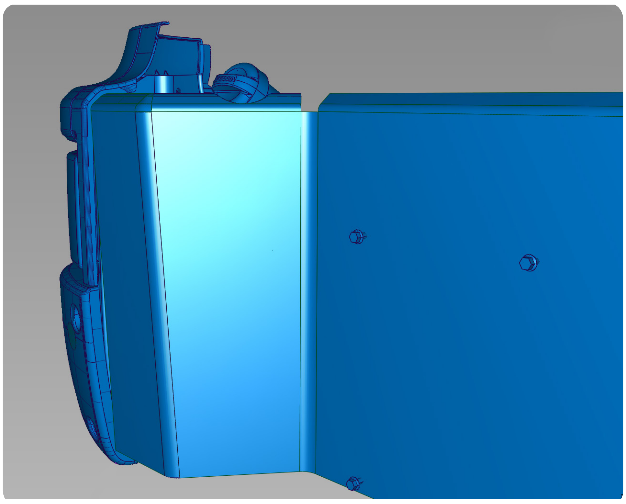


Figure 9-5 Tilted angle after the existing bumper

9.2.3. Integration

In order to integrate the new step well with the rest of the truck, especially the nearby involved parts like the bumper, headlight, headlight seal and the wheel-house. Since the top integration also has to be considered together with the top cover some limitations ascended e.g. the position of the washer fluid pipe, the complexity of the casted plastic shapes of the seal, possible placement of the steps and lack of resources narrowed down the alternatives. The solution was to follow some lines from the front all the way to the rear of the instep with a chamfer from the headlight seal all the way to the wheel-house.

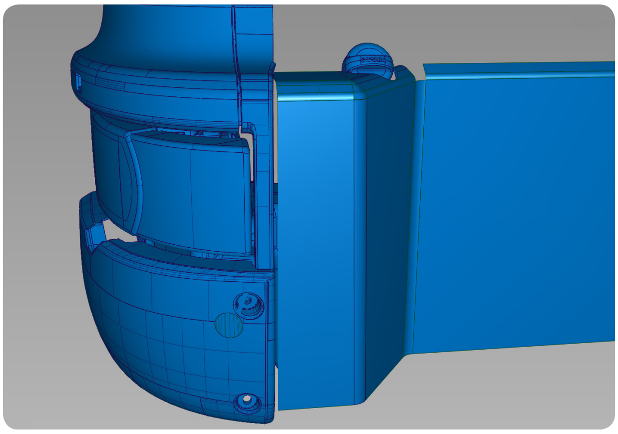


Figure 9-6 Following lines

9.2.4. Wheelhouse lock cut

The assemble order requires the wheel-house cover to be positioned in place after the placement of the instep. The wheelhouse is disassembled due to services, repair and maintenance which set a requirement for the lock to be accessible.

The lock is required to be reachable with an opening clearance of minimum 35 mm in 160° opening angle. A cut has been made with the required proportions parallel to the mudguards. See figure 9-6.

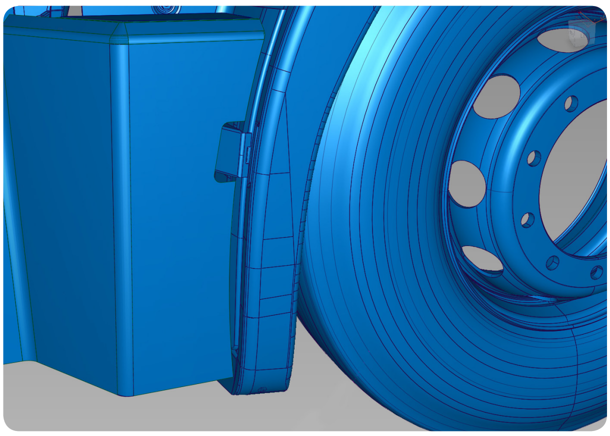


Figure 9-7 Lock position

9.2.5. Top cover

As figure 9-7 illustrates the new design causes a hole between the cut standard brackets and the step well plate. This is the space that is required to be covered.

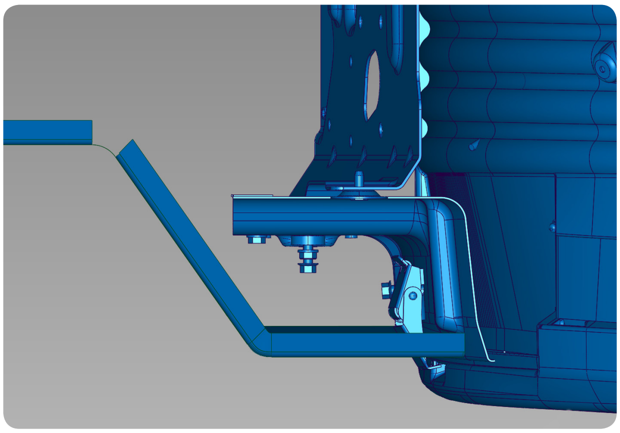


Figure 9-8 Top hole rear

The cover solutions are intended to be made in sheet metal as the rest of the instep. The reason for this choice is:

- *The high tooling costs for plastic parts*
- *The plastic cover does not fit the aesthetic expression of the rest instep*

9.2.5.1. Front top cover

The washer fluid container on the driver side should be accessible from the top to be opened and filled up easily. Therefore a cut out is necessary in order to open up space for accessing the pipe. A number of solutions on the front cover where generated. See the discarded front top cover designs due to cost and manufacturing complexity in figure 9-9.

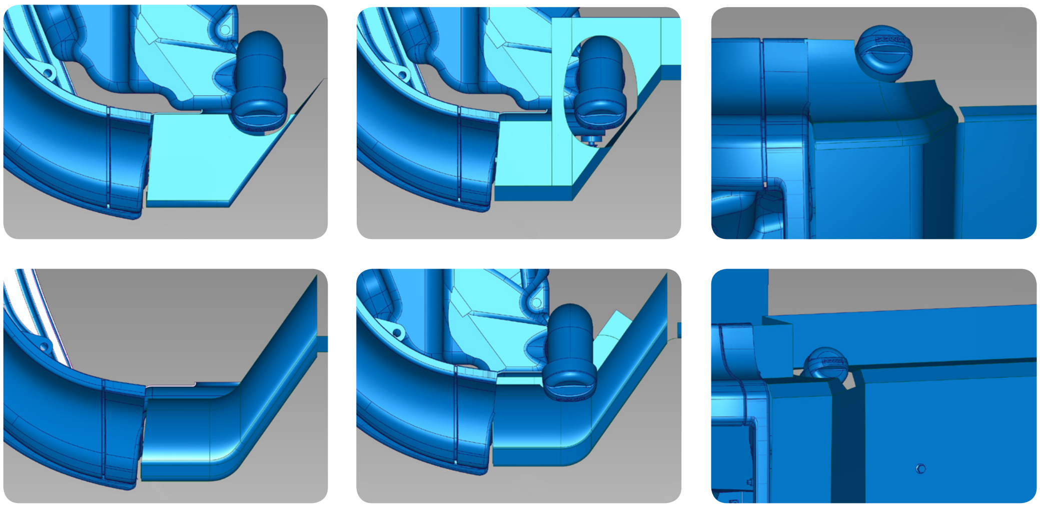


Figure 9-9 Discard front Top cover designs

The selected top cover solution is the sheet metal, bent to follow the headlight seal chamfer with a cut gives space to the pipe neck. See figure 9-10.

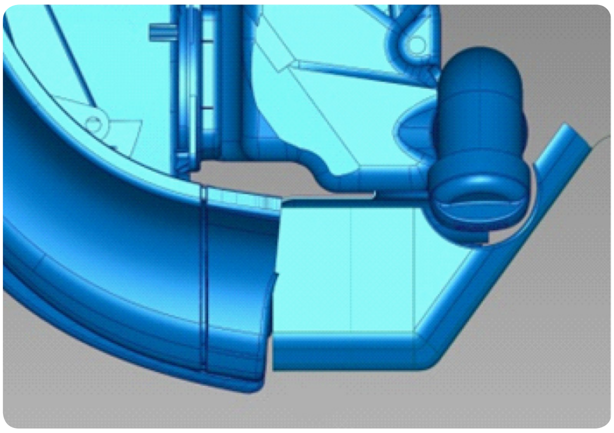


Figure 9-10 Selected Top cover front

9.2.5.2. Rear cover

The spring lock at the rear cut standard bracket is required to be reached by hand and the rear cover should be east to remove by the user. Therefore the connections should be simple and reachable from the top which means that the cover can't be connected to the standard bracket. On the other hand the rear part has a very limited space, thus the design has to provide maximum space with no sharp edges. Therefore each millimeter is important. Some design solutions were discarded due to complexity. See figure 9-11.

The selected solution is a sheet metal part, bent down in 2 edges and screwed to the step well plate top surface.

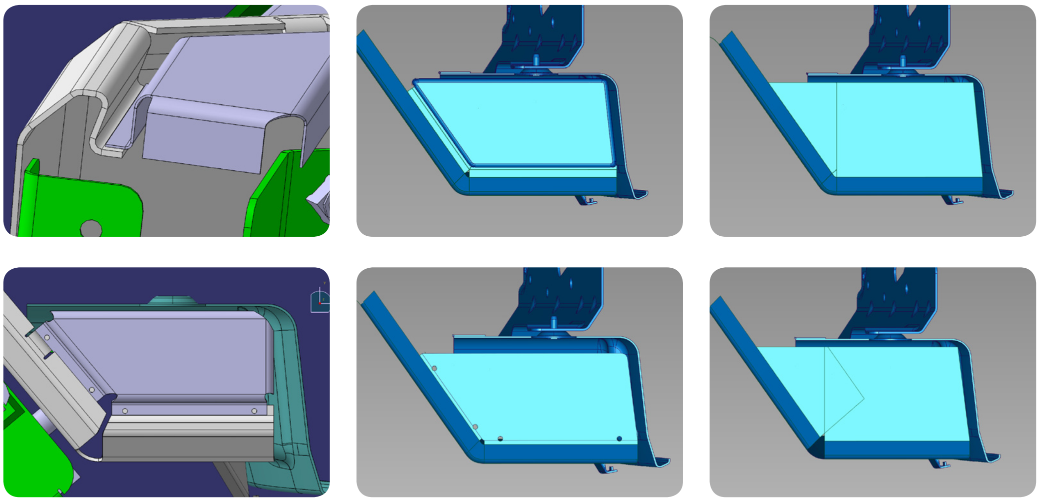


Figure 9-11 Rear top cover concepts

9.3. Step well plate 50°

The step well plate is a 2.5 mm thick sheet metal where the design shape is cut-out with a water or laser cutter. See figure 9-12.

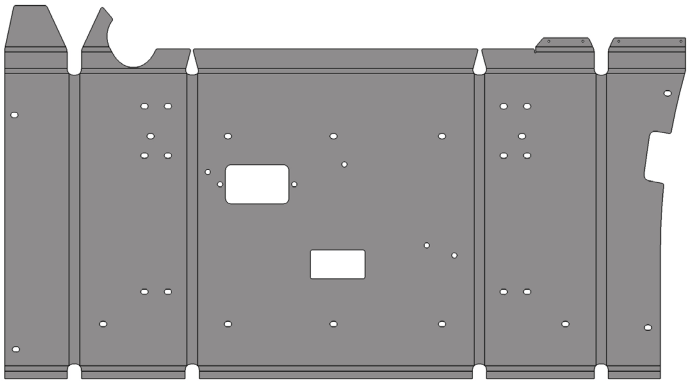


Figure 9-12 Unfolded view

The sheet is bending with 50º angles creating the structure for the step well. Bending sheet metal is not a precise manufacturing method, there is always a spring back resulting in a wide tolerance range to the hole patterns. Due to the wide tolerances, the mounting holes are oval. See figure 9-12 and 9-13

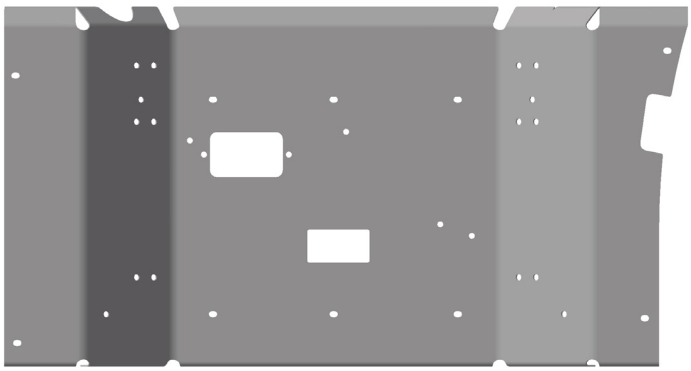


Figure 9-13 Step well plate

The front top cover is part of the step well plate, folded to cover the front hole.

Figure 9-14 Top cover- Front

- *Thickness: 2.5 mm*
- *Weight: 12 Kg*

9.3.1. Engine heater and reflector cut

The engine heater plug cut on the co-driver's side of the truck is positioned below the upper step to be less visible providing a cleaner surface.

The reflector light located on the step well plate is placed in accordance to the Commercial vehicle regulations for lightning installation.

9.3.2. Liquid level indicator

The liquid level indicator cut is removed due to the gap between the outer surface and the container. The gap between the container and the step well surface makes it hard to see throughout the container especially when the container's material is not transparent enough to see through. On the other hand an automatic indicator on the control panel is supposed to inform the user inside the cab when there is a need for refilling the container.

9.4. Rear cover

The rear cover is 1.5 mm thick sheet metal, folded down 90º to reinforce the cover structure. It's to be screwed on the rear part to be easily removable. The cover for the co-driver side is a mirror image of the driver-side cover.

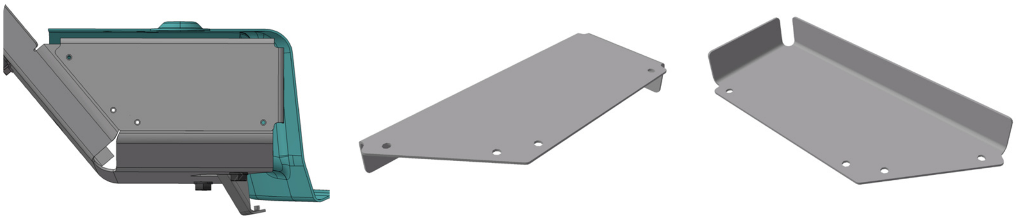


Figure 9-15 Top cover- Rear

- *Thickness: 1.5 mm*
- *Weight: 0.2 Kg*

9.5. Steps

The steps are open waved casted steps similar to the standard Scania steps. The open waved design let water, dirt and snow through the step surface. The anti-slip textures function is well established on the regular Scania trucks. See figure 9-16

Figure 9-16 Step texture

9.5.1. 50º steps

The steps are placed in an equal distance of 320 mm between the steps and the cab floor with an overlap of 90 mm and offer a step gradient angle α of 74.3º. The existing instep offers a step gradient angle α of 81º. The maximum standard required angle is 85º. See figure 9-17 and 9-18.

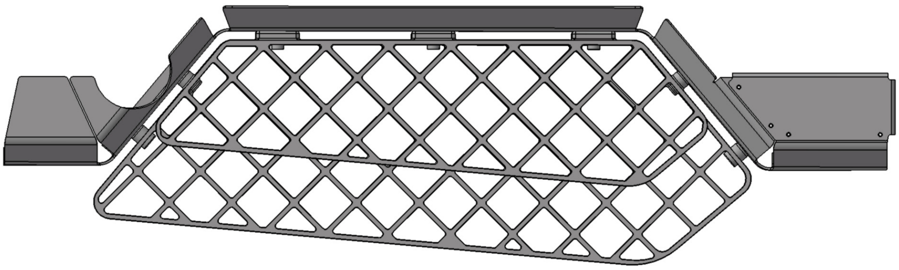


Figure 8-17 50º Step overlap

The lower step height from the ground is approximately 370 mm in driving position and 245 mm in kneeling position. See figure 9-18.

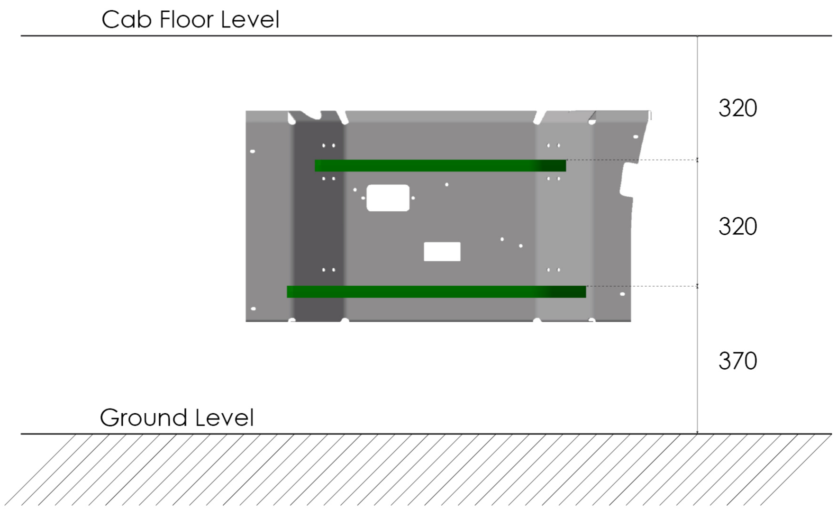


Figure 8-18 Step placements driving level

The 50º steps' pattern sizes are changed from 40 to 45 mm squares compared to the 45° steps. This is done to minimize weight and to keep consistency with the standard Scania steps.

9.5.1.1. 50º upper step

The upper step maximum depth is 170 mm and the minimum depth is 120 mm. The step's length is 650 mm. The upper step fulfils the European directives regarding the minimum foothold of 150 mm in depth at 300 mm in step width.

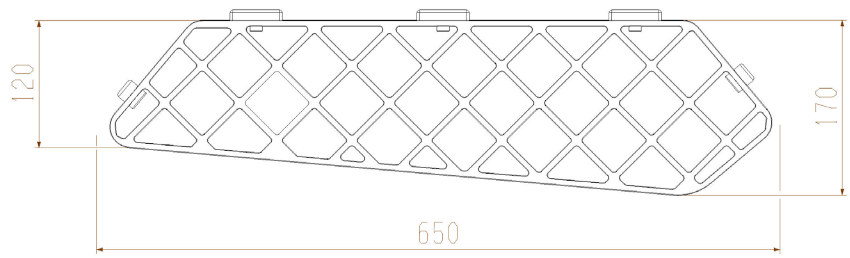


Figure 9- 19 50º Upper step overall dimension

- *Thickness: 30 mm*
- *Weight: 2.0 Kg*

9.5.1.2. *50º lower step*

The lower step's maximum depth is 260 mm and the minimum depth is 205 mm. The step's length is 780 mm. The lower step's outer edge has a tolerance to the maximum vehicle width of 10 mm. The maximum vehicle width is 2550 mm.

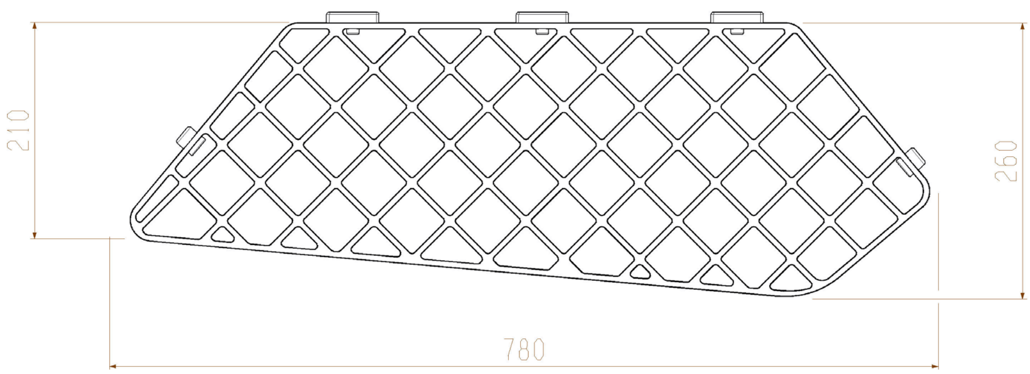


Figure 9-20 50º Lower step overall dimension

- *Thickness: 30 mm*
- *Weight: 3.2 Kg*

9.6. Brackets

The step well plate is mounted to the cut standard brackets with 6 connector brackets. See figure 9-21.

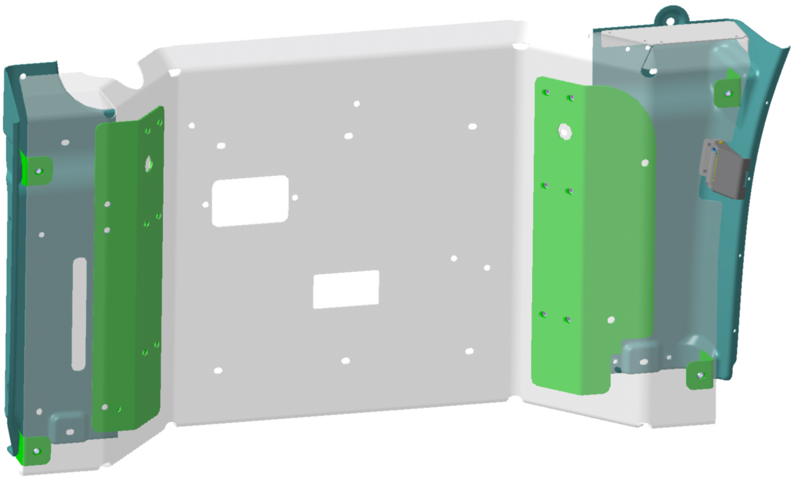


Figure 9-21 Brackets overview

The initial idea for the connector brackets was to weld them to the step well plate and then screw it to the cut standard bracket to avoid screws on the step well plate surface. But that would require the plate to be screwed from the inside of the step well. This is not possible due to the assemble order. See the section 9.7 Assemble.

9.6.1. Cut standard brackets

The standard step well is cut in two parts and is offset 550 mm in longitude direction and 37 mm in horizontal direction. See figure 9-22.

The purpose for keeping the cut standard bracket principle is that they are shaped after the inner brackets. Therefore they have the required connection points to the standard parts, and fulfill necessary functions.

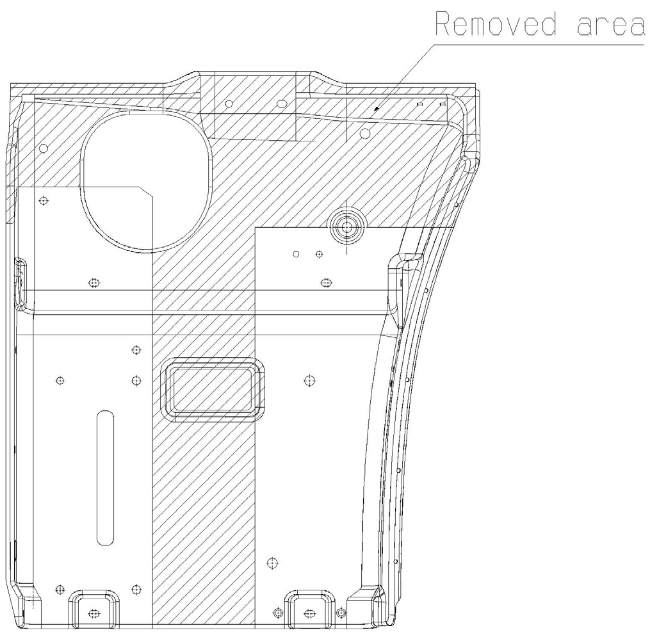


Figure 9-22 Cut standard brackets

The standard brackets are the base brackets which the instep-brackets are mounted on to carry the step well plate with the steps.

The front standard bracket is mounted to the bumper bracket and also connects the bumper and the washer fluid container.

The rear standard bracket mounts to the wheelhouse bracket and also acts as support for the mudguard which is connected to the bracket with the spring lock.

- *Thickness 1.75 mm*
- *Weight: Front: 1.7 Kg, Rear: 1.6 Kg*

9.6.2. Front instep-bracket

The front instep bracket is a 3mm thick V-profile bracket with an inside angle of 130°. The bracket's flange on the standard bracket is spot welded and screwed to the cut standard bracket. The instep bracket's function is to mount the step well plate to the truck.

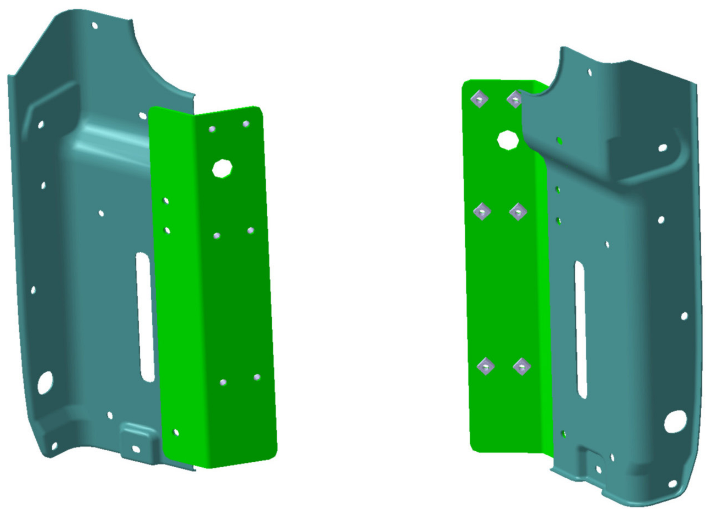


Figure 9–23 Front and rear view of the front instep bracket

The bracket has 6 weld nuts that the step well plate is screwed to. The hole on the upper edge of the bracket flange is where the upper step screw head is positioned. See figure 9-23.

- *Thickness: 3 mm*
- *Weight: 1.5 Kg*

9.6.3. Rear instep-bracket

The Rear instep-bracket is also a 3 mm thick V-profile bracket with an inside angle of 130°. The fillet on the flange against the standard bracket is there to give more space to be able to access the spring lock connection from the top. See figure 9-24.

