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“Conceptual design and development of movable rear underrun protection”

Master’s thesis in Product Development

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Cover:
CAD model of the new design for the rear underrun protection device (The Guide)

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Abstract

Rear underrun protection (RUP) is a cross member which is fitted at the rear of the truck. This is a highly demanding safety feature which protects the passengers sitting in the car from lethal injuries in the event of the collision of the car on the rear of the truck. In order to increase the safety and reduce fatalities, amendments were made to the regulation 58. On one hand RUP is a safety feature but on the other hand it poses a challenge to the operational capacity of certain trucks such as tipper trucks. The current FOSL (Foldable and Slidable) RUP does not fit on the shortest overhang chassis and interferes with surrounding parts on the chassis. Hence this project is an attempt to design a movable RUP which will fit on the shortest overhang chassis and importantly which will satisfy the legal requirements according to the amendments to regulation 58.

The project has put into practice the generic product development process. It starts with Pre study phase which includes gathering all the necessary information, understanding the work carried out earlier in Volvo GTT and analyzing the space constraints. The Research and conceptual analysis phase included studying the product offering of the competitors and analyzing the related patents. This is important in order to gain robust knowledge about the market and the work carried out by the competitors, in order to begin the conceptual analysis. The requirements brought by the stakeholders were consolidated and these requirements were translated into functions. The development phase included the generation of concepts, the selection of concepts based on certain criteria and finally detailed development of the chosen concepts. Functional analysis of prototypes of final concepts yielded more inputs which were used to refine the concept.

The final concept was tested for dimensional requirements and it successfully satisfies it. Finite element analysis showed the regions of high stress which was used to modify the design and the localized high stresses were reduced. The new concept offers the same departure angle as the FOSL solution. Moreover the product designed does not need any special tooling and can be produced in similar manner as compared to Fixed-RUP and FOSL.

Key words: Rear underrun protection; Departure angle; Interference; FOSL; Fixed-RUP; Movable

Foreword

First and foremost we would like to thank our advisors at Volvo, Mattias Hofvendahl and Hans Regnell for lending us a guiding hand throughout this project and for all we have learnt about the industry. Hearty thanks to Johan Malmqvist, our supervisor at Chalmers for guiding us in this project and keeping us on the right track. Our gratitude goes out to all our professors at the University for giving us the proper knowledge and support which shall help us go on to achieve great or least of all 'lagom' things in life.

On behalf of all the readers, a huge round of applause to Michi for making this report such a pleasant reading experience.

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Nomenclature

Volvo GTT	Volvo Group Trucks Technology
RUP	Rear under-run protection
FOSL	Foldable and Slidable
Foldable	RUP mechanism which can elevate
Slidable	RUP mechanism that can slide
Rear overhang	Rear overhang length is the length from the last axle to the end of the frame
RFL	Rear frame length
Departure angle	Angle between the ground and a line running from rear tire to the lowest-hanging component directly behind it
Ground clearance	The distance between lowest point on the vehicle and the road
Connecting plate	The plate that connects the RUP mechanism with the chassis
Intermediate bracket	The arm that connects the RUP bar with the connecting plate
RUP bar	The bar that is connected to the intermediate bracket and which in the event of an accident takes the impact loads
Air suspended trucks	Trucks equipped with air suspensions
Rigid truck	A medium or heavy duty truck that is not designed to transport a trailer
GRSG	Working Party on General Safety Provisions
RPN	Risk Priority Number

Conceptual design and development of movable rear underrun protection

1. Introduction

This chapter presents the background and the focus of the thesis. It presents the purpose of the thesis, problem definition and an account of the delimitations or pressure points to be factored into the project. The segment is then concluded by an outline/overview of the entire report.

1.1 Company Background

Volvo GTT which is one of the leading providers of commercial transport solutions. The Volvo Group employs about 115,000 people, has production facilities in 19 countries and sells its products in more than 190 markets. The Volvo Group is a publicly-held company headquartered in Göteborg, Sweden. Volvo GTT is a part of the Volvo group with over 10,000 employees around the world responsible for product development. The thesis work on rear underrun protection was carried out at the department of Chassis and Customer Adaptation at Volvo GTT.