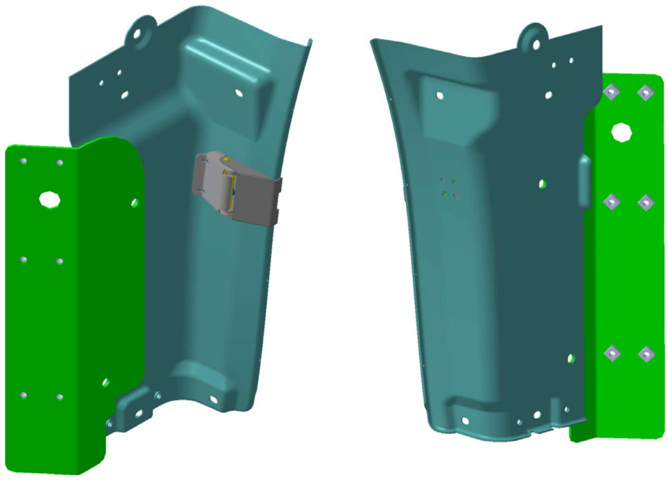


Figure 9–24 Front and rear view of the rear instep-bracket

The flange against the standard bracket is spot welded to the standard bracket and screwed to the bracket together with the wheelhouse mounting bracket. The step well plate has 6 weld nuts on the outer flange which the step well plate is screwed to.

- *Thickness: 3 mm*
- *Weight: 1.7 Kg*

9.6.4. Bracket 1 and 2

Bracket 1 and 2 are L-profile minor support brackets mounted on the side of the cut standard brackets. Their function is to support the outer edges of the step well plate. The brackets are the same size except for the positioning of the holes since the holes' pattern on the standard bracket mounted flange differs with 5mm.

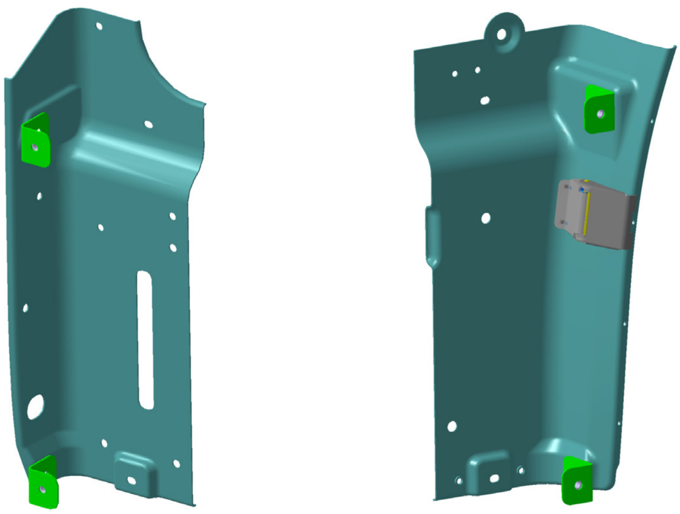


Figure 9–25 Support brackets 1 & 2

- *Thickness: 2 mm*
- *Weight: 4x 0.06 Kg*

For the side support it was not possible to have one continuous bracket similar to the front and rear instep brackets because the cut standard brackets surface is not flat. The rear bracket is curved after the wheelhouse, and the front has a slight curve on the inside.

9.7. Assemble

The assemble line is served with preassembled articles that are assembled to the truck chassis. The assemble process has to be carried out towards the work plane since all the connection points have to be reachable with the tool from the side of the cab.

The step well plate and the steps are preassembled separately. The cut standard brackets with the connector brackets are first mounted to the truck chassis. In the last phase is the preassembled step well plate with the steps assembled to the standard brackets. See figure 9-26.

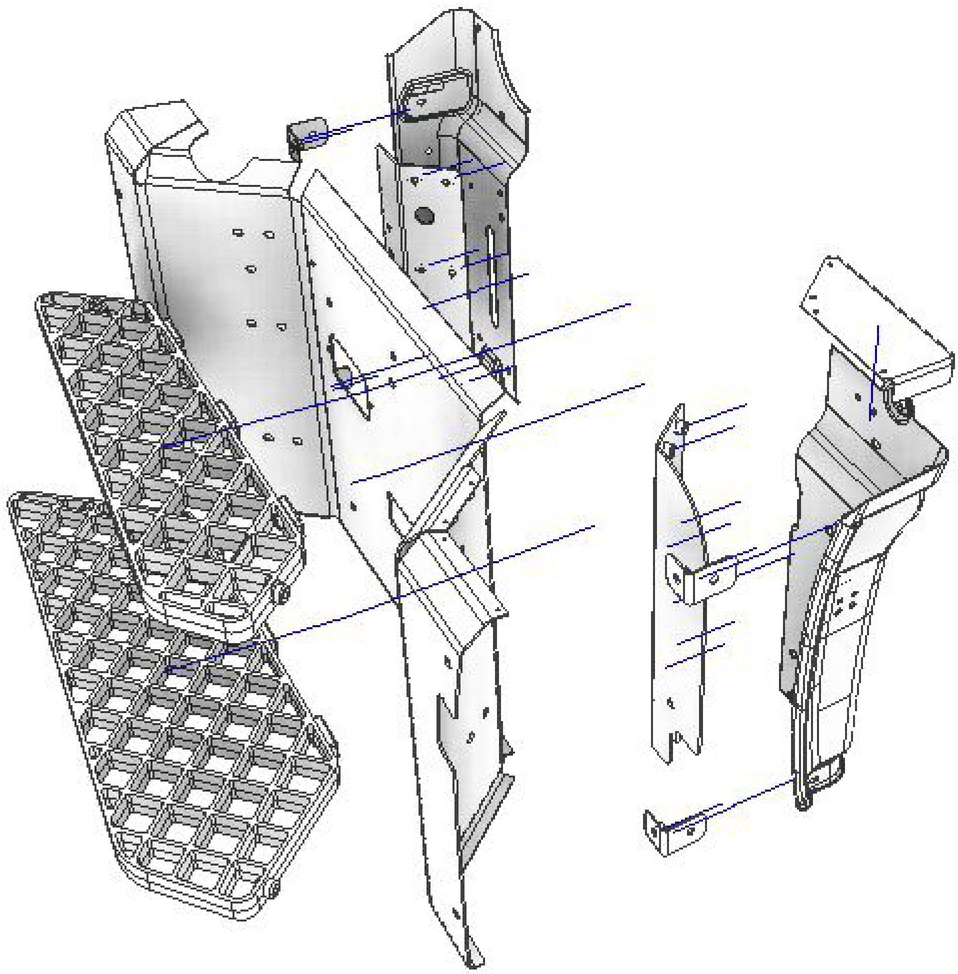


Figure 9-26 Assemble order

The instep is a robust design that has to withstand many loads, resulting in a total design weight of 24 kg.

10. PROTOTYPE

The purpose of prototyping is to evaluate the design's function and manufacturability.

The prototype for the 50º design presented in previous chapter is manufactured by Scania´s prototype workshop "Mekaniska STC".

The design and technical drawings are prepared in CATIA V5. See figure 10-1. All the prototype drawings are available in the media appendix A10.

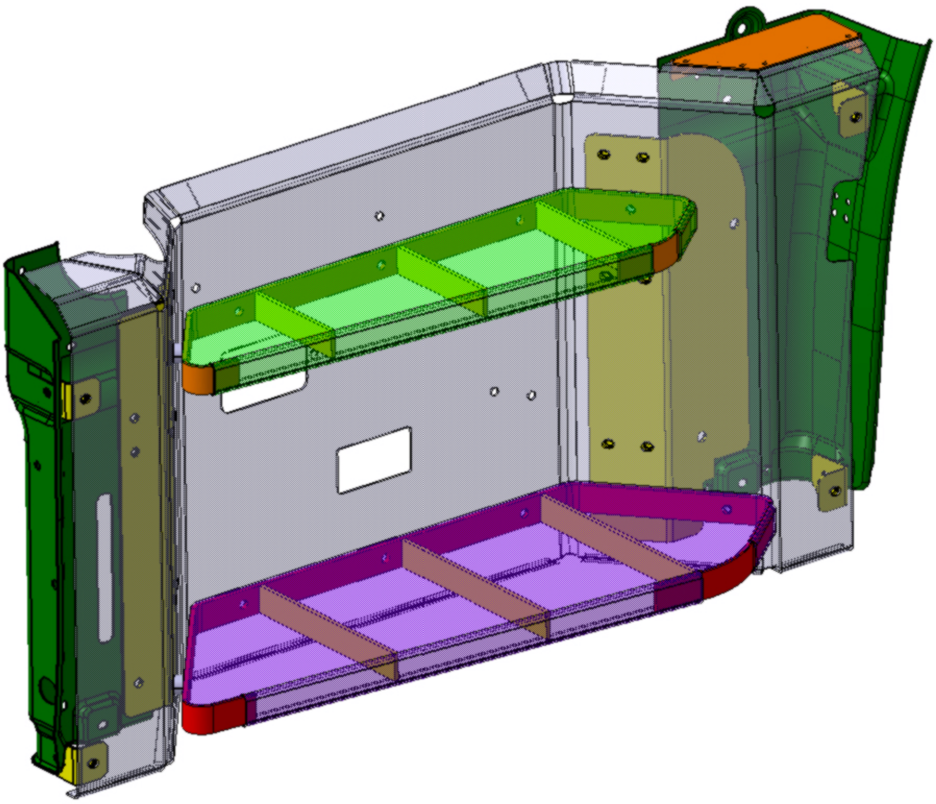


Figure 10-1 Prototype model

10.1. Simplification

Because of the cost limitations, and to be able to manufacture the prototype in the Mekaniska STC the steps are simplified. The prototype steps are built on the same principle as the existing steps with a frame that is covered by a folded sheet metal plate.

The prototype steps have an outer steel frame bent like the new step shape. This is supported with three support bars that are welded to the frame. Three distances are welded on the frame to support the frame against the step well plate. Above the frame the sheet metal plates are bent around the frame edges. See figure 10-1 and 10-2

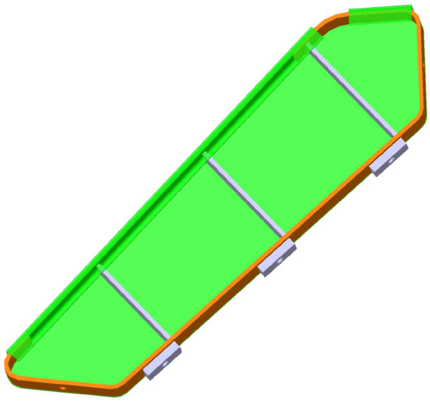


Figure 10-2 Prototype Step Structure

10.2. Assemble

The prototype is assembled and tested on the special vehicles' laboratory truck "Lägst". An overview of the result of the prototype can be seen in figure 10-3.

Figure 10-3 Prototype Overview

The assemble process was carried out in the prototype workshop at Scania by the authors. The parts were preassembled and assembled according to the designed order. In the assemble process no major problem were faced. All the parts were fitted well. See figure 10-4

Figure 10-4 Assembly process

10.3. Functionality test

The functionality and appearance of the prototype confirm and provide a feeling that the instep has good strength and robust design.

The prototype is tested by the refuse collectors at SRV-återvinning in Tumba, Botkyrka. The conclusion of the test is that the shape and placement of the steps offer a significant ergonomic improvement compared to the existing instep design. The concept allows the user to walk in and out of the cab with great comfort, especially in driving level. This is important because of the slow and not always used kneeling function. See figure 10-5.

With the open-waved casted steps and the anti-slip texture the design will be ergonomic and safe with good visibility of the step edges during egress from the cab.

Figure 10-5 Function test

10.4. Improvement

Some minor details were discovered that should be changed in order to improve the function or appearance of the concept.

10.4.1. Step well plate

After assembling the instep a gap between the step well plate and the headlight seal in the front and the mudguard in the rear were observed. See figure 10-6

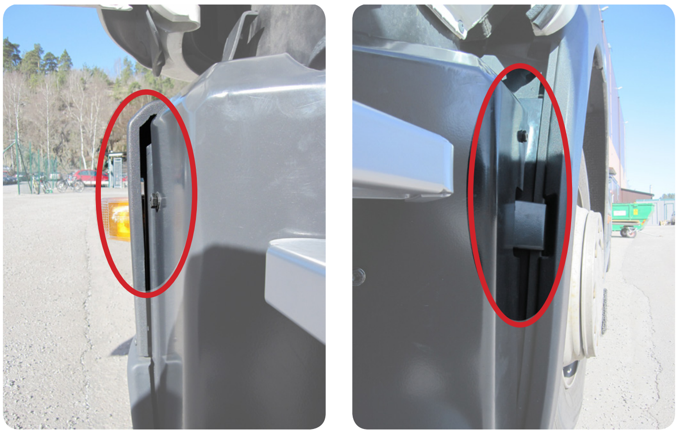


Figure 10-6 Step well plate gap

The clearance between the rear step well plate's wall and the cut standard bracket were considerably large, especially in the upper part of the rear step well plate curvature. See figure 10-7

Figure 10-7 The rear gap

10.4.2. Top cover

The cut for the washer fluid container seemed to be tight. A larger cut can provide an easier access to the container. See figure 10-8

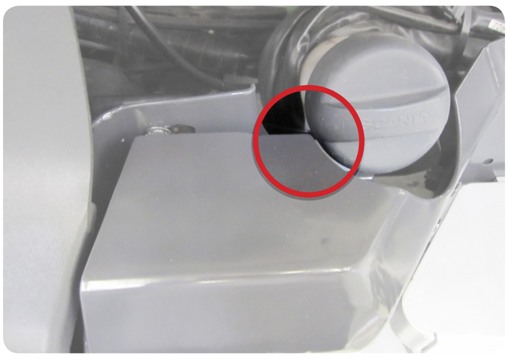


Figure 10-8 Washer fluid container clearance

Based on the prototype the chamfers did not properly follow the headlight seal chamfer. The chamfer is positioned high in comparison to the seal. See figure 10-9

Figure 10-9 Chamfer continuity

One fastening screw hole can be removed because it was revealed that 3 screws can hold the cover tight enough. See figure 10-10

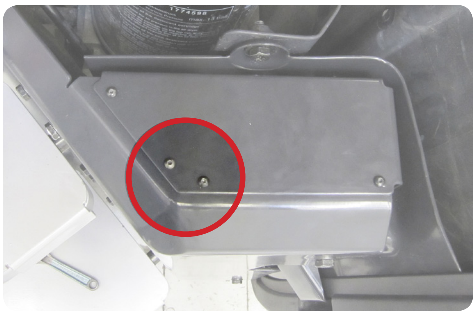


Figure 10-10 Rear cover screws

10.4.3. Mudguard lock

The step well plates rear cover edge clashes on the inside with the opening angle for the spring lock. This leads to that the spring lock cannot be fully opened, causing difficulties when closing and opening it. See figure 10-11.

Figure 10-11 Mudguard lock

11. Further development

The further development section is aimed at optimising the design by decreasing the part numbers and weight. This optimisation was done in parallel to and after the prototype manufacturing and test process. Detail drawings of the developed concept are available in appendix A9.

11.1. Step well plate

- *The side sections of the step well plate are moved forward in order to minimise the gap between the step wells and head light seal and the mudguard.*
- *The rear outer edge of the step well plate is extended from the top reducing all the way down to fill the gap and creates a cleaner surface.*
- *The chamfer in the rear part was also extended in longitude, parallel to the cut standard bracket's curvature to fill the gap.*
- *The chamfer is lowered in order to follow the headlight seal line more precisely.*
- *In order to give more space for the users hand to screw the washer fluid container's cover, an oval cut is made instead of a circular one.*
- *The thickness of the step well plate is reduced from 2.5 mm to 2 mm to minimize weight. The weight is reduced from 12 Kg to 9 Kg.*

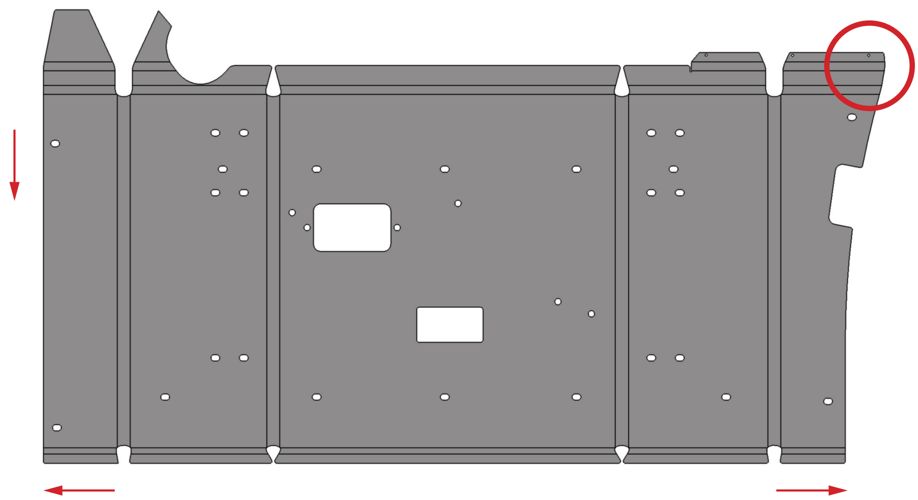


Figure 11-1 Unfolded view driver side

11.1.1. Co-driver side

The co-driver side is a mirror image of the driver side without the cut for the washer fluid container. See figure 11-2 and 11-3

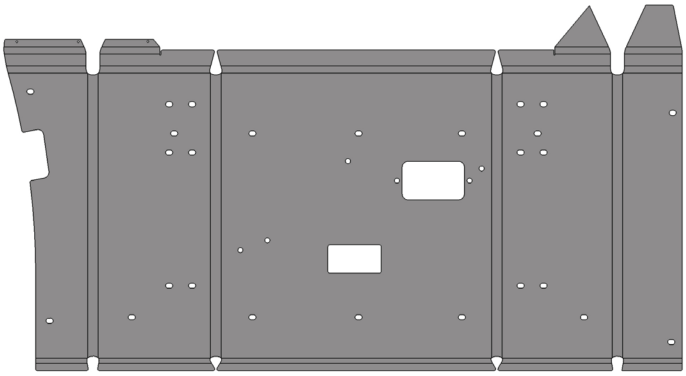


Figure 11-2 Unfolded view co-driver side

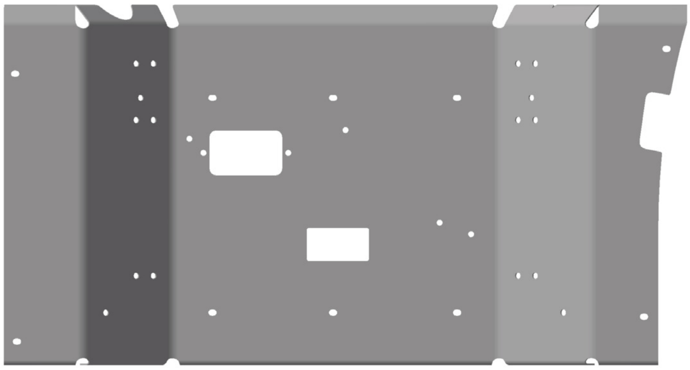


Figure 11-3 Step well plate co-driver side

11.1.2. Pipe guiding rail

The pipe guiding rail is lowered 60 mm from the former position. The reason to change the position of the guiding rail is that in the new position the screw heads are hidden by the upper step, resulting in a cleaner surface. See figure 11-4

11.1.3. Horn bracket

The horn bracket mounted to the plain side of the driver side step well plate close to the APS configuration. See figure 11-4

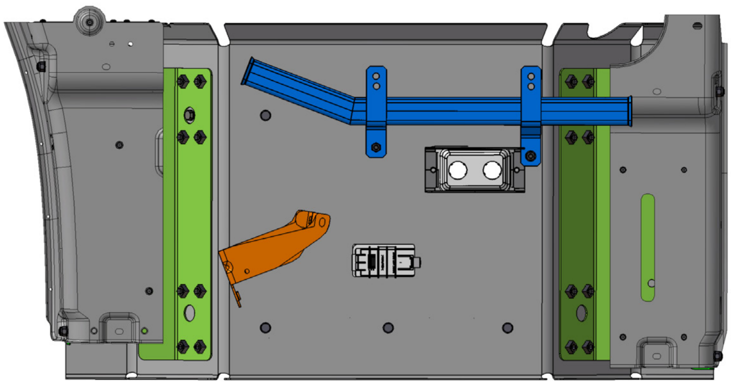


Figure 11-4 Pipe guiding rail and horn position

11.2. Steps

The pattern shapes and the anti-slip texture on the steps are optimized for the best visual appearance and function. The symmetrical pattern of the steps allows them to be flipped around and used as modular steps on both the driver and co-driver side. See figure 11-5.

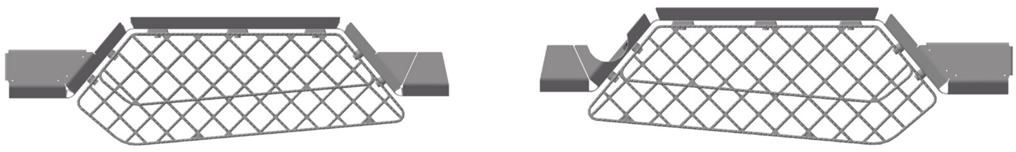


Figure 11-5 Modular step driver and co-driver side

The steps are screwed to the step well plate, where the screw holes on the steps are untapped, to prevent the screw from loosening due to vibration from the truck. The mounting holes are designed according to the STD3863.

11.2.1. Upper step

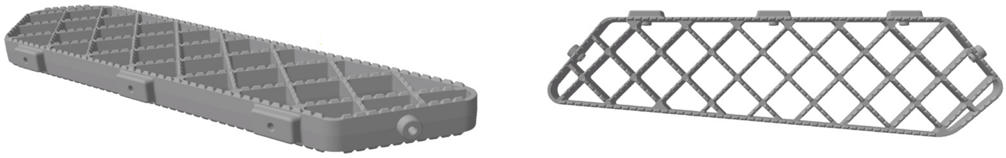


Figure 11-6 Upper step

- *Thickness: 36 mm*
- *Weight: 2 Kg*

11.2.2. Lower step

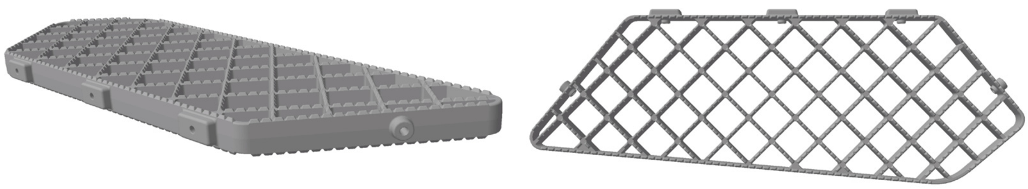


Figure 11-7 Lower step

- *Thickness: 36 mm*
- *Weight: 3.2 Kg*

11.2.3. 3D-print of the steps

3D printed prototypes of the steps are manufactured to be able to get a real feeling of the shape and size of the actual steps.

They are painted with metallic colour similar to the real steps to look as real as possible. In figure 11-8 and 11-9 are the steps mounted on the LowEntry truck "Lägst".

Figure 11-8 3D-print of steps ISO view

The open-waved casted steps offer good visibility of the lower step edge. See figure 11-9.

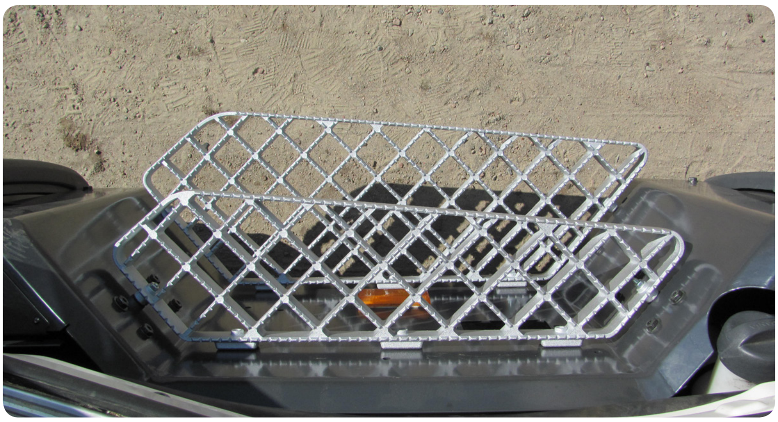


Figure 11-9 3D-print of steps top view

11.3. Brackets

The further development of the brackets focuses on minimizing the number of unique parts according to Scania´s modular system principle.

11.3.1. Cut standard bracket

The 2 cuts of the standard bracket are adapted to the new modular instep-bracket. Unnecessary treatments of the cut standard brackets and the useless holes for the old steps are removed. See figure 11-10 and 11-11

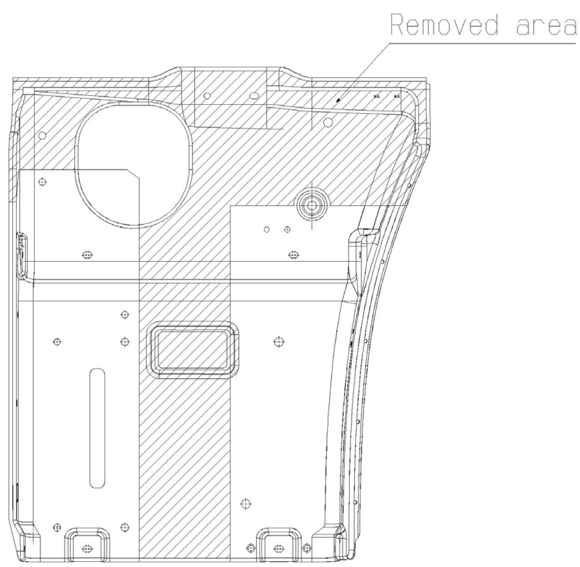


Figure 11-10 New cut standard brackets

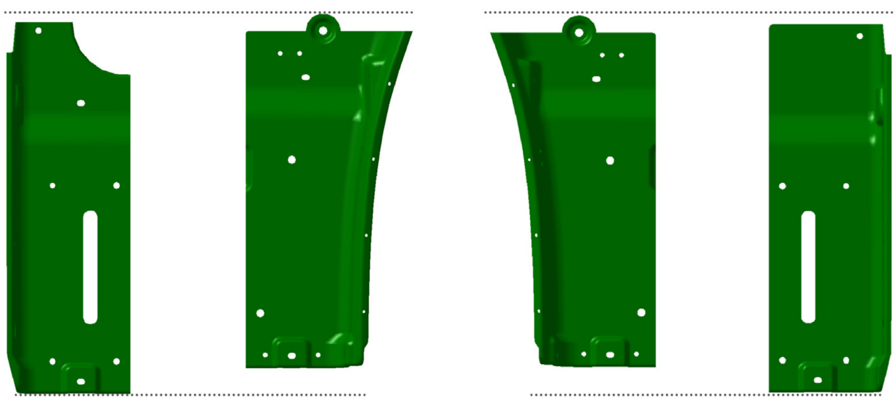


Figure 11-11 Cut standard brackets driver and co-driver side

- *Thickness 1.75 mm*
- *Weight: Front: 1.7 Kg, Rear: 1.6 Kg*

11.3.2. Instep-bracket

The two instep brackets are modified to be one modular bracket. The symmetric shape allows the bracket to be used on the front and rear standard bracket, both driver and co-driver side of the truck. See figure 11-12

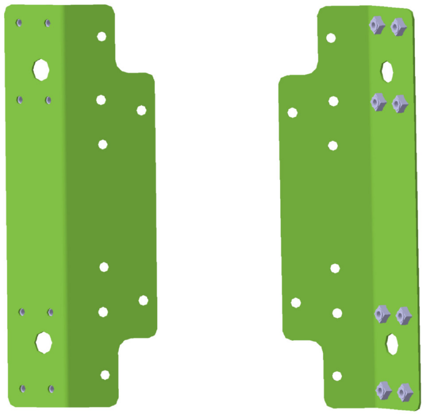


Figure 11-12 Front and rear view of the modular instep-bracket

- *Thickness: 2.5 mm*
- *Weight: 1.5 Kg*

11.3.3. Side bracket

The supporting L profile-brackets named, 1 and 2 are reduced to one single modular bracket that fits on all four positions on both driver and co-driver sides. The different positioning of the holes in the standard cut brackets are compensated with bigger holes. See figure 11-13

The brackets are also extended out after the step well plate extension described in section 11.1 in order to fit the interacting parts.

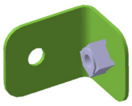


Figure 11-13 Side bracket

- *Thickness: 2 mm*
- *Weight: 4x 0.06 Kg*

11.3.4. Rear cover

After extending the rear step well plate's edge towards the cut standard bracket, the rear cover is changed after the extended plate. The cover's flange on the right side is also removed. This makes it easier to manufacture and therefore cheaper to produce.
Three screws fasten the rear cover instead of four.

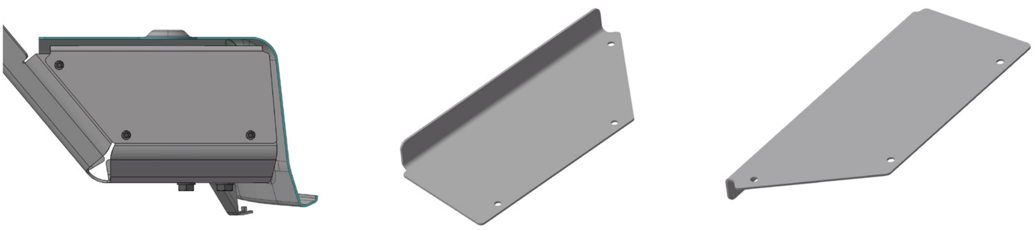


Figure 11-14 Rear cover

11.4. Further requirements

To take the presented concept further some requirements should be included. The requirements were introduced late in the development process therefore due to the lack of time they are remaining to be considered.

- *The side mark lamp required with mudguard extension.*
- *The new front placement of the cab tilting device's positioning.*

11.5. Assemble

The preassembled brackets are mounted to the bumper bracket and the wheelhouse bracket. Then the steps together with the step well plate are assembled to the brackets followed by the pipe guiding bracket and the horn bracket assembled to the step well plate back. The rear cover is assembled last; after the mudguard is assembled to the rear cut standard bracket. See figure 11-15. An animation of the assembling is available in the media appendix A10.

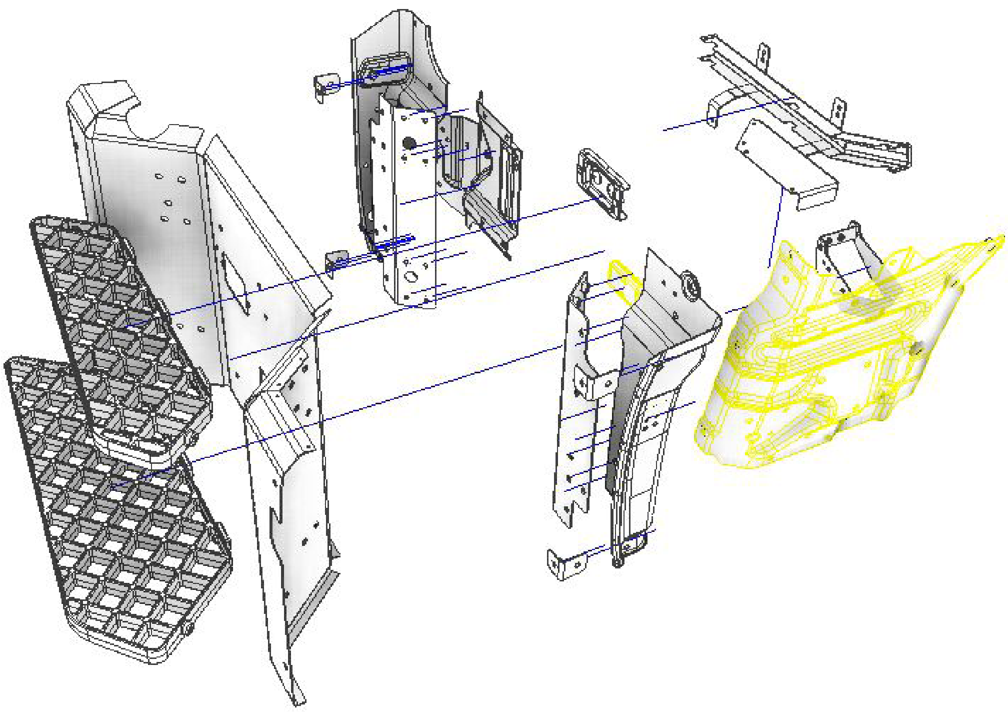


Figure 11-15 Final Assemble order

The instep's total design weight in the concept design is 22 kg which is acceptable, compared to the existing solution design weight of 19 kg.

11.6. Courtesy light

To avoid accidents when entering and exiting the cab in darkness, a suggestion is to have an automatic courtesy light that will light up the steps and ground when the door is opened by the user.

The selected suitable courtesy light lamp for the LowEntry instep is a LED-light from Braslux. Originally the lamp is used to light up the rear registration plate of the trucks in the Brazil market. The lamp is a 24 volt with a socket approved to be used outside.

This LED light is placed beneath the lower step, where it will light up the ground around the truck entrance visible through the open waved casted steps. See figure 11-16

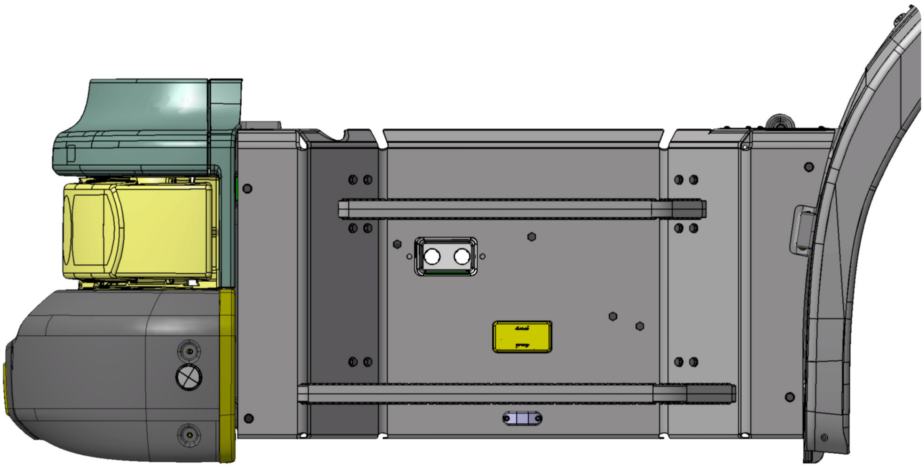


Figure 11- 16 Courtesy light suggestion

The registration plate LED lamp is available in the Scania drawing archive. (2025980)

11.7. Standard components selection

This section aims to select the appropriate standard screws, washers and nuts for the concept based on the Scania´s Guide 010 for available fasteners in production with associated STD. The selection criteria are an annual demand above 10000 units, and used in similar designs.

M8 threads are used in the existing step wells and the standard connecting weld nuts on the wheelhouse and bumper brackets. In table 11-1 the selected screws are presented. Self-tap screws are used together with the untapped weld nuts and steps to not loosen due to the truck vibration.

Use	Type	Info	STD	Part no.	Thread	Length	Pr.cl.	An.demand
Steps	Hexagon	Capt. washer	STD3855	815891	TAPT M8	25 mm	10,9	2682883
STD rear bracket	Hexagon	Incl.Washer	STD3855	1778348	TAPT M8	20 mm	8,8	840514
STD front bracket	Hexagon	Incl.Washer	STD3855	1778348	TAPT M8	20 mm	8,8	840514
Front Instep brackets	Hexagon	Incl.Washer	STD3855	1778348	TAPT M8	20 mm	8,8	840514
Side Instep brackets	Hexagon	Incl.Washer	STD3855	1778348	TAPT M8	20 mm	8,8	840514
Side Instep brackets	Hexagon	Flange Screw	STD3353	812515	M8	16 mm	8,8	951720
Horn	Hexagon	Fullythread	STD3349	808296	M8	25 mm	8,8	1094851
Pipe Guiding rail	Hexagon	Fullythread	STD3349	808296	M8	25 mm	8,8	1094851
Rear Lid	Pan head	Six point head	STD3420	815160	ST3,5	13	8,8	18248

Table 11-1 Screw Selection

The selected M8 nuts in table 11-2 are untapped weld nuts and self-lock nuts, to be able to resist the truck vibration.

Use	Type	Info	STD	Part no.	Thread	Height	Pr.cl.	An.demand
Instep brackets	Weld Nut	Untapped	STD4115	815552	M8	9	8	1321240
Side Instep brackets	Hexagon	Lock nut	STD3364	807428	M8	9,5 mm	8	5838429
Horn	Hexagon	Lock nut	STD3364	807428	M8	9,5 mm	8	5838429
Pipe Guiding rail	Hexagon	Lock nut	STD3364	807428	M8	9,5 mm	8	5838429

Table 11-2 Nut Selection

Suitable washers in table 11-3 are selected after the screw diameter.

Use	Type	STD	Part no.	d x D	Th.ness	Pr.cl.	An.demand
Side instep brackets	Plain	STD30	802998	8,4x16	1,5	8	56035
Horn	Plain	STD30	802998	8,4x16	1,5	8	56035
Pipe Guiding rail	Plain	STD30	802998	8,4x16	1,5	8	56035
Top lid	Plain	STD30	802994	5,1x9	0,8	8	18620

Table 11-3 Washer selection

11.8. Material selection

The aim is to select the most suitable material for the instep based on material properties, environmental issues and cost. The material selections are carried out with Granta CES Selector, where the material yield strength is compared to density, price and CO2 footprint.

The diagram in figure 11-17, 11-18 and 11-19 illustrates available materials with a minimum yield strength limit of 100 MPa plot against density, price and CO2 footprint.

11.8.1. Selection criteria

11.8.1.1. Properties criteria

The chosen material would have to be able to withstand the forces applied by the user and at the same time be as light as possible. This would suggest that the material would have to have relatively high mechanical properties as yield strength and young's modulus with a low density. See figure 11-17.

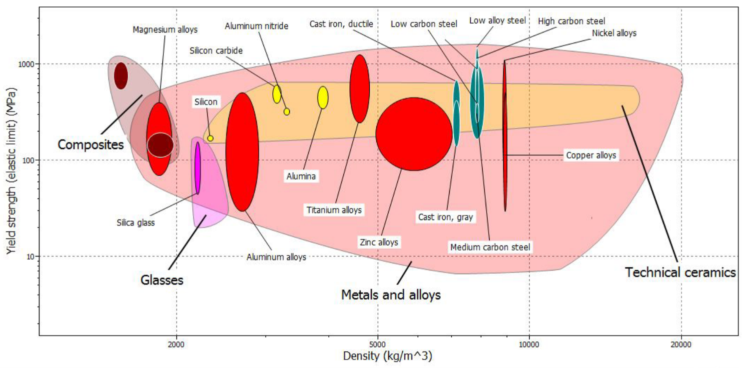


Figure 11-17 Yield strength vs. Density (26)

11.8.1.2. Cost criteria

Cost is a major factor for the material selection regarding the final price. It is important to choose a material which would withstand the required forces while being relatively cheap. In figure 11-18, the yield strength is set against the price per kg.

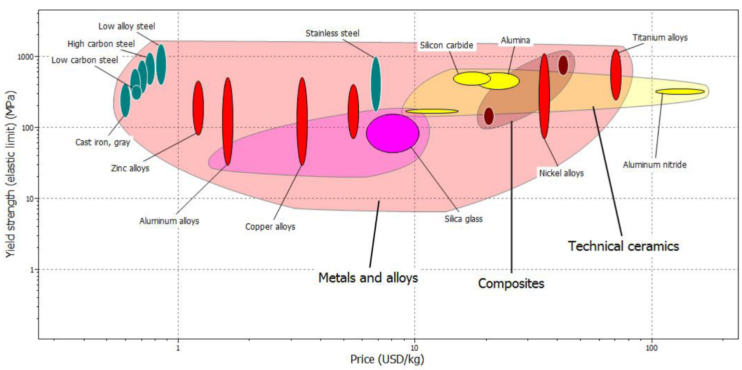


Figure 11-18 Yield strength vs. price (26)

11.8.1.3. *Environment criteria*

The selected material should have a minimum effect on the environment. In figure 11-19 the Yield strength is set against the CO2 footprint at production.

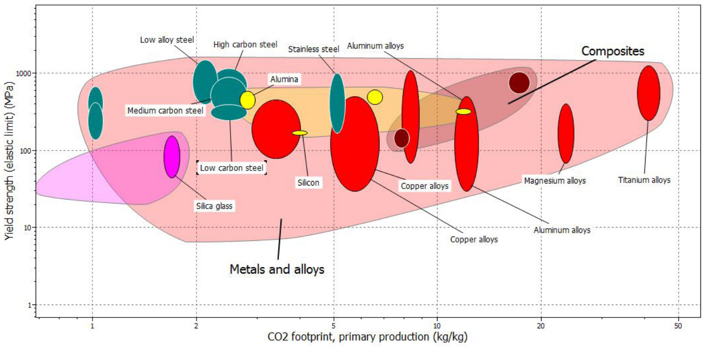


Figure 11-19 Yield strength vs. CO2 footprint, production (26)

11.8.2. Selected material

The selected material is optimized based on the three diagrams; Carbon steel is selected as a material for the step well and the brackets. Cast alumina-alloy selected for the steps. The quality class of both materials are selected based on the related STD.

11.8.2.1. *Carbon steel*

Carbon steel is a metal that is strong, tough, easily formed - and cheap. Carbon steels are alloys of iron with carbon and often a little manganese, nickel, and silicon. (26)

The specific material is selected according to the STD755. The selected cold-rolled sheet is normally used for thicknesses up to 3 mm. Brackets and structural compartments for the cab are typical uses for the cold-rolled sheet.

Mechanical properties
SS-EN 10268 HC260LA
Tensile strength: 350-430 MPa
Yield Strength: 260-330 MPa
SS-EN 10130 DC03
Tensile strength: 270-410 MPa
Yield Strength: 180-230 MPa

11.8.2.2. *Cast Al-alloys*

Aluminium, the first of the “light alloys” (with magnesium and titanium), is the third most abundant metal in the earth’s crust (after iron and silicon) but extracting it costs much energy. (26)

Almost all aluminium alloys for casting contain 5 - 22% silicon (Si) - the silicon makes the alloys more fluid so that they fill the mold and take up fine detail, even in thin sections.

Due to the low sales volume of the LowEntry truck sand casted steps are recommended. Casting in sand moulds (or plaster moulds) is the only method which is suitable for small batches, e.g. prototypes, but using automatic moulding equipment, it can also be used for large batches. The method gives relatively slow solidification and as a consequence the mechanical properties are normally somewhat lower than when casting in permanent forms.

Precise selection of cast-aluminium suitable for sand casting is selected according to STD4279. The selected cast-aluminium is appropriate for sand casting and permanent mould casting.

Mechanical properties
Scania Aluminum 42100 EN AC-42100
Tensile strength: 230 MPa
Yield Strength: 190 MPa

11.9. Design calculations

The strength calculations are carried out as a reasonable estimation of the concept dimensioning.

Due to the complex design the dimensioning process is hard to carry out with handbook methods. The design is estimated by experience and supporting FEM simulations. The strength is also tested on the prototype as well as some minor estimation calculations. Spot welding design calculations and bolt connection estimation are available in appendix A8.

11.9.1. Finite Element Method

Finite Element Method is an approximate numerical method in order to solve differential equations. Depending on the problem the results will always differ from the actual fallouts. The FEM simulations are carried out with CATIA V5´s Generative Structure Analysis feature. Due to the complexity of the design the FEM simulation are used as an estimation of the overall stresses and visualise the behaviour of the design.

In appendix A8, under the section "FEM simulations" the results are presented with comments for each simulation. The results are not fully reliable due to the assumption of the boundary condition and accuracy of the element size and meshing.

The conclusions of the FEM simulations are that none of the stresses applied to the instep concept are critical. The stresses are well below the materials yield strength limit. This is necessary so that the instep can withstand the minimum Scania standard of 75000 load cycles. The simulations are supported with the robust feeling the prototype gives.

11.10. Surface treatment

The qualities of the surface treatment are set after the Surface treatment standard STD4111.

The Scania's standard states that the products should have surface treatment which provides an attractive appearance and corrosion protection with satisfactory durability. The quality of the surface treatment is dependent on the visibility of the product. See table 11-4. Powder painting is the selected surface treatment method.

Surface finish	Exposure to corrosion and mechanical load		
	Minor Effect **1**	**Moderate effect** **2**	**Intense effect** **3**
Extremely good **A** Prominent postition in cab and bus body	Interior cab & bus Example: Interior window moulding	Interior cab & bus Example: Handle, Instrument panel	Exterior front & side of cab and bus body up to upper edge of door line Exemple: Exterior front, Door, Sun visor, Rear view mirror
Very good **B** Less visible postition in cab and bus body	Interior cab & bus Example: Roof shelf, Inner roof panel	Exterior over the door line on cab and bus body as well as interior cab and bus Example: Roof air deflector, Bus interior, chair frame	Exterior back side of cab and bus body up to the upper edge of door line Exapmle: Customer adapted painting
Good **C** Chassis and hidden position in cab & bus body	Seldon visible, hidden surface inside cab or protected position in engine compartment Example: Instrument panel bracket	Position from gearbox and forwars Example: Cab bracket, cable duct inside the frame, steering wheel column	Position from and including the grearbox and backwards Example: Engine, Air tank, chassis mounted brackets
Moderate **D** Positioning powertrain	In engine compartment Example: Cylinder block, Valve cover, Cylinder head, cool water pipes	Chassis parts and power train parts positioned from the gearbox and forward Example: Lower side of enginge	Chassis parts and power train parts positioned from and including the gearbox and backwards Example: Lower side of gearbox Axies

Table 11- 4 Requirement levels

11.10.1. Step well and top cover

The step well is a major visible part of the cab. STD411 requirement states that after three to five years there should not be any visible corrosion on the cab body.

The step well should be coloured with the standard sub-grey chassis colour. To fulfill corrosion requirement a "very good" B3 surface finish is selected for the front of the step well plate and "Good" C3 for the rear side of the plate. The top cover will also have B3 surface finish, all according to the table 11-4.

Step well Front: STD4111-B3-PP-1346692
Step well Rear: STD4111-C3-PP-1346692
Cover: STD4111-B3-PP-1346692

11.10.2. Steps

The selected treatments for the steps are the same as for the regular Scania steps. It is a "Good" C2 finish for visible parts of the step and a D2 for non-visible parts. The colour is a standard step grey found on Scania's regular insteps.

Visible: STD4111-C2-PP-1386297
Non visible: STD4111-D2-PP-1386297

11.10.3. Brackets

The brackets are non-visible because of the step well plate and will be treated with a C3 quality and a sub grey colour. According to the table 11-4
STD4111-C3-PP-1346692

12. Cost analysis

The cost analysis has been carried out together with the Purchasing department at Scania. The analysis is an estimation of the maximum price on the required tool investments and part costs.

The cost and annual demands for the parts are based on the current sales volume of the LowEntry trucks.

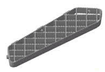
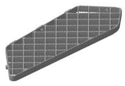
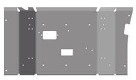
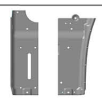
Part	An.demand	Tool cost	Pay back time	Total Part cost	Total cost
 Upper Step	100	100000 SEK (500 SEK / Unit)	2 years	2x 650 SEK	1300 SEK
 Lower Step	100	100000 SEK (500 SEK / Unit)	2 years	2x 650 SEK	1300 SEK
 Instep plate	100	-	-	2x 450 SEK	950 SEK
 Rear lid	100	-	-	2x 90 SEK	180 SEK
 Cut STD bracket	100	-	-	2x 320 SEK	640 SEK
 Instep bracket	200	-	-	4x 200 SEK	800 SEK
 Side Instep bracket	400	-	-	8x 50 SEK	400 SEK
Total cost 2x Insteps					**5570 SEK**

Table 12-1 Cost analysis

12.1. Cost analysis conclusion

The cost for the complete instep design (April 2011) is about 5570 SEK for both sides of the truck, a total cost reduction of approximately 430 SEK compared to the existing solution.

The steps are the main cost due to required investment of new production tools. To be able to reduce the cost further requires an increase in total sales volumes of the LowEntry truck.

13. Risk assessment

In this chapter the hazards associated with the use of the instep are documented. A hazard is a situation where the people, the property or the environment can get harmed. (27)

The risk caused by the hazard and the measures are introduced to reduce the risk is presented in table 13-1. This is done to minimize injury and harm to the user.

Hazard	Risk	Type	Safety Measure
Falling or slipping from the steps	Injuries due to falling	Minor to serious	Wearing good foothold shoes. Safety reflect lables on the step edges. Automatic Courtesy light.
Falling or slipping form the steps	Injuries due to falling or over-riding by oncoming traffic	Serious to fatal	Use cross-access to avoid traffic.
Ingress & egress	Injuries due to repetitive strain	Minor to serious	Do not jump off the steps. Use both steps for acces

Table 13-1 Hazards to user

14. ECO-AUDIT

The purpose of the ECO-Audit section is to evaluate the concept's main environmental impact in a life cycle perspective (material, manufacture, transport, use and end of life) with focus on energy use and carbon footprint compared to the existing instep solution. See figure 14-1. The ECO-audit has been carried out with Granta CES Selector ECO database.

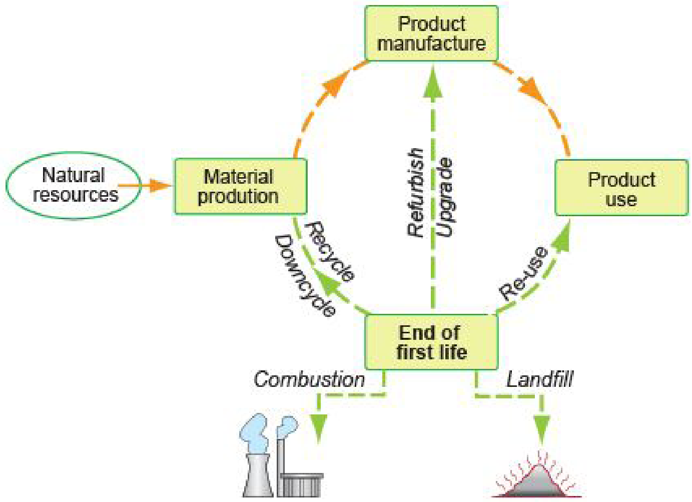


Figure 14-1 Life Cycle principle (26)

Surface treatment is not included in the analysis because of the complexity.

14.1. ECO product definition

The primary data for each life cycle phase is set by the ECO product definition.
The ECO product definition is split into three main sections; material, manufacturing and end of life, use and transport.

14.1.1. Material, manufacture and end of life

The product definition estimation shows that the rolling and casting are the primary manufacturing process with focus on energy use.

The production energy of steel is comparatively low per unit weight, about half of polymers/per unit volume. Carbon steels are easy to recycle, and the energy consumption to do so is small.

Aluminium ore is abundant. It takes a lot of energy to extract aluminium, but it is easily recycled at low energy cost. (26)

In table 14-1 and 14-2 the material, manufacturing and end of life are stated for the two instep designs.

Component	Material	Primary process	Mass (kg)	End of life
Instep plate	Carbon Steel	Forming, rolling	9,7	Recycle
Upper step	Cast Al-alloys	Casting	2	Recycle
Lower step	Cast Al-alloys	Casting	3,2	Recycle
Top lid	Carbon Steel	Forming, rolling	0,2	Recycle
Rear brackets	Carbon Steel	Forming, rolling	3,6	Recycle
Front brackets	Carbon Steel	Forming, rolling	3,4	Recycle

Table 14-1 Material, manufacture and end of life new instep design.