1.2 Rear underrun protection

Rear underrun protection (RUP) comprises of a cross member beam fitted at the rear of the truck body through one support at least. The RUP can either be a fixed or an adjustable device based on the customer's requirement. The height of the beam is lower than that of the bumper of the truck. The purpose of the rear underrun protection is to avoid fatal injuries to the occupants of the smaller vehicle in case of a rear end collision with the truck or trailer. All rigid trucks (trucks without 5th wheel) must have a rear underrun protection (see **Figure 1**), regulated by geometry, position, deformations, and load carrying abilities (Hofvendahl, M. 2014). The RUP mechanisms are of four types; fixed, foldable, slidable and foldable-slidable.

Parts of the rear underrun protection device are shown below (**Figure 2**)

Figure 1: Rear underrun protection in trucks

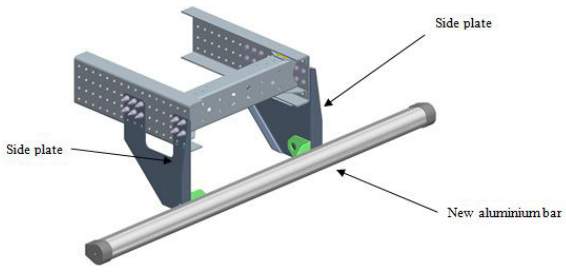


Figure 2: Parts of the RUP device

There are four main categories of RUP available in the market today.

Type 1: Fixed RUP
The mechanism (refer **Figure 3**) application is most common on the market. They usually have an underrun bar and a bracket which is fixed to the chassis

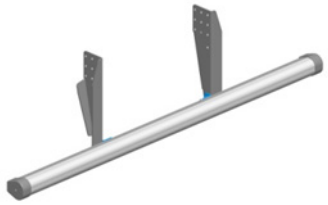


Figure 3: Fixed RUP- Volvo

Type 2: Foldable RUP
These are used when there is a need to change the position (refer **Figure 4**) of the RUP during specific operations (e.g. tipping, off-road usage). The RUP have different mechanisms which are used to elevate the underrun bar.

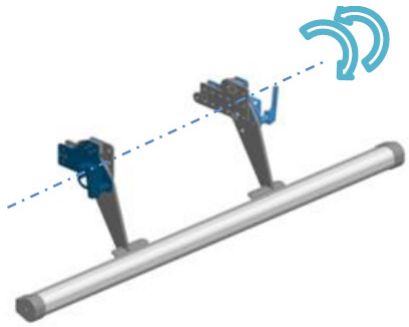


Figure 4: Foldable RUP- Volvo

Type 3: Slidable RUP
This mechanism allows the RUP bar to retract inwards towards the chassis (see **Figure 5**)

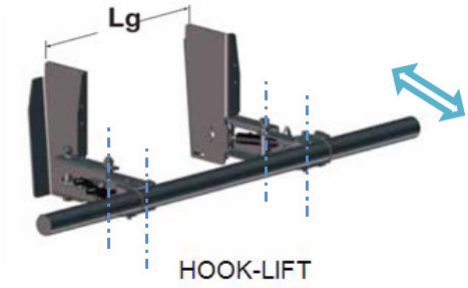


Figure 5: Foldable & Slidable RUP

Type 4: Foldable & Slidable RUP
This type of RUP allows bar to elevate in height and slide inwards towards the chassis. (Refer **Figure 6**)

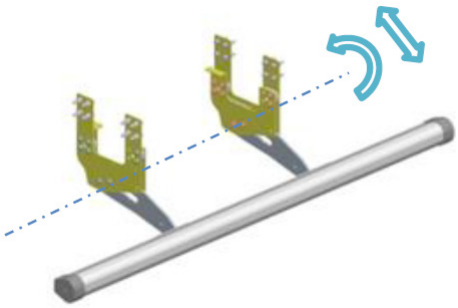


Figure 6: Foldable and slidable-Volvo

Apart from the fixed RUP, no other variant can be fitted onto a chassis with short overhang length. This project focuses on type 2, 3 & 4 which are adjustable RUPs.

1.3 Regulation 58-03

The rear underrun protection device is regulated under the Regulation No. 58. At 99th session of GRSG, Germany announced the submission of official document for the 100th session of GRSG (United Nations Economic Commission for Europe, 2014). This aimed to significantly improve the situation of rear underrun accidents by introducing more demanding force and dimensional requirements (refer **Table 1 & Table 2**) for rear underrun protection devices (RUP) on heavy duty vehicles (HDV). The objective for the amendment is to ensure a higher level of safety for the passengers of cars who have higher risk of getting severely injured in the event of a rear end collision with the truck. (Refer Appendix D) Moreover there have been changes in the positioning of the RUP cross member (see table 2) to increase the safety of the passengers in cars. All these aspects validate the need for this project.

1.4 Problem description

Currently, there is a foldable and slidable RUP mechanism in use for long (> RFL-2545) overhang chassis of Volvo trucks. But this solution cannot be implemented in the shortest overhang chassis as the space available is minimal which makes it impossible to accommodate the current RUP mechanism without it interfering with the surrounding parts (Hofvendahl, M., 2014). The main purpose of this project is to develop a RUP mechanism which should be movable (foldable or slidable) with high departure angle (same if not more than the current solution) and can be fitted onto a truck with the shortest rear overhang chassis which is equipped with air suspension. The shortest overhang in a Volvo truck segment in current market is in the chassis variant RFL-2195 (2195mm in length).