Component	Material	Primary process	Mass (kg)	End of life
Borarding plate	Carbon Steel	Forming, rolling	4,6	Recycle
Upper step	Cast Al-alloys	Forming, rolling	4,5	Recycle
Lower step	Cast Al-alloys	Forming, rolling	5,3	Recycle
STD Front	Carbon Steel	Forming, rolling	1,6	Recycle
STD Rear	Carbon Steel	Forming, rolling	1,7	Recycle
Frame	Carbon Steel	Forming, rolling	1,0	Recycle

Table 14-2 Material, manufacture and end of life existing instep design

To be able to recycle the casted steps it is required that the parts material composition is marked according to STD3871.

14.1.1.1. Transport

The transportation of the product is estimated based on the location of Scania´s suppliers and the main market for the LowEntry truck.

- *1000 Km with truck*
- *1500 Km with sea freight.*

14.1.1.2. Use

The product life span of an average refuse collector is approximately 10 years, with an average use of 52000 km per year. (28)

14.2. Energy and carbon footprint summary

The main environmental impact of the design is caused by the process of material production. The recycling of the product contributes to an end of life savings corresponding to the replacement of virgin materials.

14.2.1. New LowEntry Design

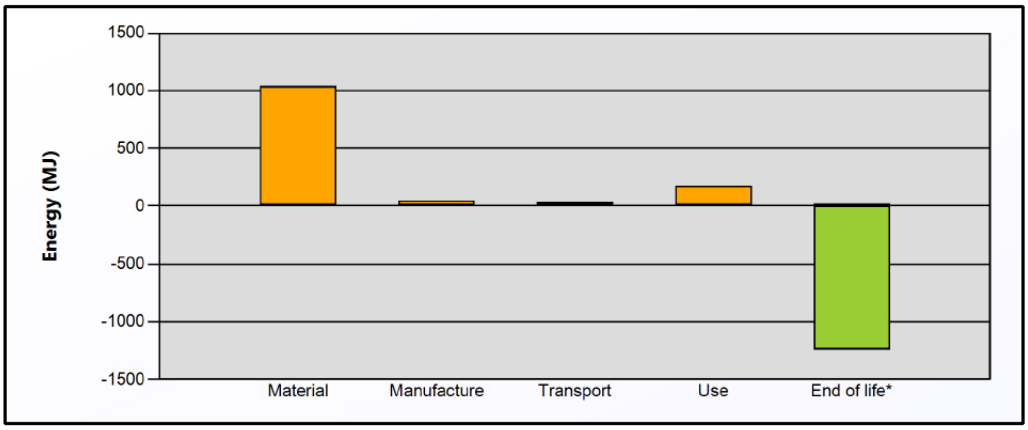


Figure 14-2 Energy use summary new design (26)

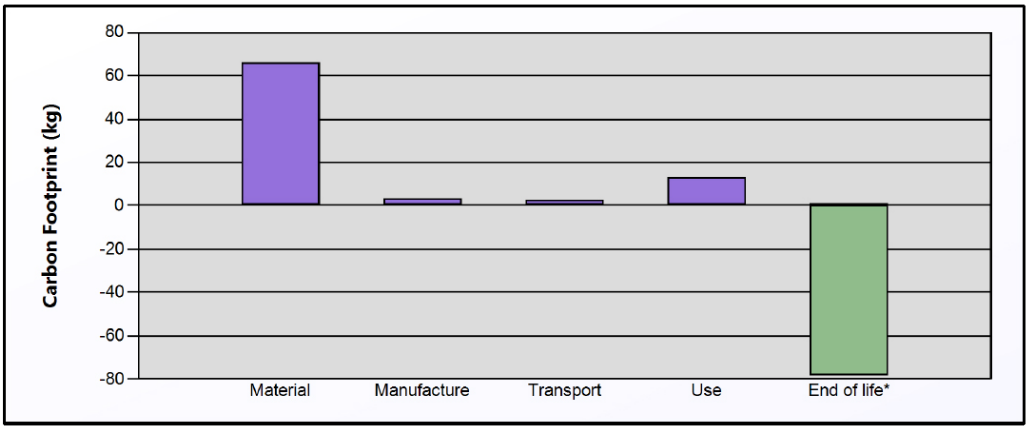


Figure 14-3 Carbon footprint summary new design (26)

Phase	Energy (MJ)	Energy (%)	CO2 (kg)	CO2 (%)
Material	1.04e+03	78.8	66.3	76.9
Manufacture	48.8	3.7	3.65	4.2
Transport	33.5	2.5	2.38	2.8
Use	184	13.9	13	15.1
End of life (collection & sorting)	13.9	1.1	0.833	1.0
Total	**1.32e+03**	**100**	**86.1**	**100**
End of life (potential saving/burden*)	-1.24e+03	-94.1	-78	-90.5
Total (including end of life saving/burden)	**78.3**		**8.18**	

*End of life saving/burden corresponds to the replacement of virgin material

Table 14-3 Energy and Carbon Summary new design (26)

The total estimated energy required for the product's life cycle is 78 MJ, and the carbon emission is approximately 8 Kg. (26)

14.2.2. Existing design

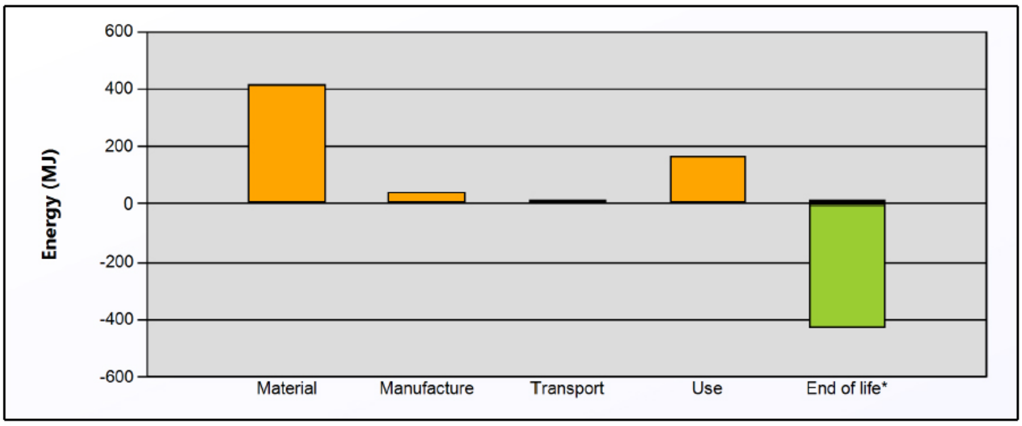


Figure 14-4 Energy use summary existing design (26)

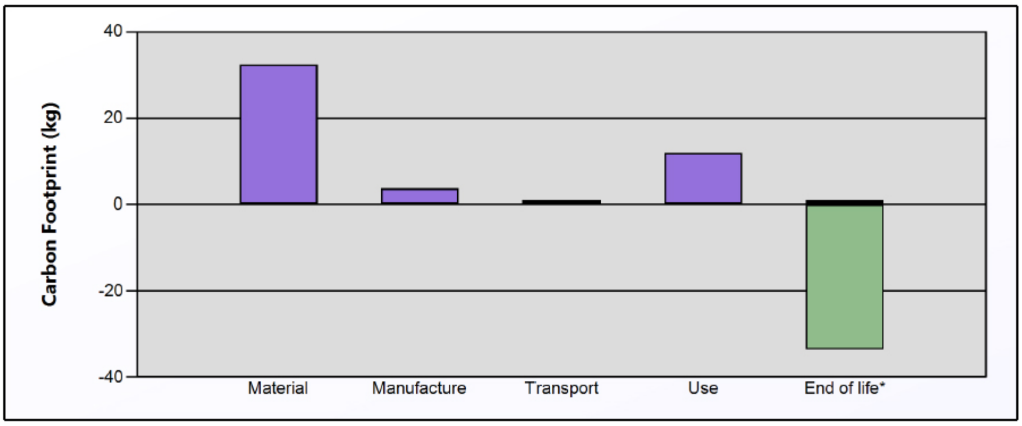


Figure 14-5 Energy use summary existing design (26)

Phase	Energy (MJ)	Energy (%)	CO2 (kg)	CO2 (%)
Material	416	63.5	32.4	65.3
Manufacture	44.7	6.8	3.58	7.2
Transport	13.1	2.0	0.929	1.9
Use	168	25.7	11.9	24.1
End of life (collection & sorting)	13.1	2.0	0.785	1.6
Total	**655**	**100**	**49.6**	**100**
End of life (potential saving/burden*)	-429	-65.5	-33.4	-67.3
Total (including end of life saving/burden)	**226**		**16.2**	

*End of life saving/burden corresponds to the replacement of virgin material

Table 14-4 Energy and Carbon Summary new design (26)

The total estimated energy required for the product's life cycle is 226 MJ, and the carbon emission is approximately 16 Kg. (26)

14.2.3. Eco conclusion

The ECO-audit illustrate that the new instep design requires more energy to produce the material compared to the existing design due to that the aluminium casting process requires a lot of energy. In the further life-cycle stages the two designs are similar in energy usage. The new instep design has a higher potential environmental impact saving with the end of life recycling due to the potential energy savings of producing new aluminium from recycled material compared to creating aluminium from virgin minerals.

The new instep design has a minor potential environment saving effect compared to the existing solution.

There are no sophisticated test-machines to measure embodied energies or carbon footprints. International standards, detailed in ISO 14040, lay out procedures, but these are vague and not easily applied. The differences in the process routes by which materials are made in different production facilities, the difficulty in setting system boundaries and the procedural problems in assessing energy, CO2 and the other eco-attributes all contribute to the imprecision. The imprecision derivation is approximately 20 %. (26)

15. Final solution

In this chapter are photo realistic images of the final design in detail and integrated on the truck with the protruded bumper presented. The images are done with Autodesk 3d Max.

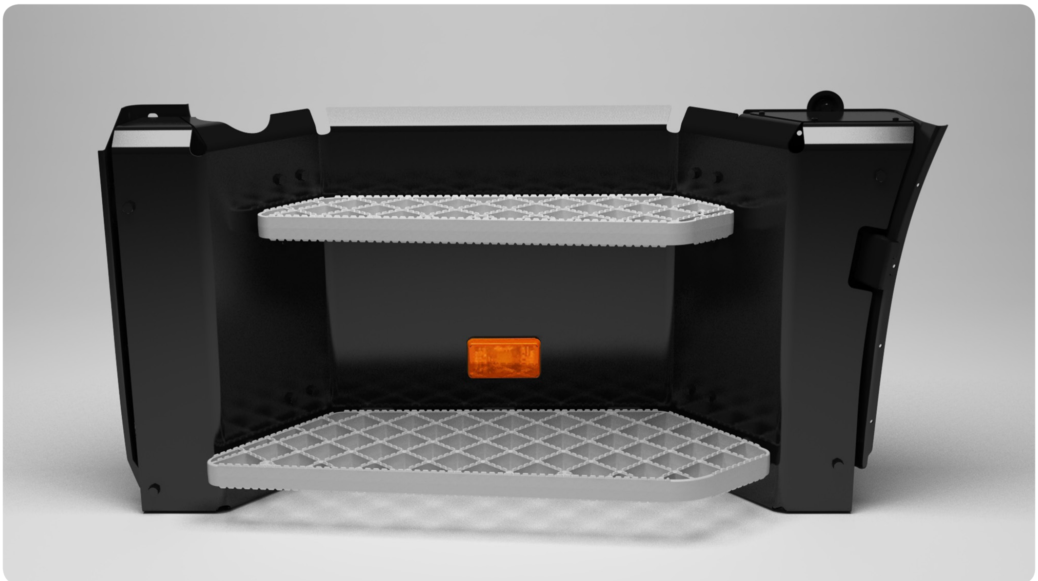


Figure 15-1 Detailed view driver side

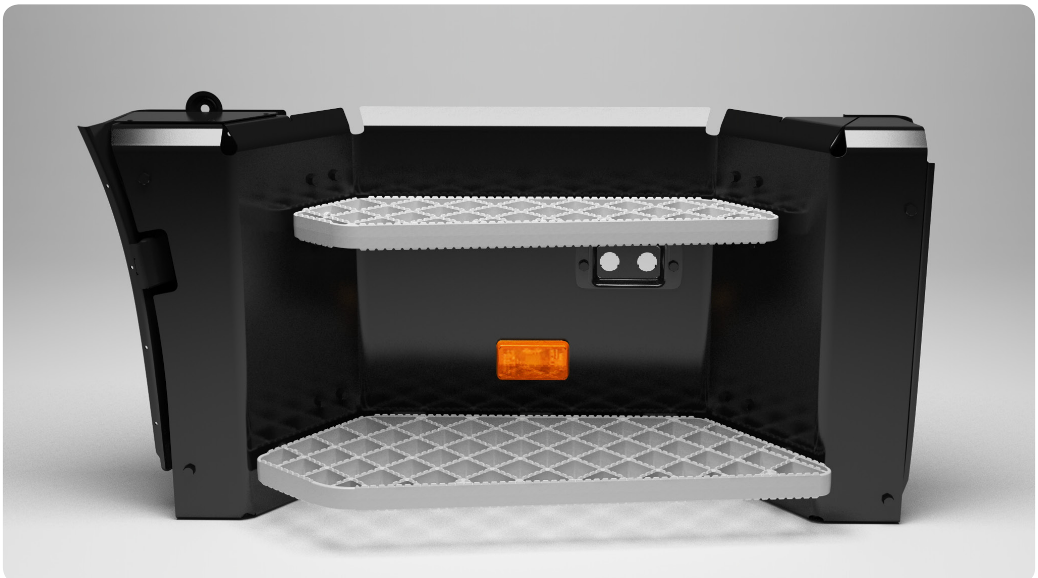


Figure 15-2 Detailed view co-driver side

Figure 15-3 ISO-view with protruded bumper

Figure 15-4 Front view instep

Closing Analysis

16. Discussion

The approach to the whole project was based on the presented objectives; a modular, safe, ergonomic, robust integrated and preferably single step instep. As the project went on new input emerged to the surface in the project which caused many revisions and start overs.

Scania's modular system has made the Scania products highly modularized. This has brought many advantages like minimizing the unique parts and cost as well as fast and easy service. On the other hand since, in the modular system, parts are designed and shaped after each other, changes to the parts are not easily possible without changing the related parts.

Soon in the design phase many barriers were revealed which influenced the final design notably. Perhaps other solutions could have been sought and considered to a larger extent if the current circumstances could be changed or if more resources were available.

The solution is designed for the current truck with the current tightly interactive parts with low sale numbers and very limited resources. The result could be highly different if there were areas of freedom.

16.1. Result

This thesis has resulted in a double step instep which is:

Modular
The concept has less unique parts compared to the existing LowEntry instep (12 parts on both side compared to 22 parts) which helps in lowering the price, ease of manufacturing and assemble.

The design fit both driver and co-driver side. The steps, the brackets and the step well plates are highly modularized. The step well plate and the rear cover are different parts on the driver and co-driver side but they are mirrored and shaped after the same principal.

Safe
Safety has been a major issue in the current instep for LowEntry. The new steps have anti-slippery pattern and texture as the regular Scania step which provides a safe foothold on the steps, which let dirt and snow through.

Ergonomic
Based on the prototype test the minimum comfortable width for the upper step and the maximum width for the lower step with the 74.3º step gradient angle provide a good visibility over the steps and a good shinbone clearance and consequently an easier ingress and egress.

Robust and Quality Impression
Based on the calculations and the prototype test the concept's design is very robust and can withstand the design load well. This gives a long life and durable quality to the concept.

More integrated with the cab exterior
The concept follows the design of the exterior to some possible extent. Clean large surfaces with smooth broken angle and continuity all around were considered in the new design. As mentioned, limited available resources have narrowed down the material selection and the properties of the material limited the form giving process.

The casted aluminum steps based on the Scania standard step's principals also help the product to look more like a Scania product.

In the end a result close to completion is presented which fulfills the requirements to possible extent in the given time and possible frame.

16.2. Conclusion

Product development is a long process. The limited time has directed this project to some extent. The time that was spent on doing very basic researches and gathering information from the company and the co-workers, structuring the information, finding a working solution which is feasible within Scania and Laxå Special Vehicles has left too little time for truly creative work and innovative solutions. Although the focus has been on realistic solutions a lot of interesting ideas arised in the beginning of the concept design phase and soon discarded by the limitations. Some of the ideas were not documented.

Scania LowEntry trucks are manufactured in low volumes and the advertisement on the segment has been underprivileged. During the pre-study the fact had revealed that dealers even in Sweden were unaware of this Scania product. In order to make a successful segment out of LowEntry, engineering, design and human factors disciplines as well as financial investments should work hand to hand. It might require the LowEntry trucks become a standard order in Scania instead of special order.

The current solution on the instep is done by Laxå Special Vehicles without considering Scania's exterior design standards in design and development. This lack of integration damaged the coherency of the product family.

16.3. Recommendation

Document all information about LowEntry e.g. requirements, different parts and CAD files at Scania. It speeds up related projects to a large extent.

Manufacture the parts as Scania parts inside Scania to be able to keep track of them, reduce the cost and maintain the coherency.

Spread more information about LowEntry inside and outside the company.

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Supporting Documents

Methods descriptions

This section includes brief descriptions of the methods used to carry out this master's thesis.

Objective tree
The object tree method is a structured way of clarifying the design brief in to statement which is easily understood. (1)

Elements breakdown
The uses of explicit design cues are product design a strategy for companies to create visual consistency and product recognition.

Element breakdown is a tool to extract implicit and explicit design cues of a brand used repeatedly over the companies' entire product portfolio as a guide for further design development. (29)

Semi structured interviews
Semi structured interviews is a combination of open and structured interviews. The interviews are flexible, allowing new questions to be brought up during the interview as a result of what the interviewee says. The interviewer in a semi-structured interview generally has a framework of themes to be explored. (30)

Usability testing
There are many ways of doing usability tests, both empirical and non-empirical. One empirical method is to perform controlled experiments. In such the users are asked to use the design to carry out specific tasks while their behaviour is observed. (31)

User scenarios
User scenario is a story about a well-defined hypothetical user, using the product. The purpose of the user scenarios is to present a comprehensive understanding about how and in what environment the product is used, and reveal the opportunity for improvement. (1)

Morphological chart
The Morphological chart encourages the designer to identify novel combinations of elements or components. The chart sets out a complete range of elements that can be combined to generate a complete range of alternative designs. (1)

Pugh matrix
The Pugh Matrix is an evaluation tool where design concepts are compared, scored and screened comparing to each other. (2)

Computer Aided Design
In this master's thesis the Computer Aided Design (CAD) has been used vastly and in different levels. Since a truck is a complex product with lots of parts, the existing CAD files have been of a great use to investigate interacting parts and connections as well as testing the design proposals in the context to see the weakness and strength points.

The CAD applications like CATIA V5, Autodesk Studio tools has been used in order to explore form in an exact and detailed level. This for sure causes a reduction in time and cost for the product development process as well as the possibility for instant modifications and several tests. (32)

CES Selector

A sophisticated toolkit to support eco-friendly designs by selecting materials and processes based on environmental criteria. (26)

Finite Element Method

Finite Element Method (FEM) is an approximate numerical method for solving differential equations. The calculating volume is discredited into a large number of elements with simple geometries which are used to solve complex structural analysis. (33)

Risk assessment

Risk Assessment is a method to identify hazards and evaluate the level of risk they present to be able to introduce means to reduce them. (27)

Appendix 1 Ergonomic guidelines

The ingress and egress path is determined by the relationship between all components of the access system; the steps, hand rails, the door's opening angle, seat and steering column. (34)

General principles

The access path should encourage normal, balanced movement of the body.

All steps and handrails should be within comfortable easy reach and positioned to minimize strain on the knees, back, hip, arms and shoulders of the user.

The relationship between steps and handrails should enable three point body contacts (for stability) throughout both ascent and descent.

The alignment of the door opening, the seat edge and the steering column should allow ease of movement in and out of the seat. Hence, adequate space between the steering column and the seat is required.

The access path should be obvious to the user during both access and egress. Enhancing the access pathway in a contrasting color will aid visibility and depth perception. The location of steps during egress needs to be particularly obvious.

The steps

The first step should be no more than 500mm (preferably 400mm) from ground level. The height should be less than that which can be comfortably ascended as descent is more difficult.

Subsequent steps should be equally spaced and the distance between them 250mm to 400mm (preferably 300mm).

Steps should be constructed from an open weave material to reduce build-up of water and dirt.

Each step should have side plates approximately 50mm high to prevent sideways slipping of feet.

Toe clearance should be at least 150mm (preferably 200mm)

Steps should be at least 320mm wide (preferably 380mm) to accommodate two feet or in the case of laterally staggered steps be at least 190mm wide to accommodate one foot.

Steps should be on a slight gradient (80^o) to assist in step location, to allow shin clearance and to improve balance. The steeper the gradient the more users is reliant on handrails.

Appendix 2 Instep Standards

General access to the driver's compartment

This summary of dimensions for steps covers both the European directive requirement and the German occupational safety requirements of BGV. See table A1-1 and figure A1-1. (35) (36)

- *The distance (A) from the ground to the upper surface of the lowest step, measured with the vehicle in running order on a horizontal and flat surface, shall not be more than 600 mm.*
- *The distance (B) between the upper surfaces of the steps shall be not more than 400 mm. The vertical distance between two subsequent steps shall not vary by more than 50 mm. The last requirement shall not apply to the distance between the uppermost step and the cab floor.*
- *In addition, the following minimum geometrical specifications shall be fulfilled:*

- *Step depth (D): 80 mm*
- *Step clearance (E) (include step depth): 150 mm*
- *Step width (F): 300 mm*
- *Width of the lowest step (G): 200 mm*
- *Step height (S): 120 mm*
- *Transversal offset between steps (H): 0 mm*
- *Longitudinal overlap (J) between two steps in the same flight, or between the uppermost step and the cab floor: 200 mm*
- *The lowest step may be designed as a rung, if this is necessary for reasons relating to construction or use, and in the case of off-road vehicles*
- *In such case the rung depth (R) shall be at least 20 mm.*
- *Rungs of round cross section are not permitted.*
- *While getting down from the driver's compartment the position of the uppermost step shall be easily found out.*

- *The upper surface of the steps shall be non-slippery. In addition, steps exposed to the weather and the dirt during driving shall have adequate run-off draining surface.*

Pos*	Step surfaces	EU Directive	Germany,
A	Distance from lowest step surface to ground	max 600	max 500
	- dist. A for heavy construction and off-road vehicles	max 700	max 650
	- distance A for fire-fighting trucks	–	max 625
B	Distance between step upper surfaces	max 400	max 400
	- if technically necessary and for fire-fighting trucks		max 500
	- dist. B variations shall be as small as possible	max 50	max 10%
	- distance B variations, for off-road vehicles	max 100	
D	Step depth (step surface depth)	min 80	min 80
E	Step clearance (step front to fixed object)	min 150	min 150
F	Step width *(BGF recommends min. 400 mm)*	min 300	min 300
	- step width for off-road vehicles	min 200	–
G	Step width, lowest step	min 200	–
H	Transversal offset between steps	0 mm	–
J	Longitudinal overlap (J) between two subsequent steps in the same flight, or between the uppermost step and the cab floor:	min 200	–
R	Rung depth (lowest/off-road step)	min 20	–
S	Step height clearance *(BGF recommends min. 190)*	min 120	min 150

Table A2-1 General access to the driver's compartment

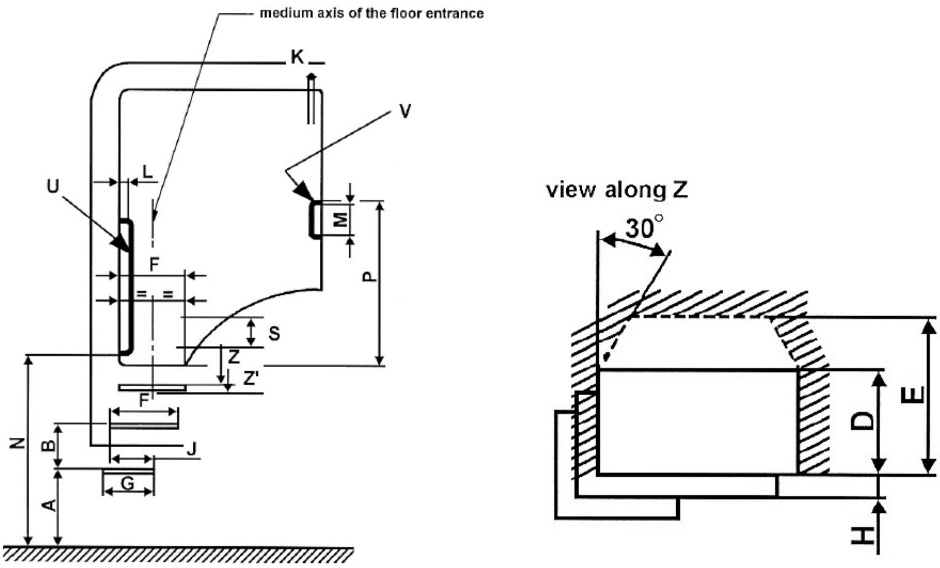


Figure A1-1 Illustration of placement (35)

Refuse Collector Standards

For refuse collector vehicles, the cab should have a safe access at each side of RCV, with the first step at a distance of ≤ 450 mm from the ground. (25)

Fire and rescue service vehicles Standards

Step access to crew compartments shall comply with the dimensions in Table A1-2 and figure A2-2. (37)

Description	Values of Figure 10	
Horizontal distance (c_1, c_2, etc.) between the step nose of two consecutive steps	≤ 150 mm	> 150 mm
Height of first step from the ground (d): — category 1 (urban) — categories 2 and 3 (rural and all terrain)	≤ 550 mm ≤ 600 mm	
Height (b) between steps (all categories) If there are two or more vehicle mounted steps the height (b_1, b_2) between adjacent steps shall differ as little as possible and in no case exceed 150 mm.	≤ 400 mm	≤ 450 mm
Depth of foot space (a_1, a_2, etc)	≥ 150 mm	
Width of step	≥ 300 mm	
α_1, α_2, etc	≤ 85°	

Table A2-2 Fire and rescue service vehicles standards

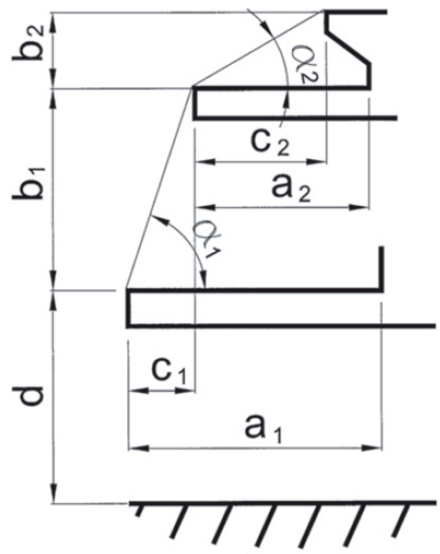


Figure A1-2 Illustration of placement (37)

Appendix 3 User Analysis

SRV-Återvinning, Tumba

Interview part

The refuse collector staffs at SRV-Återvinning are most of the times two in the cab. They enter and exit the truck approximately 200-300 times per workday. A great pressure on knees, joints and hips are reported. The result of this is that some of the elder refuse collectors has problem with repetitive strain injuries. The instep design is very important for the refuse collectors to carry out the work in a safe and convenient way, and minimize repetitive strain injuries.
The workers use the Mercedes Econic II low-entry truck, and their experience of the truck is:

Advantages

- *The low and single instep's height saves knees from extra pressure*
- *Not so high if you fall*
- *The folding door on the co-driver side is good*

Disadvantages

- *The entry is too narrow*
- *The door opening angle is 60°*
- *The driving comfort is low*
- *No place for the passenger's right foot because of the entry cut in the floor.*
- *Loud noise in the cab due to the folding door*
- *The instep collects snow and dirt*

Test of Scania LowEntry

The drivers at SRV-Återvinning prefer Scania in general, because of the high level of comfort while driving and the quick service Scania offers. The drivers like the wide entry and the 90° opening angle on the LowEntry truck door. It makes it easy to enter the cab. The truck is a tool and a workplace for the drivers, which is used very rough. Especially the door and instep is exposed to hard conditions because of the repetitive ingress and egress.

Entry

The drivers use the instep as both single and double instep. The front parts of the steps are useless. All of the drivers support themselves by grabbing the door handle by one hand, while some of the drivers reach for the steering wheel with the other hand. The handrails were designed for climbing out instead for stepping out. The users need to reach for the steering wheel to be able to get a 3 points grip. The kneeling function is too slow; the user is already in the cab before the kneeling is complete.

Exit

The users walk out of the cab. The egress process is very quick. It seems to be hard to reach the lower step and get a 3-point support exiting the cab, because of the placement of the lower step. The front widths of the steps are not used. The user is out of the cab before the kneeling is complete. It is too slow.

Improvements and opinions
The steps

- *The steps collect dirt and snow, should let them through*
- *The steps are slippery, should have better anti-slip texture*
- *The front part of the steps are useless*
- *The upper step should be placed deeper so the lower step is visible*
- *The steps aren't at their deepest where the users step on*
- *The lower step should be broader than the upper one*
- *The instep should have a smaller step gradient angle*
- *The narrow overlapping between the steps causes risk of hitting the shinbone to the steps' edges.*
- *The distance from the upper step to the floor is too big.*
- *The low step is too low when kneeling*
- *Want a stair-feeling*

Kneeling function

- *The kneeling function is too slow*
- *The truck should stay in kneeling position when the user is outside the truck*
- *They suggest using the parking brake as the only kneeling parameter*

Other

Better placement of the handrail, to be able to get a 3 points support exiting the cab.(28)

Reno, Hässleholm

Interview part

The refuse collectors at Reno in Hässleholm collect garbage at 28000 households with 22 Scania P- series trucks. The company offers 12 fractions of garbage collection.

Usually the driver carries out the task alone, except for 2 trucks active in the city centre of Hässleholm, where they are 2 persons in the cab because of the traffic. The driver stops 300 to 350 times in the urban area and 200 to 250 times in the rural area during a workday (7:00-16:00) causing a great pressure on knees, joints and shoulders. The result of this is that some of the elder refuse collectors has problem with repetitive strain injuries.

The instep design is very important for the refuse collector driver to be able to carry out the work in a safe and convenient way, and minimize repetitive strain injuries. According to the manger at Reno a refuse collector driver last on average 12 years in the field.

One repeated statement was function before exterior design; it is a tool. The refuse collectors didn't care about the exterior design, it has to work.
The workers use regular Scania P-series, and their experience of the truck is:

Advantages

- *Good comfort*
- *Quick repair*

Disadvantages

- *The entry level is too high*
- *The entry is off center of driving position*
- *No cross access, have to go out in the traffic*
- *The instep collects snow and dirt, because of the light below the second step, eventually becoming slippery*
- *The steps are too narrow to walk out, have to climb out*
- *Plastic covers beneath steps collects dirt and snow*

The drivers would like a solution there they are able to walk in and out of the cab instead of climbing. The truck is a tool and a workplace for the drivers, which are used very rough. Especially the door and instep is exposed to hard conditions because of the way the drivers handle it. There is an intense wear on the steps; the anti-slip texture was wear down after 2 year of use. On some of the Scania Trucks, the users had put an extension off the lower step, with a few centimetres. They said it was very helpful to get an easier ingress and egress. See figure A3-1.

Figure A3-1 Step extension

One of the drivers who had used Mercedes Econic II, thought the Econic instep was to narrow, the comfort was low, (Spine problems driving on bad roads). The height of the instep was the only thing he liked.

Entry

The driver use both steps accessing the cab, they use the left foot on the lower step, and grab the door and the steering wheel to get a 3 points grip. The steps are narrow, so the user only uses the edge of the second step; important with a god ant-slip texture on the steps. The steps are off-centred from the driving position; the driver needs to pull himself up with the help of the door. The off centred position forces the body to twist backwards.

Figure A3-2 Accessing P-series cab

Exit
The user walks out of the cab instead of climbing out, and uses both steps, but just touches the lower step, because it's hard to reach. The younger drivers often jump off the upper step. This is not recommended because it puts a lot of strain on the knees. The steps are off centred from the driving position. The drivers put one foot on the first step and then swing him out of the cab, with support of the wheelhouse. This movement forces the ankle to twist, and the user gets problems with his feet. In one case the problem was so severe that the driver had to stop driving the truck, and work in another department of the company.

Improvements and opinions
The steps

- *The upper step should be placed deeper so the lower step is visible*
- *The lower step is too narrow to use as a step, hard to use exiting the truck*
- *The instep should have a greater angle from the lower step's outer edge to the upper step's outer edge.*
- *The chair should be lowered automatically when the parking brake is applied to give more space for the knees getting out*
- *They would like to have enough space to set down both feet on the upper step and then walk out.*
- *The steps should give a stair-feeling*

Other

- *Better placement of handrail, to be able to get a 3 points support exiting the cab*
- *More comfort, spine problems happen driving in bad roads*
- *Some kind of "frame" over the fans in front of the dashboard. They use the fans to dry the gloves. It*
- *gets foggy in the cab due to the cover of the fans with the wet gloves.*
- *Adjustment in the chair movement, when applying the parking brake to provide more space for*

- *Egression*
- *A clean surface on the inside of the door, get stuck with the feet's on the way out in the door.(38)*

Renhållning AB, Älmhult

Interview part

The refuse collector staff at Renhållning AB in Älmhult collects garbage at 13000 households with 4 trucks. They are always alone in the truck, and stop about 250 to 300 times during a workday (7:00-16:00). They have just one fraction, "household garbage" They burn everything, including glass, metal etc.
The day starts with a coffee at the garage with the other drivers, around 7. Then they set off in their trucks. Renhållning AB has one Econic II, one Scania LowEntry and two regular P-series; they also have one old Scania 93m as backup.

Figure A3-3 Scania 93m refuse Collector

The Econic II driver uses the old Scania 93m instead of the Econic II up to three days a week, because it offers better comfort than the Econic II, especially on country roads. The Econic II door is too narrow; the driver gets stuck with the clothes.

The user of the Scania LowEntry likes the extra space and the wide entry in the cab especially compared to the Econic. The comfort in the cab is a great advantage; the truck is mainly used on the country side, with bad roads, so the comfort is important.

The driver does not use the cross access, it is a bit to narrow and the front of bench is used to store papers. But he thinks it is a good idea, good way to avoid stepping out in traffic.

The kneeling function has been removed; it was too slow and didn't work well on the bad country roads, risk of hitting the ground, and getting stuck in the snow.

The working day ends at the dump, where the driver weighs the truck to estimate the amount of garbage and then empties the sweeper and cleans it afterwards. After the dump, all the refuse collectors meet at the garage for a late afternoon coffee.

The Scania LowEntry's driver has worked as a refuse collector for 2 years, and has yet no strain injuries. Some of the colleagues has problem with their knees. The driver says: "It is important to use all the steps on the way out, when you jump out you put a lot of strain on your knees."
The driver in Älmhult also said: "Function before design; it is a tool."

Advantages

- *Good comfort*
- *Wide instep*

Disadvantages

- *The edges are slippery*
- *The steps are weak*

Entry

The driver uses both steps accessing the cab, and grabs the door and the steering wheel to get a 3 points grip. The door opens in most of the times to a 90° angle. The reason is that the steps have a small clearance to be able to walk in with comfort. The driver is very careful entering the cab. He has fallen a few times, and hurt his shinbone and doesn't want to wear his body out, like a few of the colleagues have.

Exit

The driver climbs out of the cab and uses all the steps, this is a safety precaution and a habit, and user always climbs out of trucks because the risk of falling is less this way. The steps are too narrow and slippery, to walk out comfortably.

Improvements and opinions

- *Anti-slip texture*
- *Stronger and more robust instep (39)*

IKEA´s- lager, Älmhult

Interview summary

The workers at IKEA storage have 4 Scania Low-Entry Trucks, 3 newer and one truck with 4th generation cab with the open waved step solution. They needed to ingress and egress the cab at least 10 times every hour, for 8 hours. There is just the driver in the cab who didn't use the kneeling function, it had been removed. The driver thought it was a safety precaution because of the risk of getting squeezed of the kneeling.
In general they liked the placement of the steps, but maybe the upper step could be a bit higher to get an even distance between the steps.

Advantages

- *The width of the instep*
- *Driving comfort*

Disadvantages

- *The instep collects snow and dirt*
- *The instep is too weak; welding has been done on the instep.*
- *The edges are slippery*

The older 4th generation step solution is better than the new one because it gives a better grip. But the steps are narrower than the 5th generation one which makes it even harder to walk out.

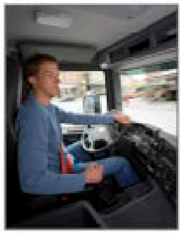
Entry
The driver uses both steps to get in the cab; they walk in from the side, with the door open at 60º. They support themselves on the door and the steering wheel, to get a 3 points support. The right handle is bad placed to get a good grip.

Exit
During the winter the driver climbs out of the truck, the steps are too slippery to be able to walk out. In the summer time the driver walks out, but it´s hard to reach the lower step, it is just touched on the way out.

Improvements and opinions
The steps

- *The steps collect dirt and snow, should be designed to let it through*
- *The steps are slippery; should have better anti-slip texture*
- *The upper step should be placed deeper so the lower step is visible*
- *The depth isn't at its biggest where the users step on.*
- *The lower step should be broader than the upper*
- *The distance from the upper step to the floor is too big.*
- *The steps should give a stair-feeling (40)*

Figure A3-5 User Scenario Refuse Collector



Mark is 28 and has been working as **STORAGE DISTRIBUTOR** in IKEA for 2 years. He drives a Scania **LOW-ENTRY** truck with **KNEELING FUNCTION** and distributes containers to different warehouses inside the storage area. He usually works together **WITH ANOTHER COLLEAGUE.** They divide the driving task between them during the day, but both exit the truck for the delivery and loading process.

They have a **TIGHT SCHEDULE** of delivering 4 to 5 containers every hour. Each load and delivery requires 5 to 6 exit and entry in order to be able to connect and disconnect the container on the truck. In an 8 hours working day They have at least **200 TIMES** ingress and egress.

Mark always approaches the cab entrance from the back of the truck, he opens the door and the cab kneels. He grabs the **DOOR HANDLE** and reaches for the **STEERING WHEEL** and lift himself up using **BOTH STEPS**, long **BEFORE THE CAB IS FULLY KNEELED**. If the truck is already in kneeling position, he sometimes uses only the upper step because he feels the lower step is placed too low. But the upper step is too high to be always used as a single entry step.

In order to be **FAST**, Mark needs to **step in and out** instead of climbing the stairs. But the lower step is hard to reach in a fast pace. Most of the times he just touches the steps edge with his foot paw. Because of the steps position and the **slippery steps**, there is a risk of falling. Mark has slidden on the steps several times and feels **UNSECURE** exiting the cab, so he often jumps off from the upper step. He is aware that the frequent jumps put a lot of **strain on his knees** and in the long term he will get problems with his knees, like his elder colleagues.

Mark needs an instep with a **STAIR FEELING, EASY TO REACH without gripping** the door and steering wheel. with a good **ANTI-SLIP** texture.

Figure A3-6 User Scenario Distributor

Appendix 4 QFD-chart

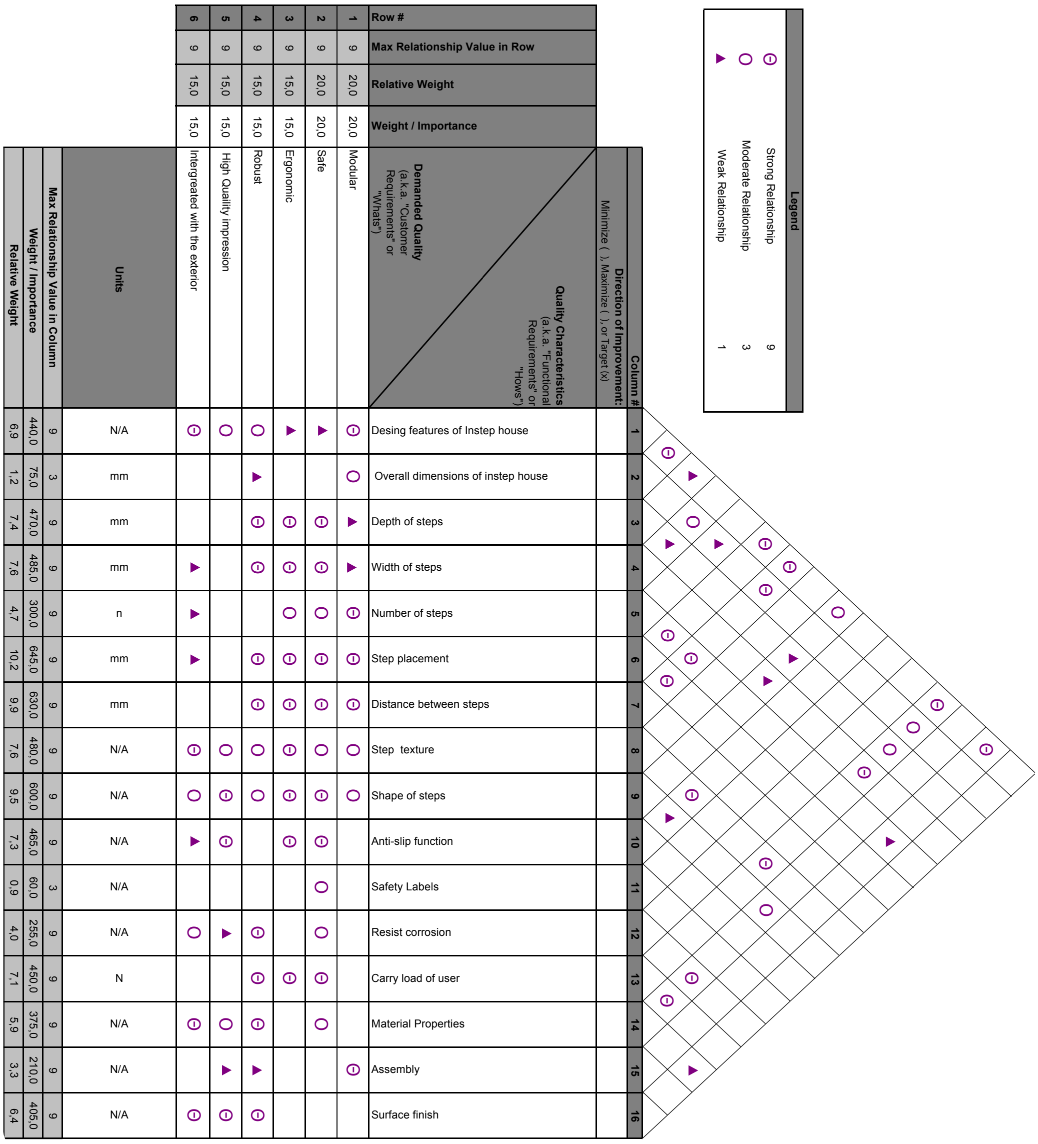


Figure A4-1 QFD-Chart

Appendix 5 Step concept test

The tests of the step concepts are carried out with a total of 7 different test persons including 3 vehicle ergonomists within the Scania R&D department. The step placements are carried out according to the EU-Directive for truck insteps. This is a summary of the test results. Supporting video recording is available in the media appendix A10.

Delimitation

The prototypes are in simple shapes just to be able to try the validity of the principles.

Test Analysis

The analysis of the principle step concepts manufactured in wood aims is to confirm the steps function and height placement.

Concept 1 "Positive Wave"

Test data

- *Step with: 300 mm*
- *Upper step depth: 200 mm*
- *Lower step depth: 250 mm*
- *Distance between steps: 340 mm (not changeable)*
- *Lower step height: 360 mm*

The "Positive Wave" concept is a very fine ergonomic design entering the cab; the steps offer a good stair feeling with a good visibility of the step edges from the cab. See figure A5-1.

The problem with the design is that the ingress and egress process is completely opposite. The design concept requires the user to place the foot that is positioned away from the steps (the right foot on the driver side and the left on the passage side) first to be able to exit the cab. The safety issue is the empty space above the lower step and the upper step, if the user accidently places the foot in the gap exiting the cab it can result in a severe accident

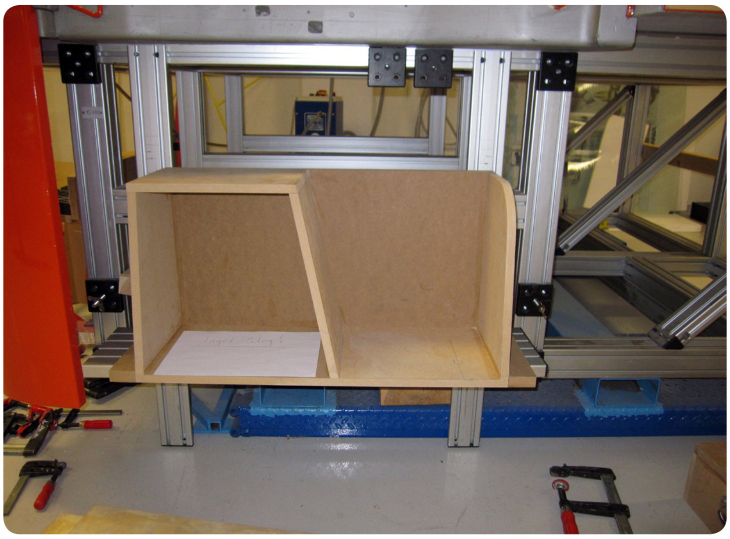


Figure A5-1 The Positive Wave test

Concept 2 “Negative wave”

Test data

- *Step width: 340 mm*
- *Upper step depth: 200 mm*
- *Lower step depth: 250 mm*
- *Distance between steps: 340 mm (not changeable)*
- *Lower step height: 360 mm*

The analysis of the “Negative Wave” concept makes it obvious that it is a bad ergonomic and unsafe solution. The angle between the steps creates a narrow passage; the result is that it is hard to put the right foot on the cab floor comfortably entering the cab. The narrow step clearance makes it hard to place the foot on the lower step exiting the cab. “The Negative Wave” concept also has the same problem as the “Positive Wave” concept with the complete opposite entering and exiting process. The risk is that the user can accidently place the foot in the gap trying to exit the cab, which can result in a severe accident.

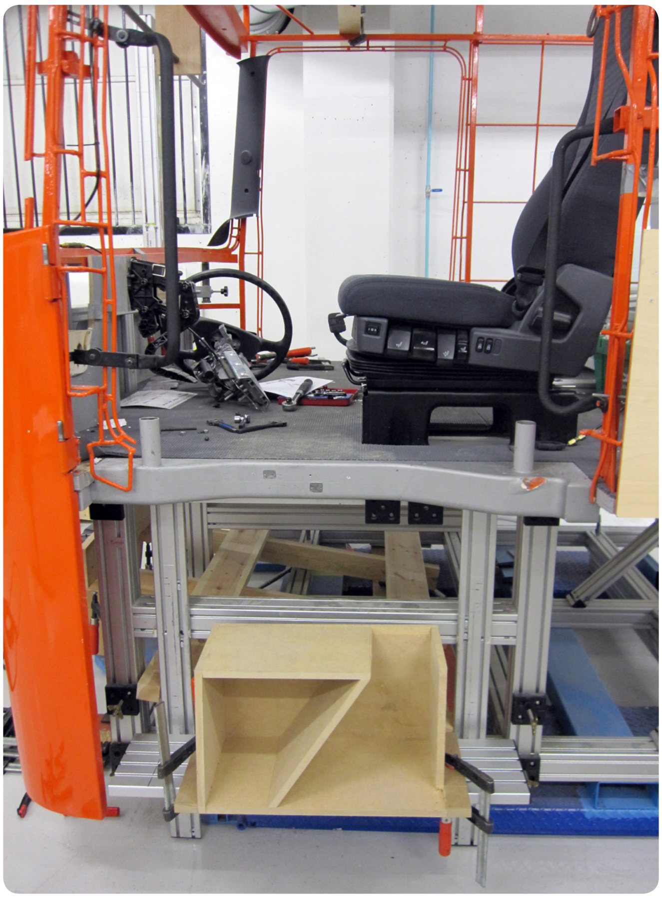


Figure A5-2 The Negative Wave test

Concept 3 “Wedge”

Test data

- *Total step width: 680 mm*
- *Upper step depth: 100-200 mm*
- *Lower step depth: 250-200 mm*
- *Distance between steps and cab floor: 300, 310,320,330,340,350,360,400 mm*

The “wedge” concept offers a comfortable step with a good stair feeling entering the cab. The design offers good shin clearance entering the cab. But exiting the cab the lower step is hidden by the wedge shaped upper step. That makes it hard to walk out. The width of the upper step feels a bit narrow while entering the cab.

The best placement of the steps is an equal spaced distance between the steps and the cab floor.

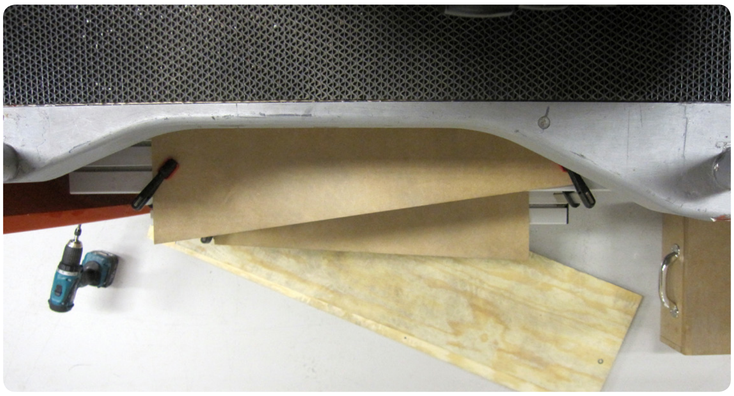


Figure A5-3 Wedge test

Concept 4 “Inverted wedge”

Test data

- *Total step width: 680 mm*
- *Upper step depth: 100-200 mm*
- *Lower step depth: 250-200 mm*
- *Distance between steps and cab floor: 300, 310,320,330,340,350,360,400 mm*

The “Inverted wedge” concept offers a comfortable step with a good stair feeling specially exiting the cab because of the good shin clearance the inverted wedge offers. The width of the upper step feels good both entering and exiting the cab. In general the concept is a working solution.

The best placement of the steps is an equal spaced distance between the steps and the cab floor.

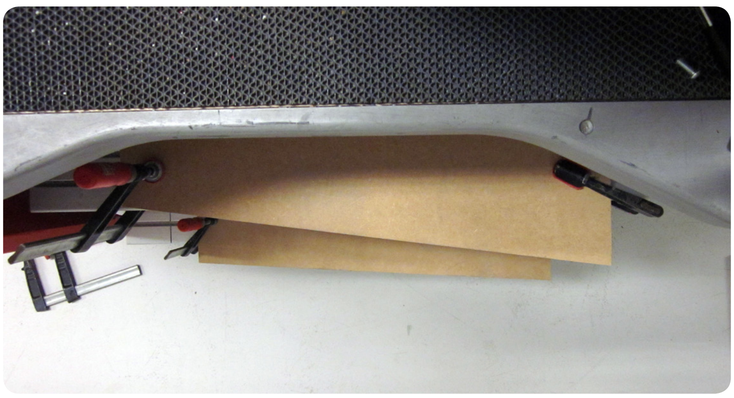


Figure A5-4 Inverted Wedge test

Concept 5 “Double step”

Test data

- *Total step width: 680 mm*
- *Upper step depth: 100, 150, 180, 200 mm*
- *Lower step depth: 250, 278 mm*
- *Distance between steps and cab floor: 300,310,320,330,340,350,360,400 mm*

The aim of the “Double Step” concept test is to test different widths and heights of the steps to find the most comfortable solution possible.

The conclusion of the double step concept test is that an equal spaced distance of 300-340 mm with a step gradient angle (α) of maximum 75° offers the best ergonomic entering and exiting the truck. The minimum depth of the upper step to offer a good ergonomic solution is 150 mm.

It is hard to reach the upper step as a single instep in kneeling position.