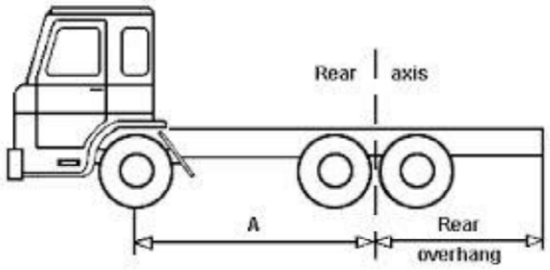


Figure 7: Rear Overhang in trucks

Table 1: Comparison of impact loads before and after amendment

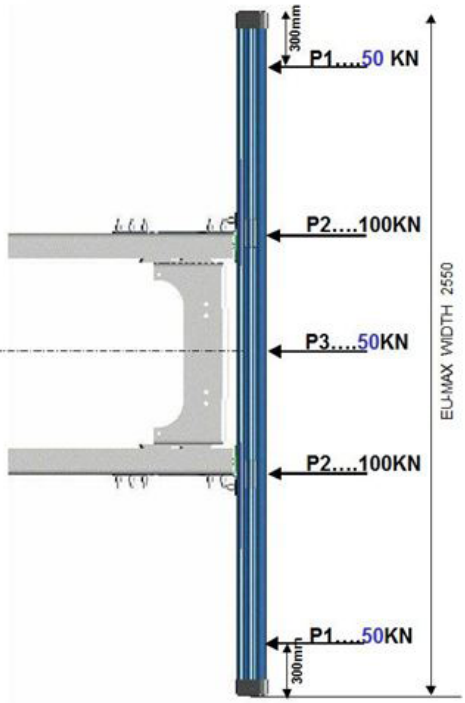
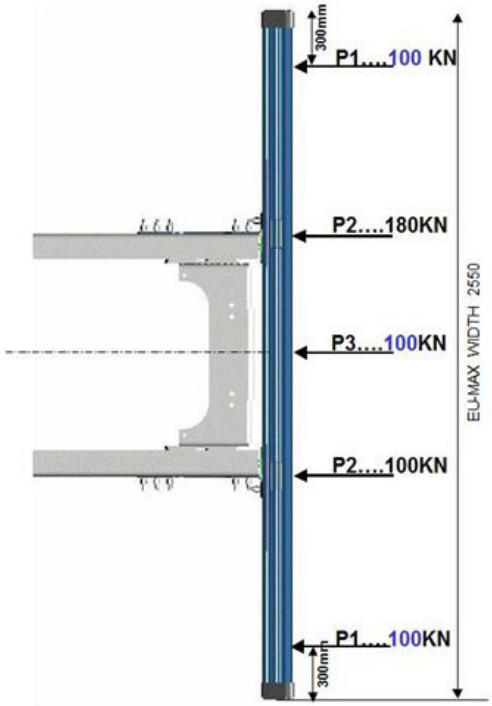
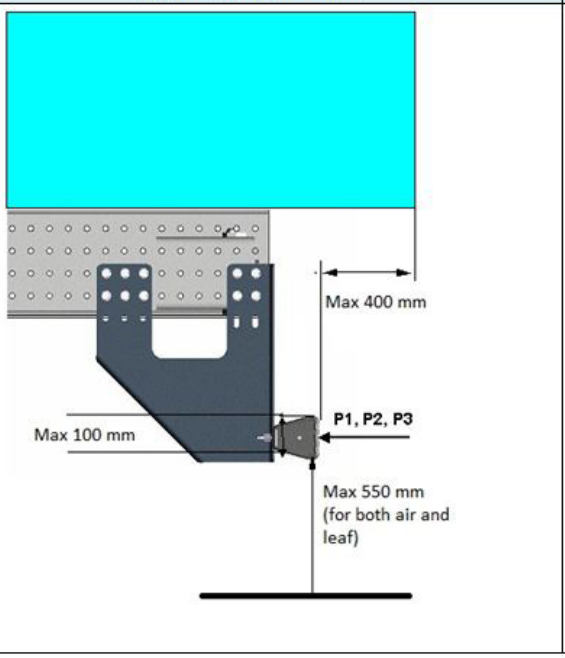
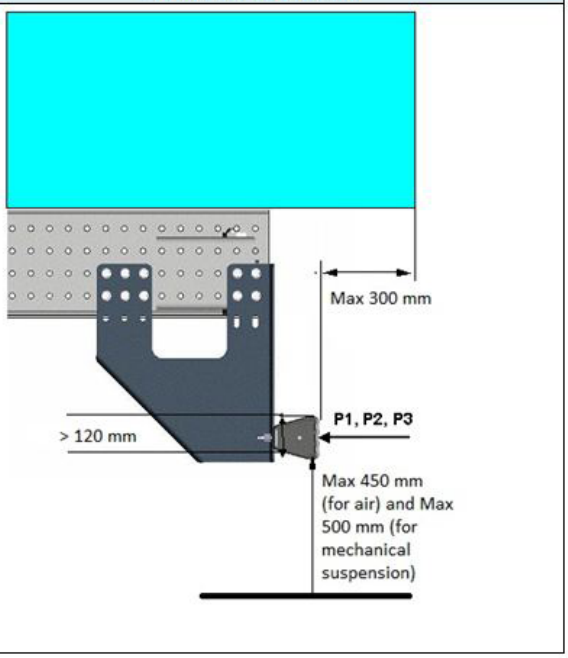
Before amendment	After amendment
	

Table 2: Comparison of dimensions and RUP positioning before and after amendment

Before amendment	After amendment
	

In addition to this, the RUP should be of movable type, in order to be fitted on trucks without any obstruction during the tipping operation or to the attachment of a tow member.

1.5 Purpose and objectives

Based on the problem description, there is a need to develop a new design for the movable RUP mechanism for the shortest overhang chassis segment that addresses the aforementioned design constrains and legal demands.

What is a good solution?
The challenge in this project is to design a solution for the aforementioned problem that will provide higher departure angle(s) than that of the current fixed solution, sustain impact loads as per new amendments and fits in the limited space available on the shortest overhang chassis (RFL-2195). The solution should be easy to adapt to various chassis heights without any additional cost toward redesign or manufacturing costs. The solution should be such that it can be manufactured without additional investments to the tooling and also be easy to maintain (e.g. parts undergoing wear are made as modules so that they can be replaced cost effectively). The important target here is to satisfy all the requirements as per the requirement specifications (Chapter 5).

The goal of this project is to provide following deliverables.