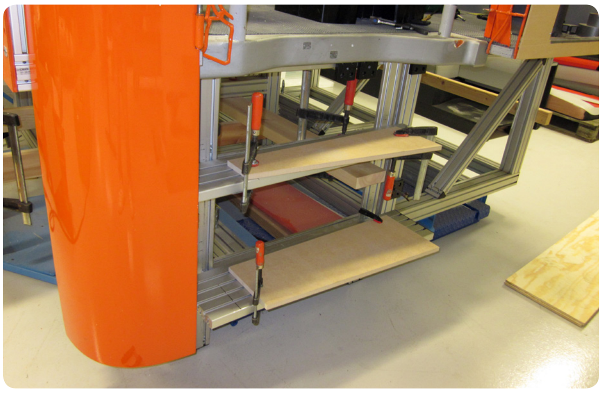


Figure A5-5 Double step test

Concept 6 “Double wave”

Test data

- *Step width: 680 mm*
- *Upper step depth: 200 mm*
- *Lower step depth: 250 mm*
- *Distance between steps: 400 / 200 mm*
- *Lower step height: 360 mm*

The test of concept 6 design illustrate that the concept is not ergonomic and it is confusing how the steps are supposed to be used both entering and exiting the cab.

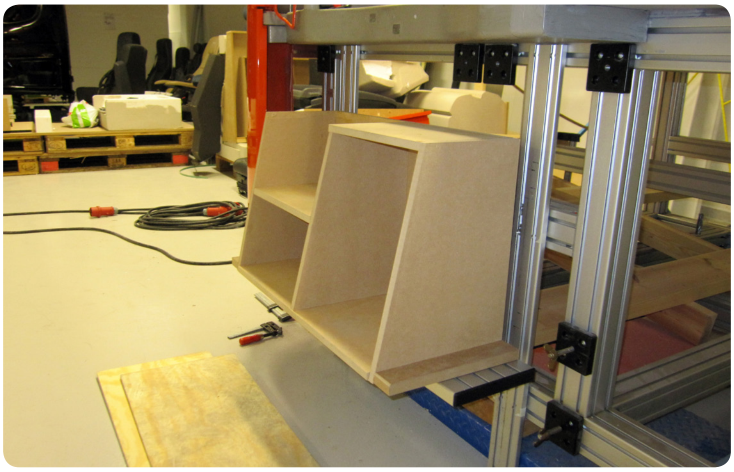


Figure A5-6 Double Wave test

Single instep test

Test data

- *Step width: 680 mm*
- *Step depth: 200 mm*
- *Distance between step and cab floor: 400 mm*
- *First Step height: (kneeling) 485, 450, 400 mm*

The test with a single instep demonstrates that it is not an ergonomic solution with the current cab floor height of 885 mm even in kneeling position. The user needs to put a lot of extra strain on knees and hips with a single instep.

The legal distance from the step to the ground is 450 mm. Even 450 mm requires the user to put a lot of extra strain on knees and hips entering and exiting the cab. A step height of 400 works very well as a single step.

Concept X "Combined"

Test data

- *Total step width: 680 mm*
- *Upper step depth: 200 -100 mm*
- *Lower step depth: 278 -200 mm*

The concept X test shows that the concept is an ergonomic solution. The advantages from the "Wave" concept allow a stair feeling entering the cab. The wedge shape gives the user good visibility of the lower step. With a step gradient of 75º it as an effortless walk out of the cab.

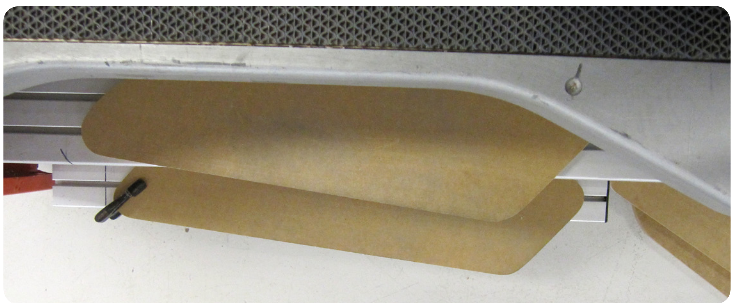


Figure A5-7 Concept X test

Appendix 6 “Future concepts”

The “future concepts” is a diversion from the purpose of the project. These suggestions have been done in a short time on the instep part without considering the Scania´s modular system’s limitations, without any deep study on details or cost consideration to discover what has to be changed to provide new possibilities.

Prerequisites for the concept

The concept is a single step solution, which requires Scania to lower the cab to at least 800 mm in kneeling position while the kneeling function is much quicker than the existing one.

A suggestion is to trigger the kneeling function only on the parking brake. The advantage of having the kneeling triggered on the parking brake is that the cab kneels as soon as the parking brake is applied, and the truck will always be in the kneeling position entering the cab. To speed up the actual kneeling process, the air suspension can be designed with bigger blow out pipes.

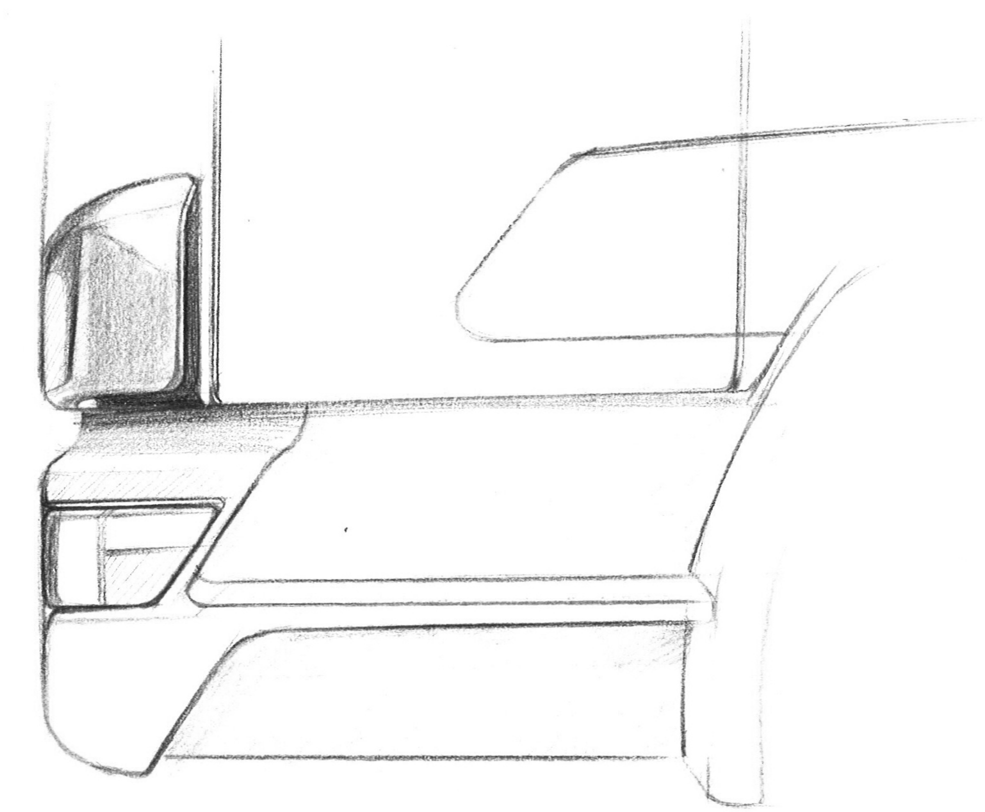


Figure A6-1 Future single step Concept

The instep is well integrated with the exterior with smooth lines and curves of plastic following the cab’s exterior design.

The step is made of an open waved texture that lets through water and dirt. The single instep allows an effortless ingress and egress of the cab.

The user would be able to walk in and out of the cab naturally, with an equal 400 mm distance between the step and the floor relative to the ground.

The reason for not doing a "cut in" step as the competitors is that it is very expensive. It requires cutting the main support beam between the A- pillar and the B- pillar of the whole cab floor. Another disadvantage of a "cut in" is that it will be a narrower instep and it will require a new door that covers the instep cut in.

Appendix 7 "Add-on 45°"

The "add-on" 45° concept developed before the issues with the APS coil were discovered.

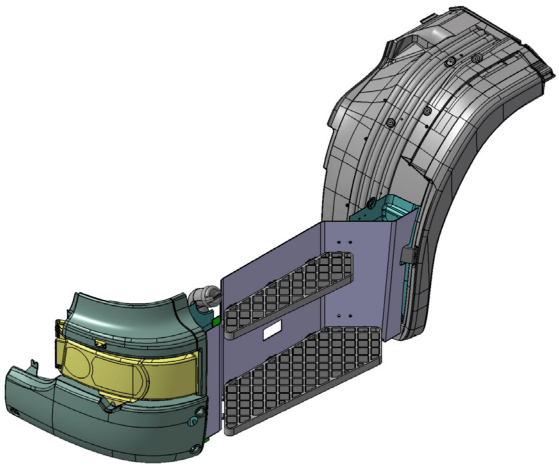


Figure A7-1 Add-on 45° ISO view

The step well plate is bent 45° with a small tilted angle on the lower plate edges to follow the shape of the bumper. The bracket for mounting the step well plate to the truck, were originally developed for the 45° angle. Later, it was adopted to fit the 50° concept. See figure A7-2.

Figure A7-2 45° Brackets 45º Steps

The 45º angle steps are placed in an equal distance of 320 between the cab floor and the steps with an overlap of 100 mm. The placement offers a step gradient angle (α) of 72.6º. The existing instep offers a step gradient angle (α) of 81º. The minimum angle is 85º. See figure A7-3.

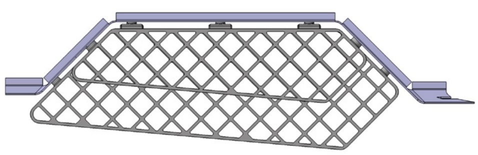


Figure A7-3 45º Step overlap

The lower step's height from the ground is approximately 370 mm in driving position and 245 mm while kneeled. The rectangular patterns on both steps are 40 square mm at the angle of 45° against the inner edge of the step.

45° Upper step

The upper step's maximum depth is 165 mm and the minimum depth is 110 mm. The step's length is 680 mm. The upper step fulfills the standards regarding the step size of a minimum foothold of 150 mm in depth and 300 mm in step width.

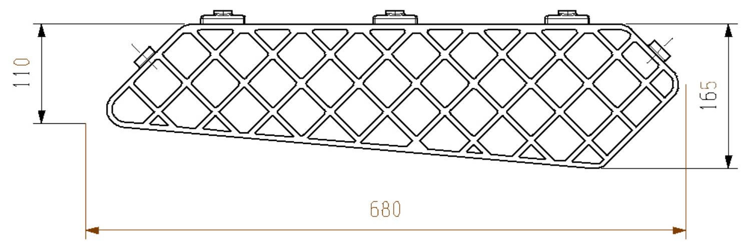


Figure A7- 4 45° Upper step overall dimension, 40x40mm

- *Thickness: 30 mm*
- *Weight: 2.3 Kg*

45° Lower step

The lower step's maximum depth is 265 mm and the minimum depth is 210 mm. The step's length is 845 mm. The lower step outer edge is at the position of the maximum vehicle width of 2500 mm, with a 10 mm tolerance.

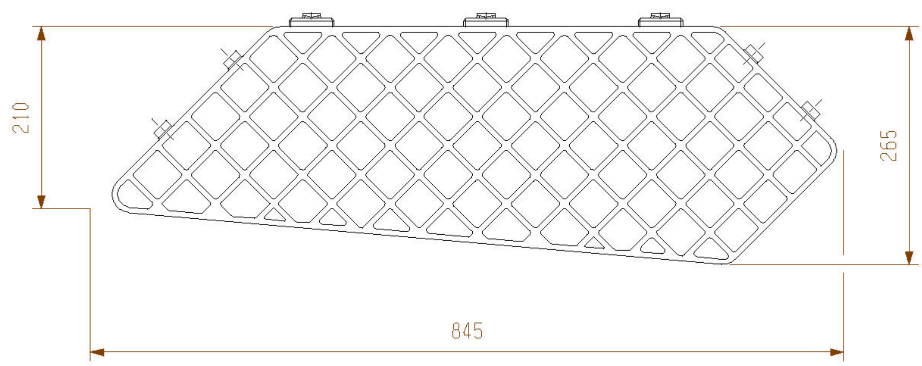


Figure A7-5 45° Lower step overall dimension, 40x40

- *Thickness: 30 mm*
- *Weight: 4.0 Kg*

Appendix 8 Design calculations

Step Gradient angle

The angle between steps or gradient angles (α) is a line drawn from the nose of one step to the nose of adjacent step. The commercial vehicle regulation states that the maximum step gradient angle is 85°.

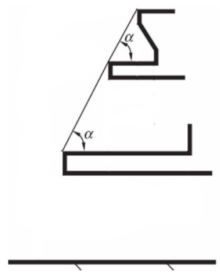


Figure A8-1 Step Gradient α (25)

α= arctan(h/ l) (A8-1)

New design

- *h = distance between steps: 320 mm*
- *l = step overlap: 90 mm*
- *Equation A8-1 gives a step gradient angle of 74.3°.*
- *Existing LowEntry instep*
- *h = distance between steps: 318 mm*
- *l = step overlap: 50 mm*
- *Equation A8-1 gives a step gradient angle of 81°.*

Spot welding design

- *The spot welds on the front and rear instep-brackets are designed according to the Scania standard STD725.*

Dimensioning of spot weld

- *Cut standard bracket; t = 1.75 mm*
- *Rear and Front instep-bracket; t = 2.5 mm*
- *Bracket Front L: 78 and 34 mm => (L/2): 36 and 17 mm*
- *Bracket Rear L: 80 and 37 mm => (L/2): 40 and 18.5 mm*

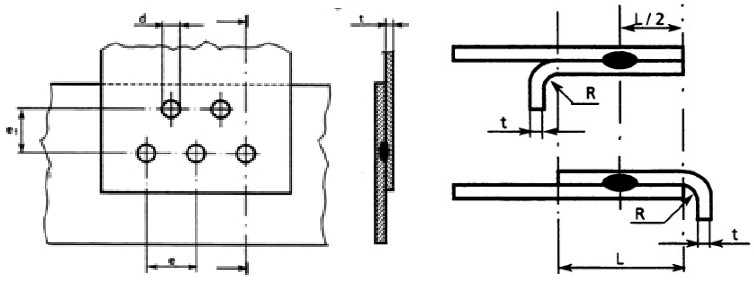


Figure A8-2 Designations

- *t = thickness of thinnest sheet (max sheet ratio 2:1)*
- *d = spot weld diameter*
- *e = spot weld pitch*
- *e1 = rows distance*
- *L = overlap*

When welding sheets with different thicknesses of the welding sheets; the weld nugget diameter should be adapted to the thinner sheet and the flange width and spacing to the thickest sheet.

t mm	L min mm	e mm	e_1 mm	d mm
1,5	16	35	30	6
2	18	40	35	7
2,5	20	45	40	8
3	22	50	43	9

Table A8-1 Design of spot welds

Ultimate shear strength (in Newton) of the spot weld is determined approximately by:

$$F_s = K_1 \, t \, d \, \sigma_T \tag{A8-2}$$

The tensile strength (in Newton) follows the expression:

$$\sigma_T = K_2 \, F_s \tag{A8-3}$$

σT N/mm²	K1	K2
290-360	2,9	0,7
360-410	2,9	0,35
400-500	1,7	0,15
500-600	1,3	0,12

Table A8-2 Strength coefficients

According to the equation A8-2 and A8-3 the spot welds design for selected Carbon Steel: SS-EN 10268 HC260LA.

- *Tensile strength: 350-430 MPa*
- *Yield Strength: 260-330 MPa*
- *Ultimate sheer force: 14200 N*
- *Tensile Strength: 4970 N*

Bolted connection

It is an evaluation of the sheer stress applied on the bolted connections. The force P is set to 3 KN.

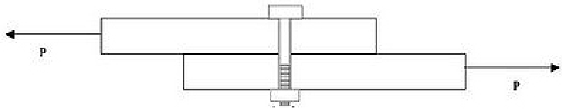


Figure A8-3 Illustration bolted connection

Where X is number of bolts.

$$\tau = P / (x \cdot A_{bolt}) \quad \text{(A8-4)}$$

Equations A8-4 and A8-4 for M8 bolts gives:

$$A_{bolt} = \pi r^2 \quad \text{(A8-5)}$$

Side brackets

- *A sheer stress of 60 MPa.*

Instep Brackets

- *A sheer stress of 10 MPa.*
- *The bolted connection is robust.*

FEM simulations

The FEM simulations are carried out with CATIA V5´s Generative Structure Analysis feature.

The design load simulates a driver stepping into or out of the cab. It is a static load and its direction is parallel to the gravity axis. It is applied to the most critical spots of the concept. The instep is required to withstand 75000 load cycles which implies; the stresses due to the load is not allowed to exceed the yield limit of the material.

The concept is required to withstand 180 kg load at the weakest point. The FEM simulations on the steps are carried out with a load of 250 kg.

Steps

The steps are clamped at the connection holes, simulated screwed to the step well plate. The simulation is carried out with an Octree Tetrahedron Mesh with a parabolic element size of 5 mm SAG 0.25 mm and a local mesh size of 2 mm. The anti-slip surfaces are negligible due to meshing complexity.

Upper step

The main stress occurs around the side connections with a maximum Von Mises stress of 14.7 MPa, with a factor of safety of 13 to the Yield strength. See figure A8-4.

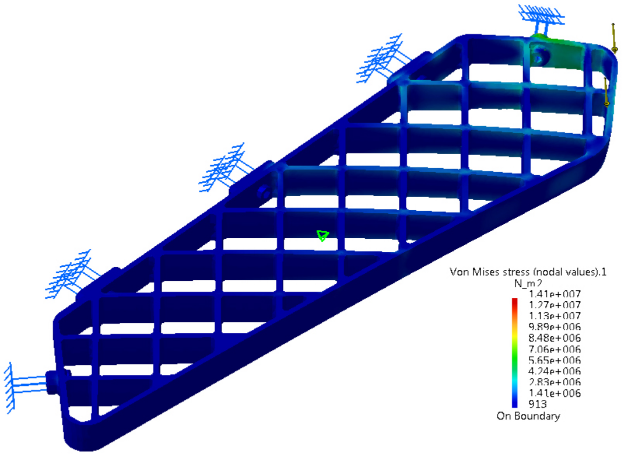


Figure A8-4 Von Mises Stresses upper step

The double diagonal bracing does the step very stiff. That results in a minor deflection of only 0.06 mm. See figure A8-5.

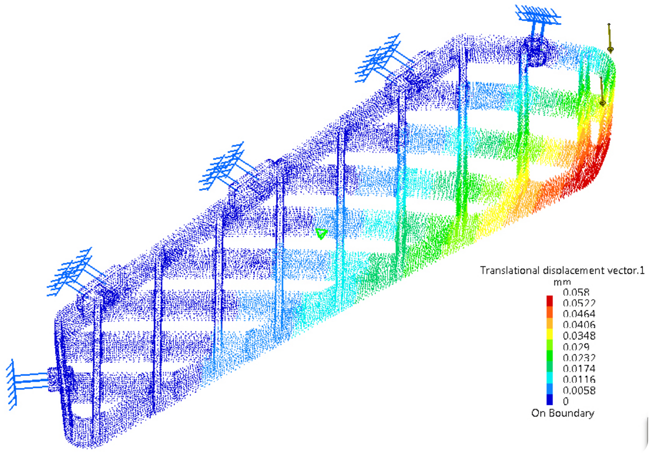


Figure A8-5 Displacement upper step

Lower step

The maximum Von Mises tress is 25.5 MPa, a factor of safety of 7.5 to the yield strength. See figure A8-6

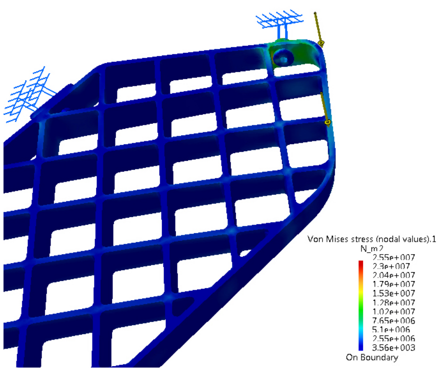


Figure A8-6 Von Mises Stress Lower step

Maximum deflection on the lower step due to the design load is 0.15 mm which is negligible. See figure A8-7.

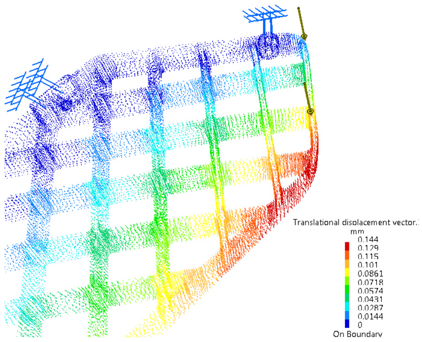


Figure A8-7 Displacement Lower step

Step well

Due to meshing complexity the steps are replaced with a plain step surface without any pattern. The steps connection points are the same as the actual steps. The steps and the brackets are rigged connection property to simulate the bolted connections. The instep and side brackets are clamped on the flanges to simulate the cut standard bracket connections. The simulation is carried out with an Octree Tetrahedron Mesh with a parabolic element size of 5 mm SAG 0.25 mm on the step well plate and size of 10 mm with 1 mm SAG on the brackets and the steps.

The maximum Von Mises stress occurs at the step connection points, where the maximum stress is 28 MPa a factor of safety of 9 to the yield limit. See figure A8-8 and A8-9.

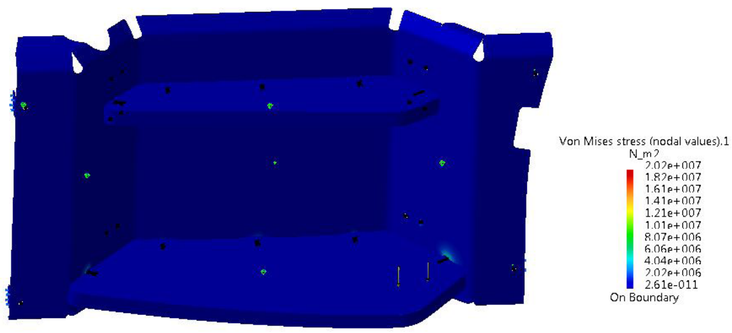


Figure A8-8 Instep house Von Mises stress

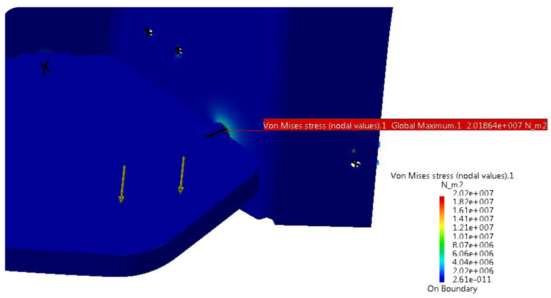


Figure A8-9 Step well Von Mises stress close up

The displacement of the step well is very small. The maximum deflection is 0.065 mm.

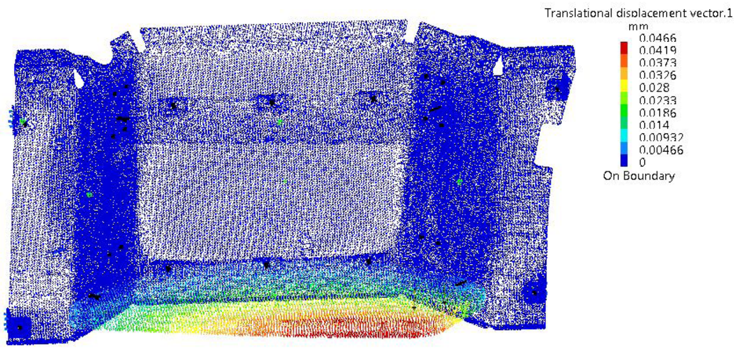


Figure A8-10 Step well displacements

Instep bracket
The simulation is carried out with an assumption load of total 3000 N, distributed on the holes. The inner flange is clamped to simulate mount to the cut standard bracket. The simulation is carried out with an Octree Tetrahedron Mesh with a parabolic element. Size 5 mm SAG 0.25 mm and a local mesh size of 2 mm.

The maximum Von Mises Stress is 44.6 MPa in holes, a factor of safety of 5.8 to the yield strength. The maximum displacement is insignificant. See figure A8-11.

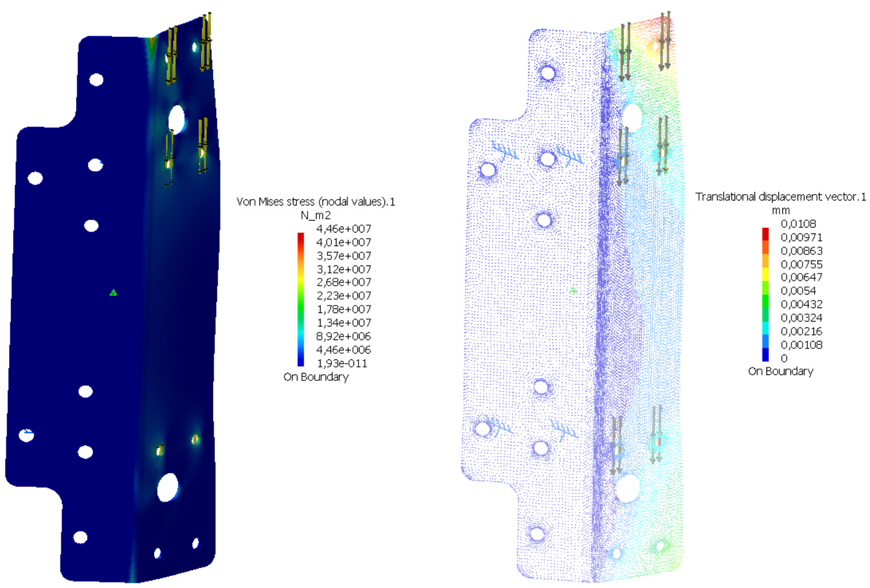


Figure A8-11 Instep bracket Von Mises stress & Displacements

Side bracket
The simulation is carried out with an assumption load of 2000 N, distributed on the holes. The inner flange is clamped to simulate mount to the cut standard bracket. The simulation is carried out with an Octree Tetrahedron Mesh with a parabolic element. Size 2 mm SAG 0.1 mm and a local mesh size of 2 mm.
The maximum Von Mises stress 15.8 MPa occurs at the upper bend angle. See figure A8-12.

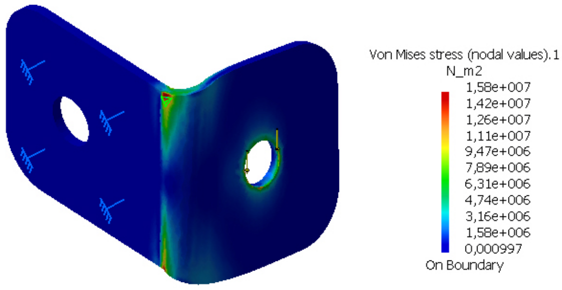


Figure A8-12 Side bracket Von Mises Stress

The displacement of the side brackets is minimal. See figure A8-13.

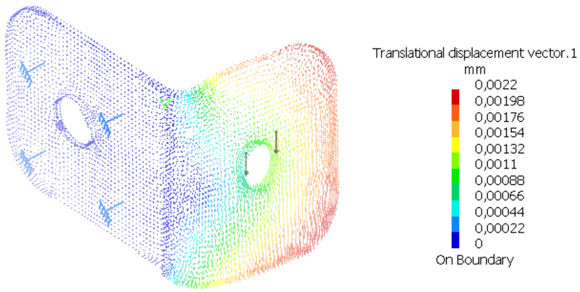
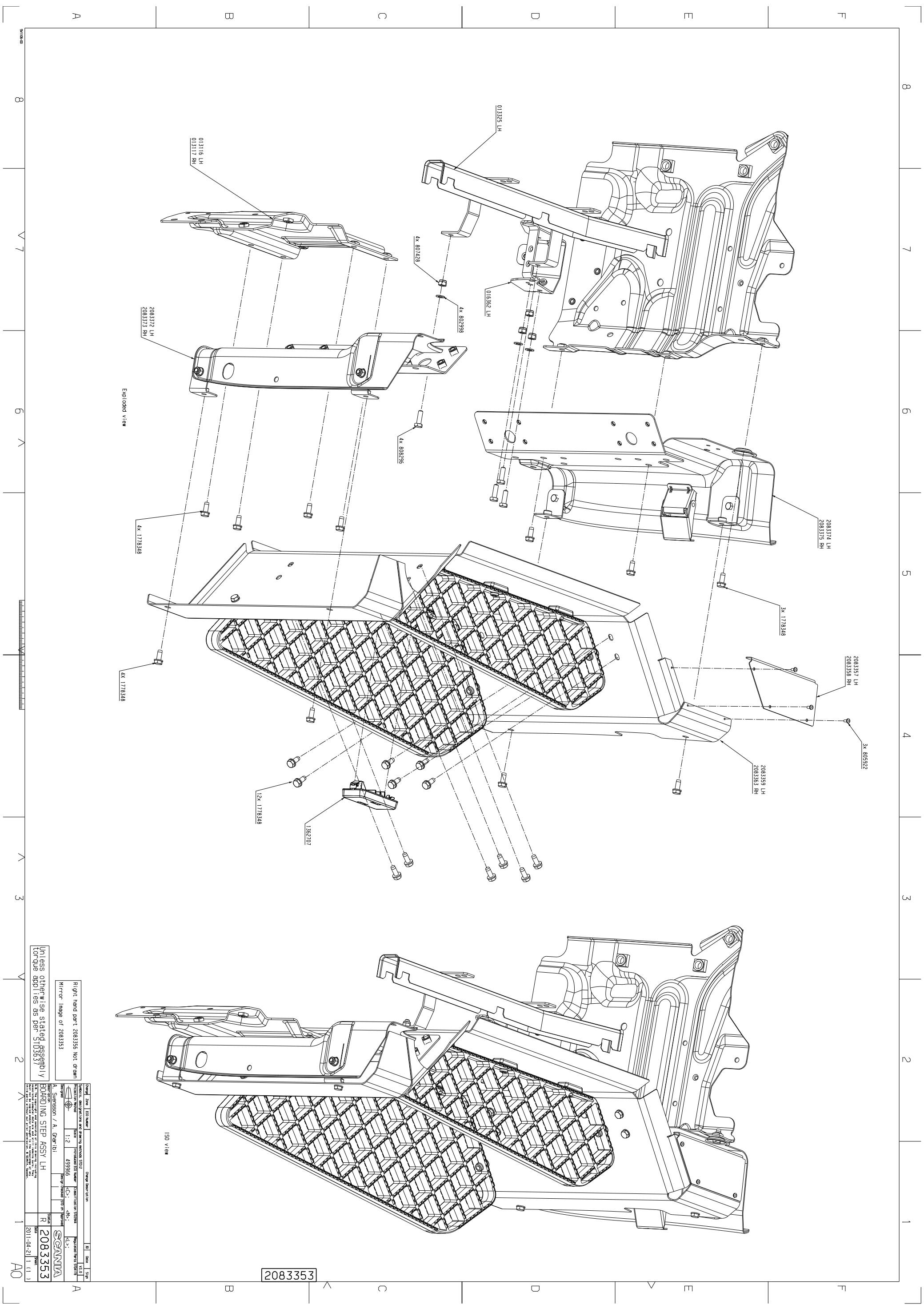


Figure A8-13 Displacement Side bracket

Appendix 9 Drawings

The design consists of following drawings available in the appendix and in Scania´s Drawing archive.

Article	Denomination
2083353	Boarding step assy LH
2083356	Boarding step assy RH
2083357	Cover rear LH
2083358	Cover rear RH
2083359	Plate boarding step assy LH
2083363	Plate boarding step assy RH
2083364	Plate boarding step LH
2083366	Plate boarding step RH
2083370	Step plate upper
2083371	Step plate lower
2083372	Boarding step structure front assy LH
2083373	Boarding step structure front assy RH
2083374	Boarding step structure rear assy LH
2083375	Boarding step structure rear assy RH
2083376	Bracket
2083377	Bracket
2083381	Cut dwg boarding step plate
2083382	Boarding structure front LH
2083383	Boarding structure front RH
2083384	Boarding structure rear LH
2083385	Boarding structure rear RH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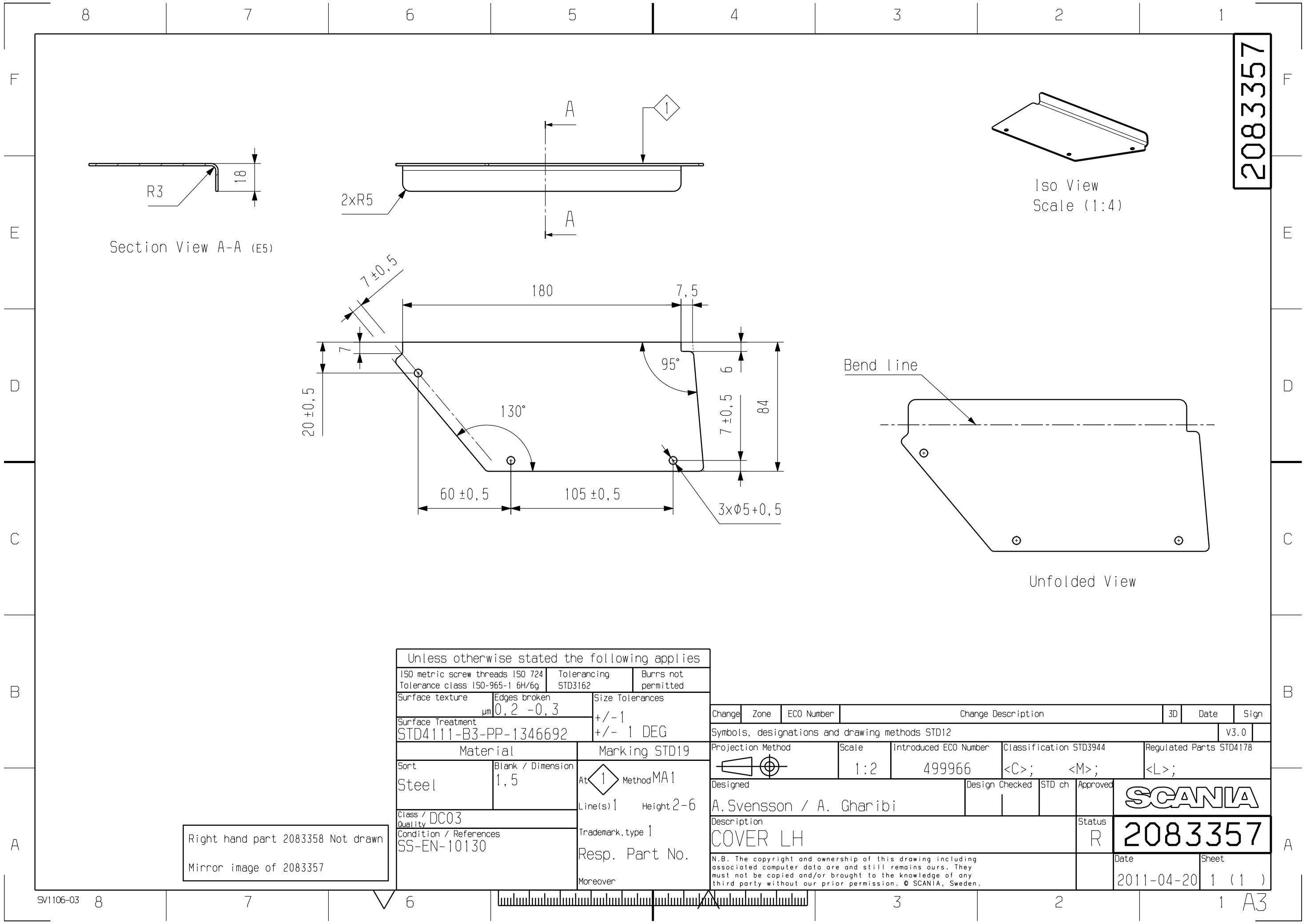
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Section View A-A (E5)
R3
18
2xR5
A
A
1
Iso View
Scale (1:4)
180
7,5
7 ±0,5
7
20 ±0,5
95°
130°
6
7 ±0,5
84
60 ±0,5
105 ±0,5
3xΦ5+0,5
Bend line
Unfolded View
Unless otherwise stated the following applies
ISO metric screw threads ISO 724
Tolerance class ISO-965-1 6H/6g
Tolerancing STD3162
Burrs not permitted
Surface texture µm
Edges broken 0,2 -0,3
Size Tolerances +/-1 +/- 1 DEG
Surface Treatment STD4111-B3-PP-1346692
Material
Sort Steel
Blank / Dimension 1,5
Class / Quality DC03
Condition / References SS-EN-10130
Marking STD19
At 1 Method MA1
Line(s) 1 Height 2-6
Trademark, type 1
Resp. Part No.
Moreover
Right hand part 2083358 Not drawn
Mirror image of 2083357
Change Zone ECO Number Change Description 3D Date Sign
Symbols, designations and drawing methods STD12 V3.0
Projection Method
Scale 1:2
Introduced ECO Number 499966
Classification STD3944 <C>; <M>;
Regulated Parts STD4178 <L>;
Designed A.Svensson / A. Gharibi
Design Checked
STD ch
Approved
SCANIA
Description COVER LH
Status R
2083357
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Date 2011-04-20
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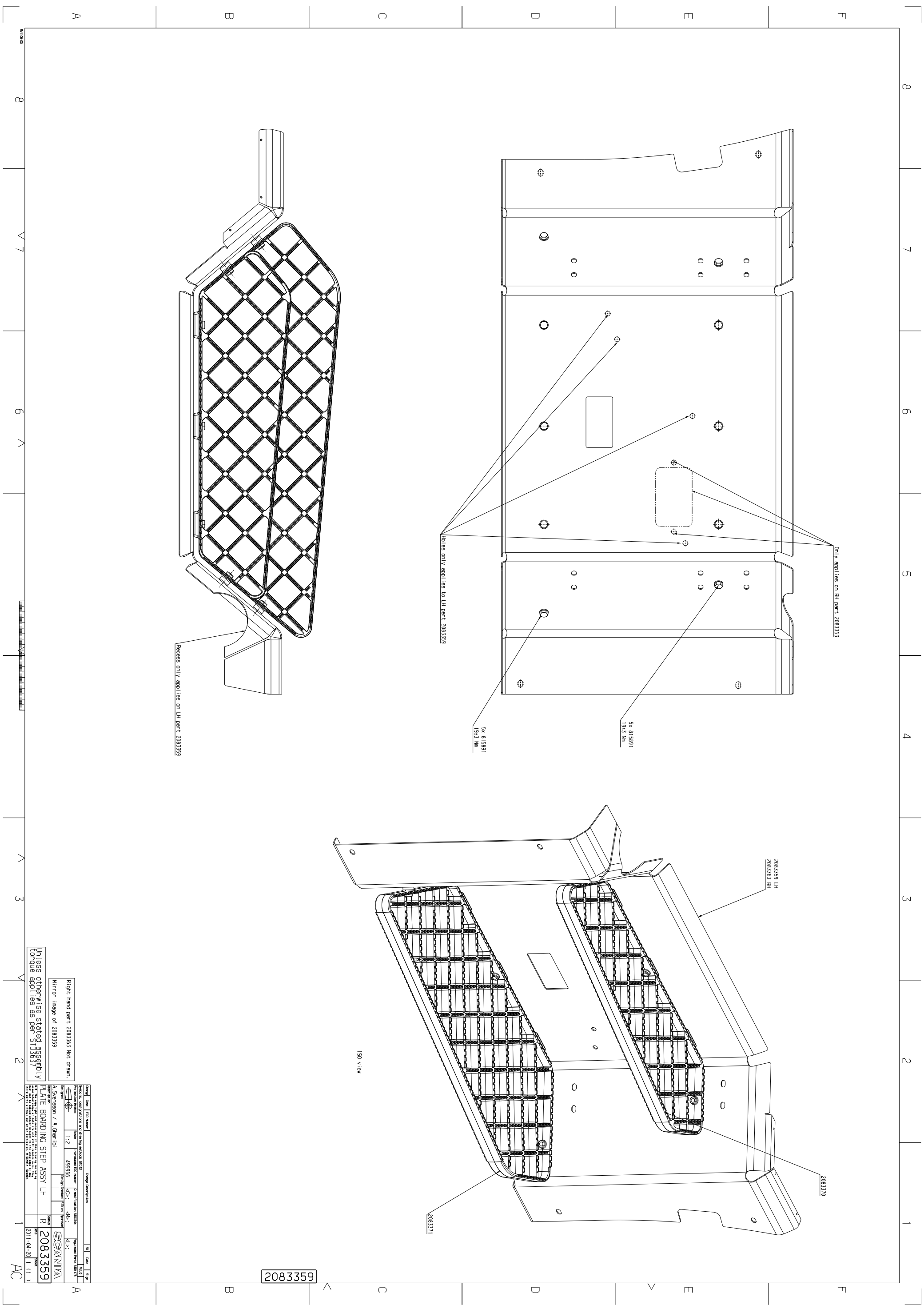
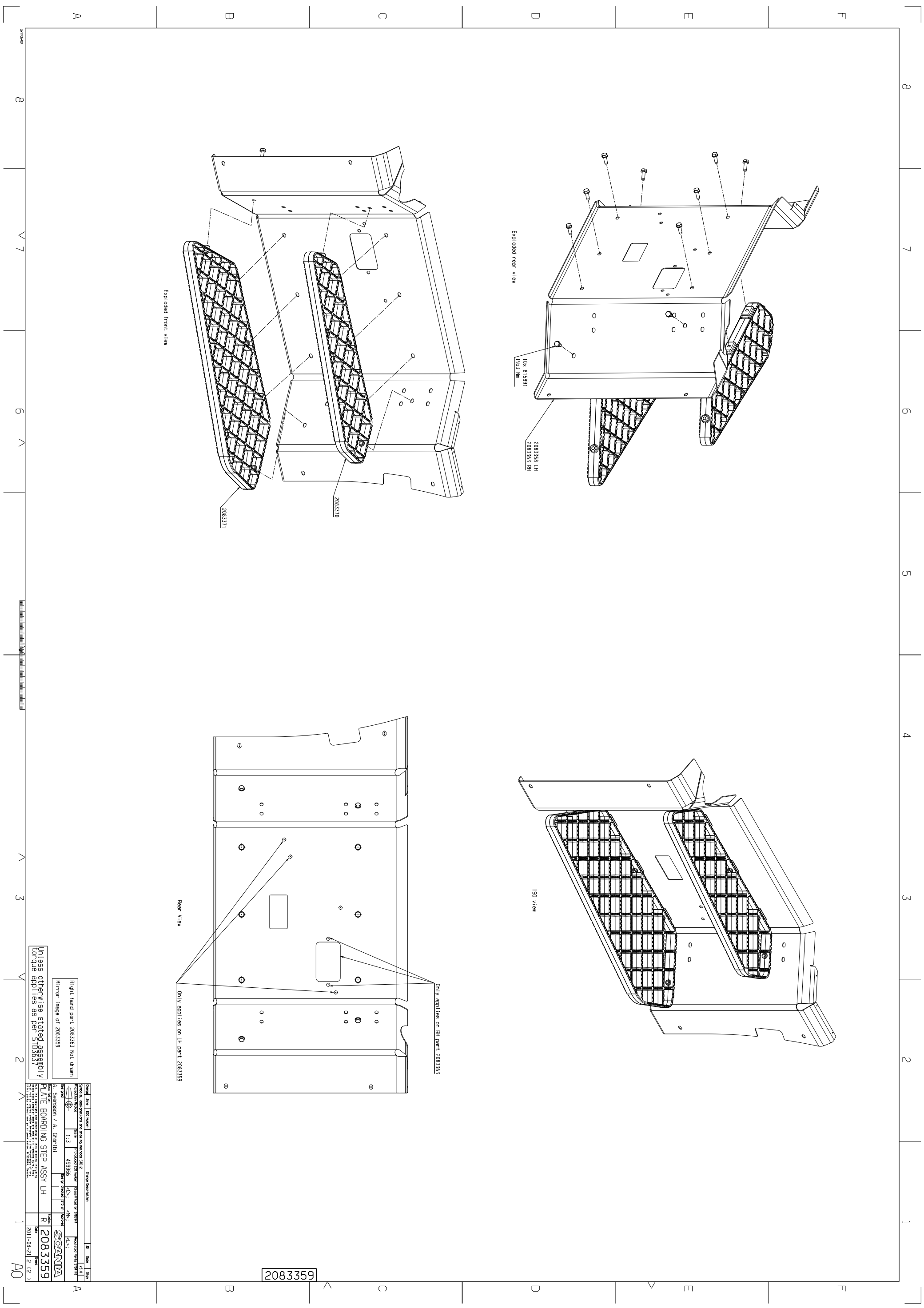

Access only applies on LH part 2083359
Only applies on RH part 2083363
Right hand part 2083363 Not drawn.
Mirror image of 2083359
Unless otherwise stated assembly torque applies as per STD3637
PLATE BOARDING STEP ASSY LH
A.Svensson / A.Gharibi
Scale 1:2
499966
SCANIA
2083359
2011-04-20
A0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Exploded rear view
Rear view
ISO view
PLATE BOARDING STEP ASSY LH
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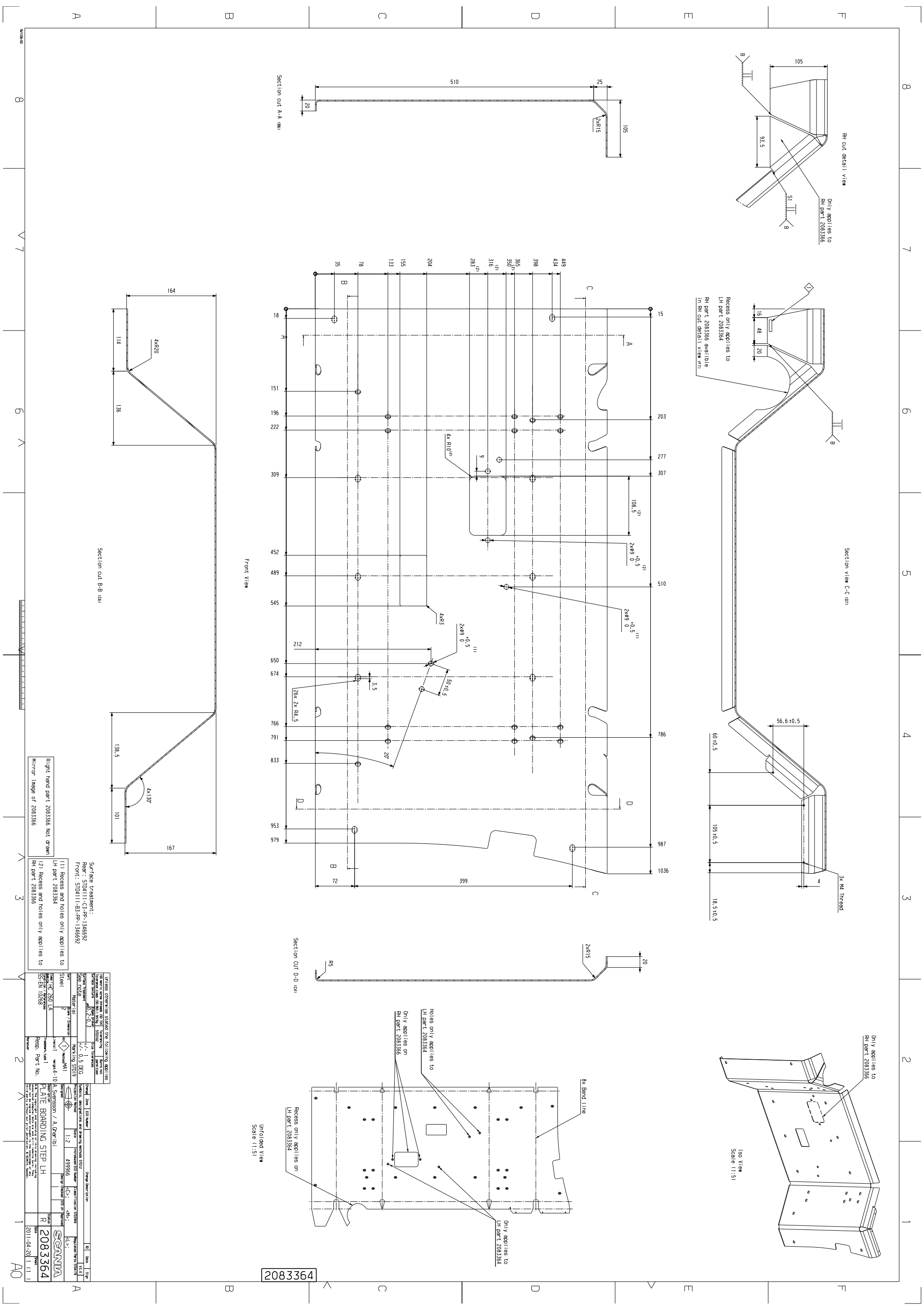
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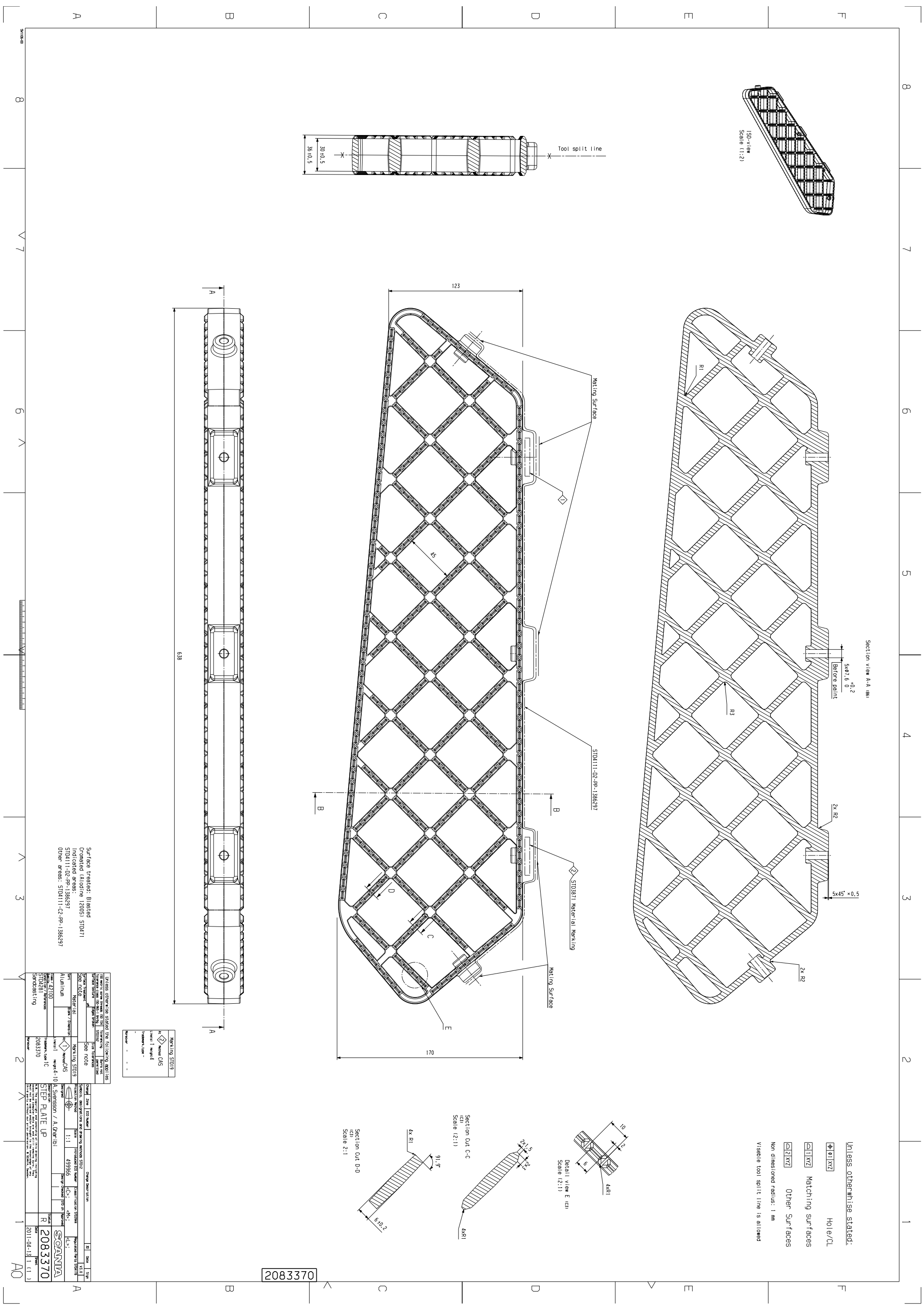

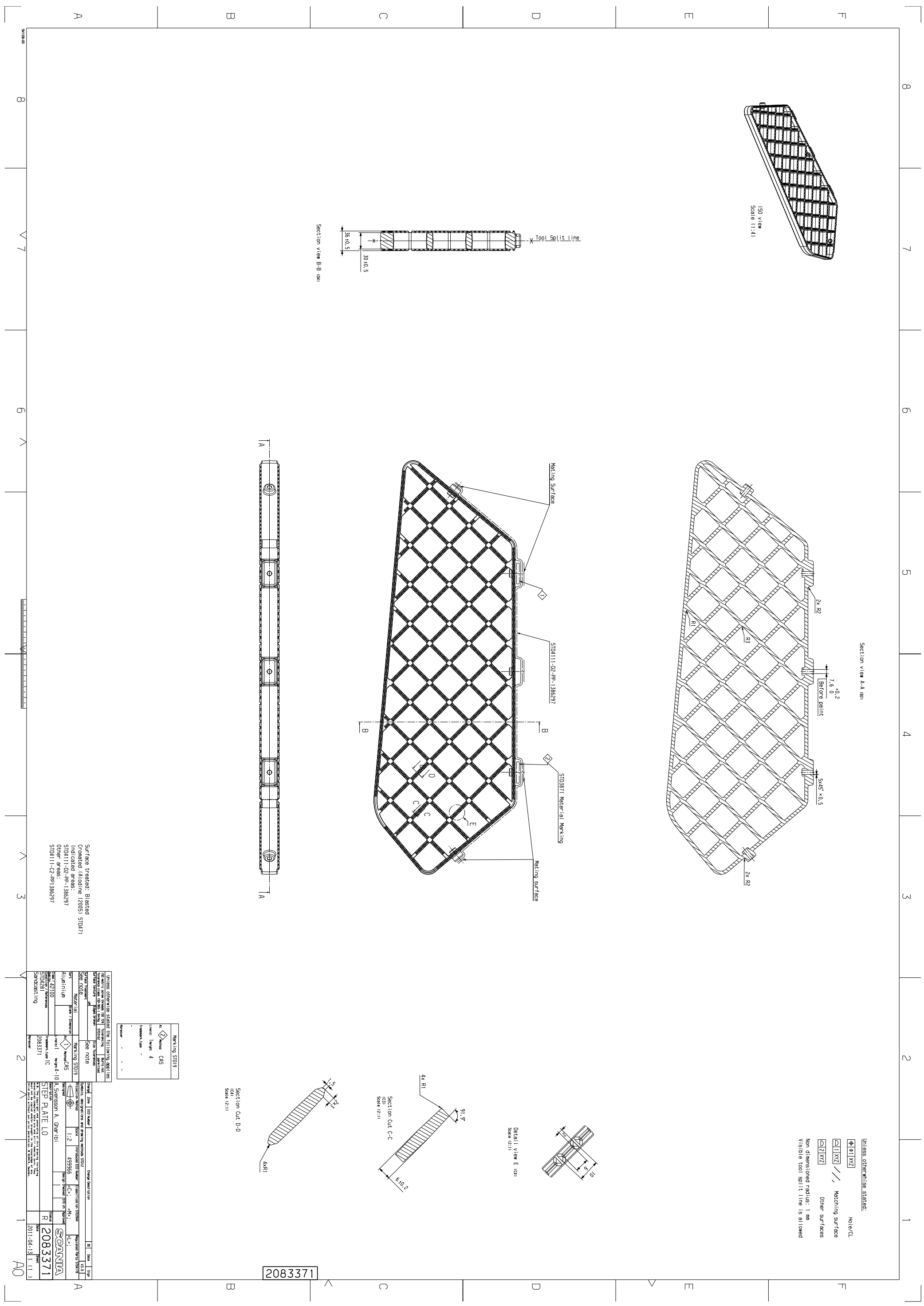
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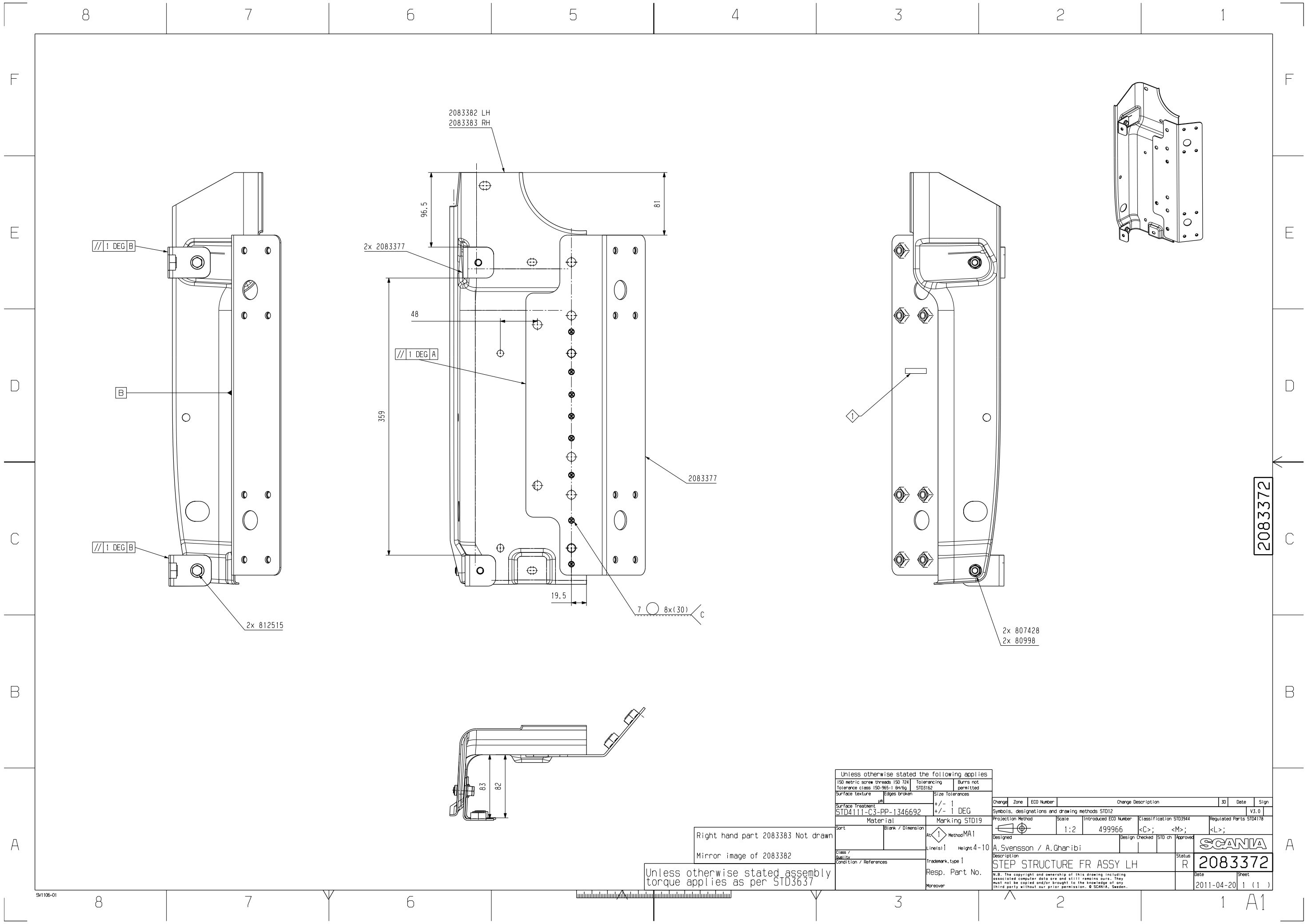
2083382 LH
2083383 RH
96,5
81
2x 2083377
48
// 1 DEG A
359
2083377
19,5
7 8x(30) C
// 1 DEG B
B
// 1 DEG B
2x 812515
2x 807428
2x 80998
83
82
2083372
Right hand part 2083383 Not drawn
Mirror image of 2083382
Unless otherwise stated assembly torque applies as per STD3637
Unless otherwise stated the following applies
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Burrs not permitted
Surface treatment
STD4111-C3-PP-1346692
Size tolerances
+/- 1
+/- 1 DEG
Material
Marking STD19
Method MA1
Height 4-10
Resp. Part No.
Symbols, designations and drawing methods STD12
V3.0
Projection Method
Scale 1:2
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<C>; <M>; <L>;
A.Svensson / A.Gharibi
SCANIA
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R
2083372
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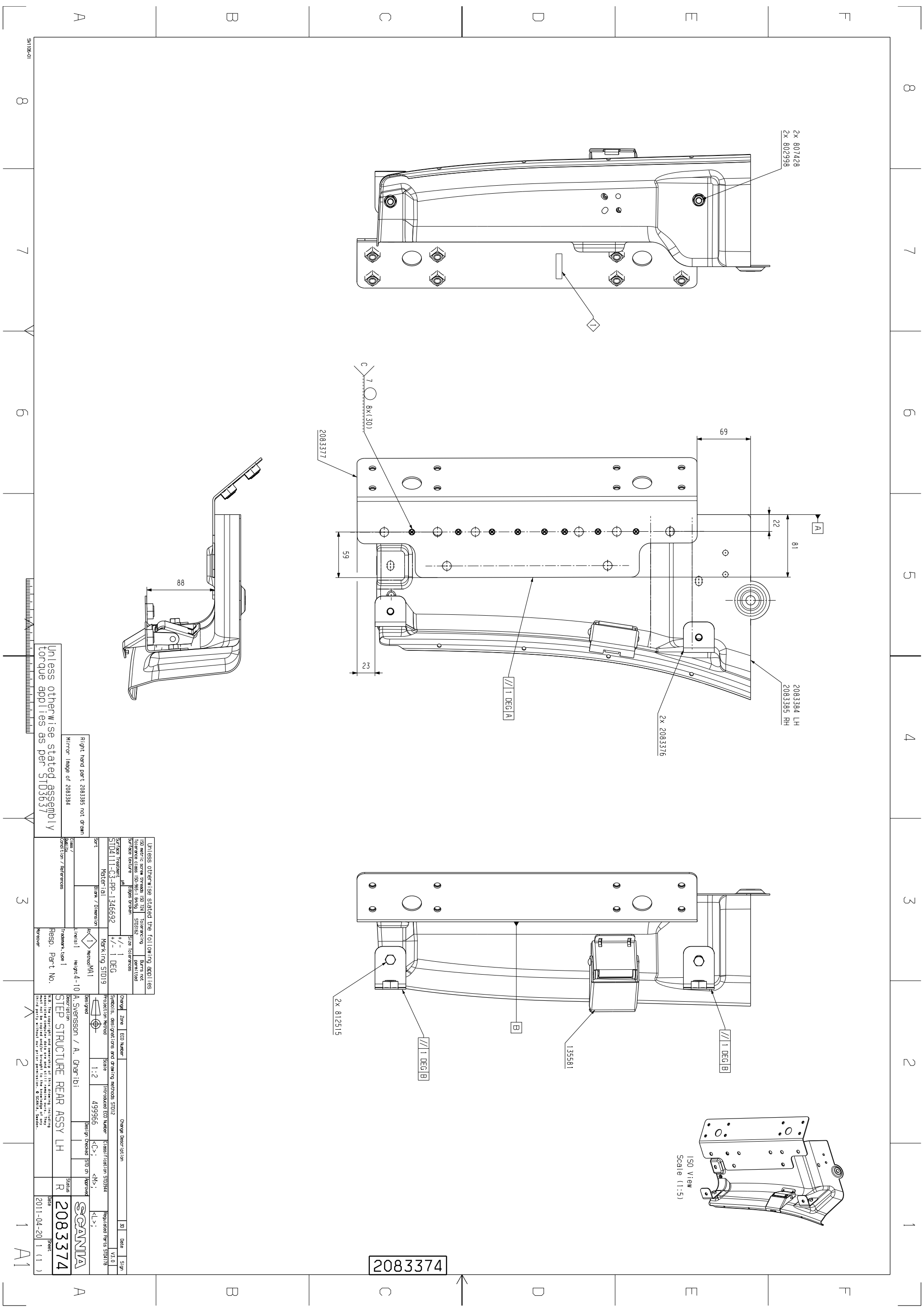
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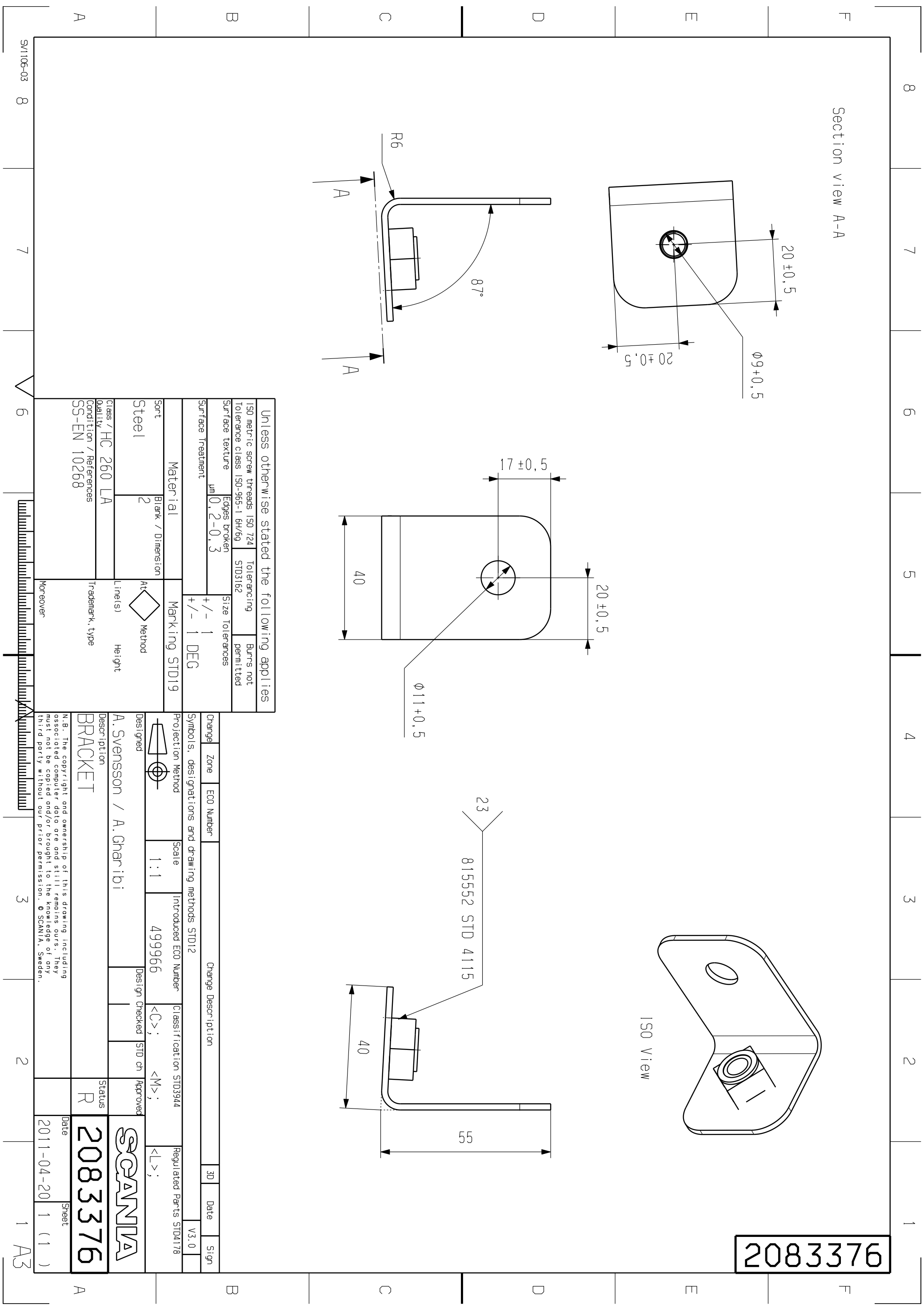
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ISO View
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87°
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20 ±0,5
Φ9+0,5
17 ±0,5
40
20 ±0,5
Φ11+0,5
23
815552 STD 4115
40
55
2083376
Unless otherwise stated the following applies
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Tolerance class ISO-965-1 6H/6g
Tolerancing STD3162
Burrs not permitted
Surface texture
Edges broken 0,2-0,3
Size tolerances +/- 1 +/- 1 DEG
Surface treatment
Material
Marking STD19
Sort Steel
Blank / Dimension 2
Class / Quality HC 260 LA
Condition / References SS-EN 10268
Method
Line(s)
Height
Trademark, type
Moreover
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Projection Method
Scale 1:1
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Regulated Parts STD4178
V3.0
Designed A.Svensson / A.Gharibi
Design Checked
STD ch
Approved
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Status R
SCANIA
2083376
Date 2011-04-20
Sheet 1 (1)
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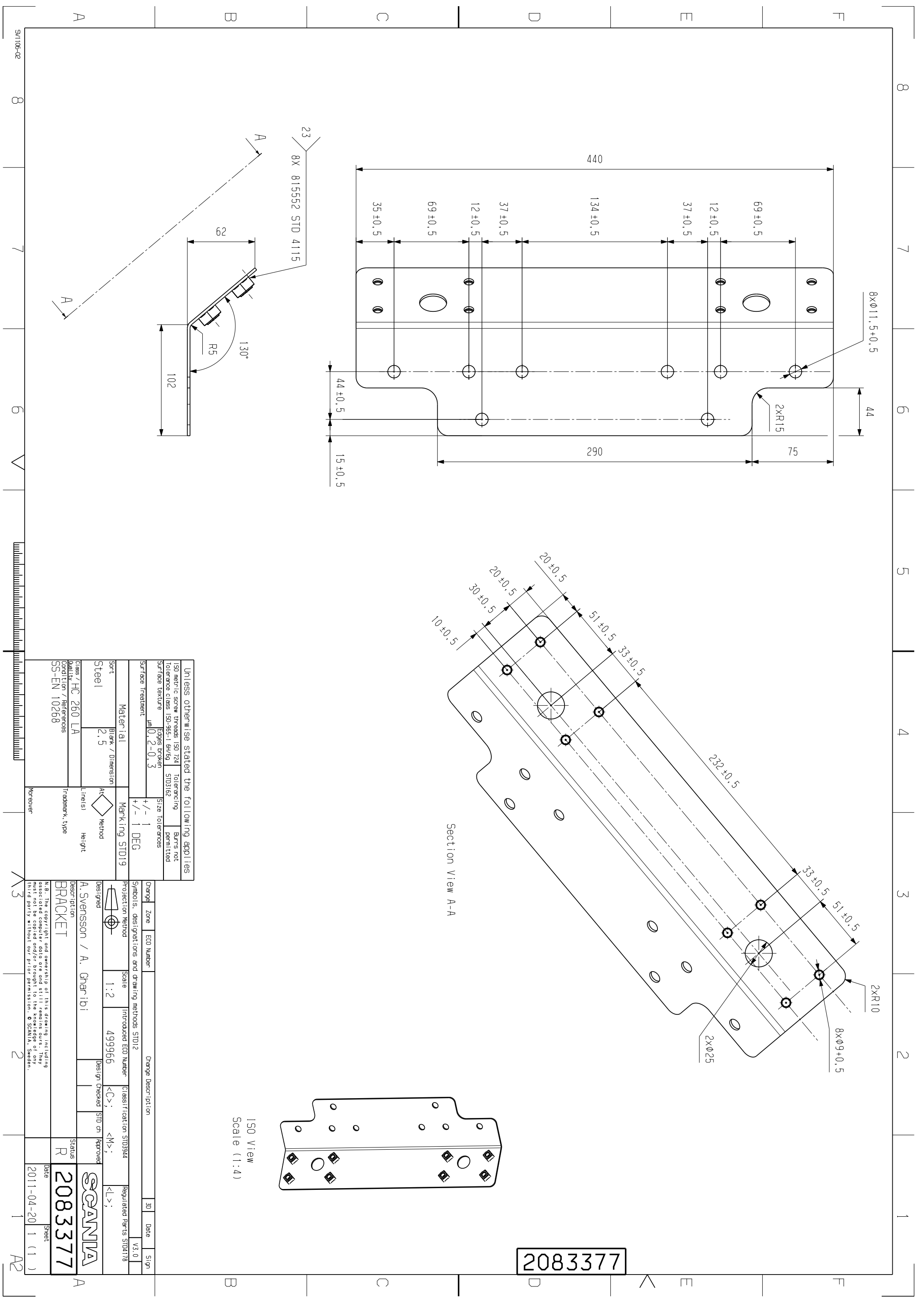
SV1106-03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HC 260 LA
SS-EN 10268
Marking STD19
+/- 1
+/- 1 DEG
A.Svensson / A. Gharibi
Description
BRACKET
1:2
499966
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Symbols, designations and drawing methods STD12
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2083377
2011-04-20
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ISO View
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290
75
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2xR10
2xΦ25
8xΦ9+0.5
8xΦ11.5+0.5
8X 815552 STD 4115
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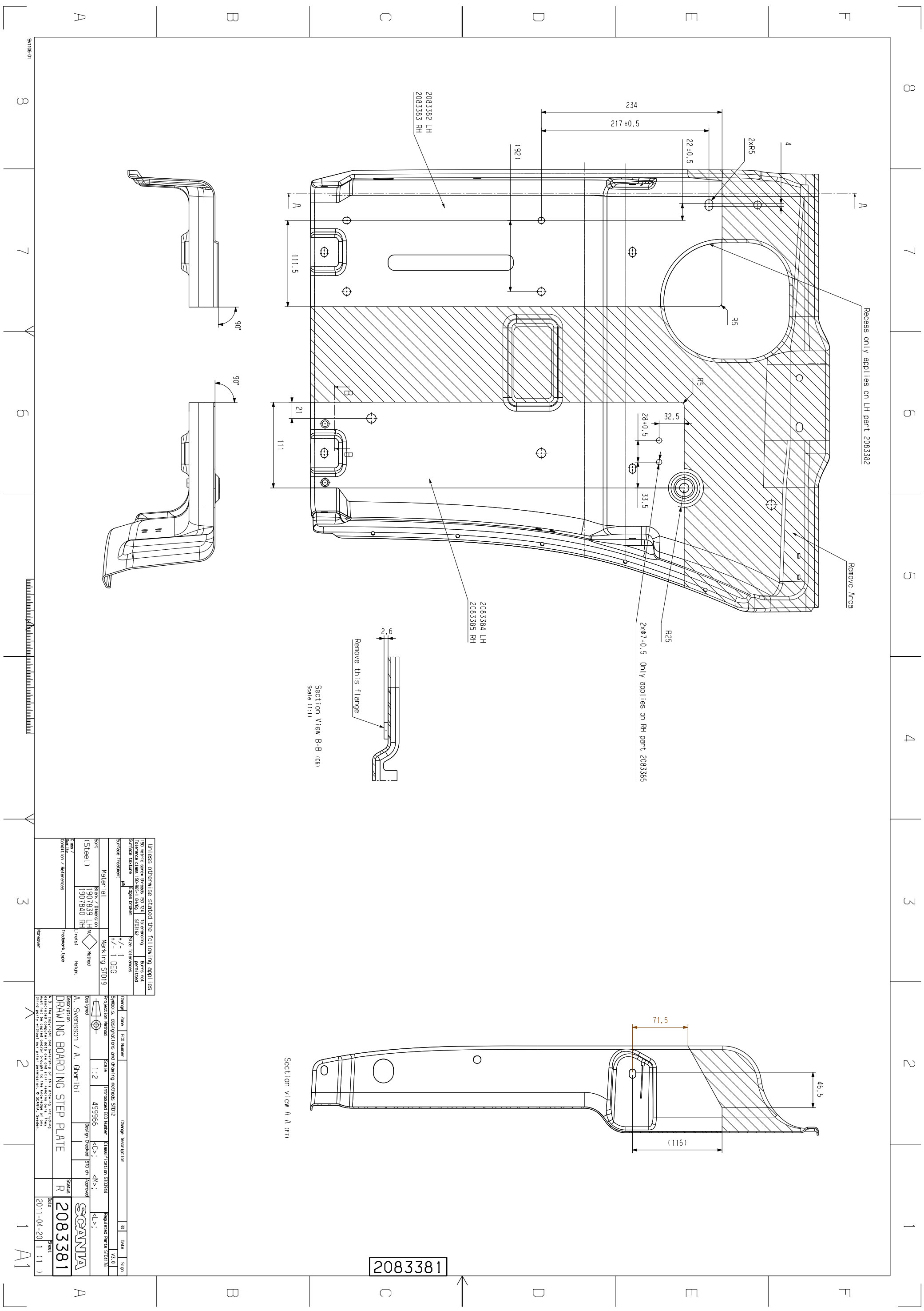
102
R5
130°
232±0.5
2083377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2083383 RH
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22±0.5
2xR5
4
(92)
A
111.5
R5
Recess only applies on LH part 2083382
21
111
28±0.5
32.5
33.5
R25
Remove Area
2x⌀7±0.5 Only applies on RH part 2083385
2083384 LH
2083385 RH
2.6
Remove this flange
Section View B-B
71.5
46.5
(116)
Section view A-A
DRAWING BOARDING STEP PLATE
SCANIA
1:2
2083381
2011-04-20
A1

Appendix 10 Media appendix

The media appendix consists on the DVD disc attached to the booklet.

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