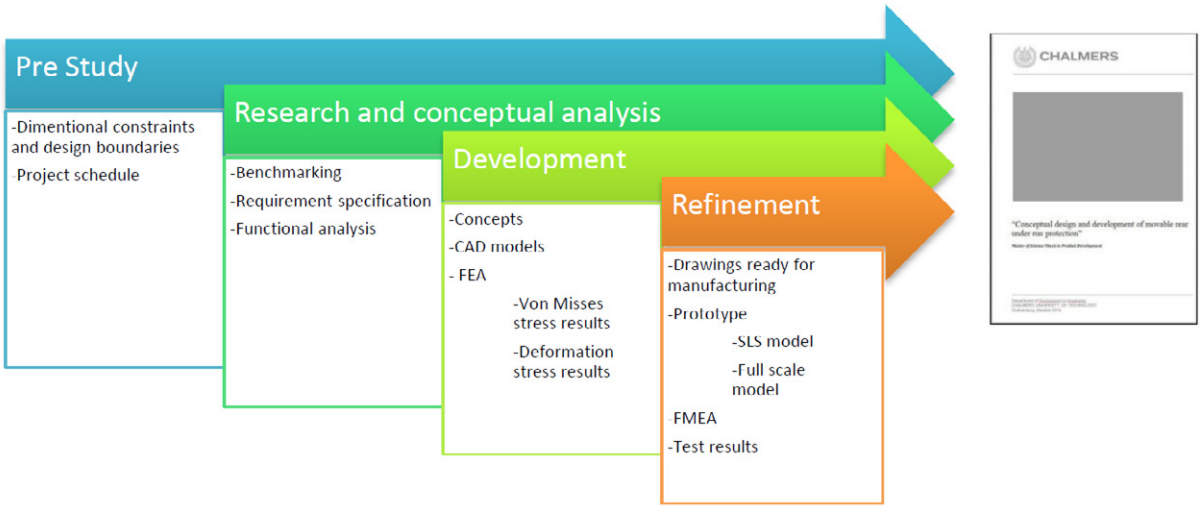


Figure 8: Deliverables in various phases of the project

Project deliverables

This project has several deliverables under different phases of product development, which is described as follows.

1. **Pre Study phases deliverables**

   This phase presents the study on dimensional constraints and defines the boundaries for designing the new concept (Refer chapter 3.1 and 3.2).

2. **Research and conceptual analysis deliverables**

   This phase will present the benchmarking done to understand the competence of Volvo's RUP concept in comparison with its competitors RUP. Also, it will deliver requirement specification which consolidates the requirements of the stakeholders which the product needs to satisfy. Moreover it will present functional analysis which is a list of functions that the concepts have to perform in order to be completely functional and ready. (Refer chapter 6).

3. **Development phase deliverables**

   This phase will present concepts at start with concept sketches. Further it will deliver CAD models of the concepts. These 3D models will be tested on finite element software which will yield the stress and deformation results to ensure its structural integrity. (Refer chapter 7).

4. **Refinement phase deliverables**

   This phase will deliver detail designs of funneled down concepts. Also delivered at this stage are the SLS prototype, fullscale prototype and test results from the prototyping. (Refer chapter 8.1 and 8.2). The objective of SLS prototype is to dive deep into the operational feasibility and understand and study the potential areas for improvement.

5. **Final project report**

   A comprehensive project report will be submitted which will include in detail the process and steps and finally the recommendation for future development.

1.6 Delimitations/Challenges

The scope of the project is to develop a mechanism which will allow RUP to be movable or adjustable which meets the legal demands of dimensions (Refer Appendix C). The RUP must have large enough departure angles for various operational situations such as tipping.
The critical issue here is making the RUP mechanism strong enough to withstand higher loads according to the new regulations (R58-03) but at the same time making them foldable and slidable which might tend to make them weaker. These requirements are contradictory to each other and thus the important issue in this project is to find the right trade-off between them.

1.7 Report outline

The outline of the report is as follows:

Introduction: The introduction presents the background and focus of the thesis. It presents the purpose of the research, problem definition and goals of the thesis. It explains the overall approach and concludes with the scope and delimitations of this thesis.

Product development process: This section provides with the research methodology that has been followed. It also provides a description of the product development phases.

Pre-Study: This section explains the importance of pre study stage in the product development. It provides analyses of the space constraints.

Research and Conceptual Analysis: This section presents the study done to identify the competitors and their products, amendments in regulation R58 and study of relevant patents pertaining to the field.

Requirements specification: This section presents the various requirements generated after extensive research and discussion with Volvo.

Functional Analysis: This chapter provides the overview of the functions which the RUP needs to perform.

Development: This section presents the complete development process of RUP from concepts generation, concepts selection, funneling down of feasible concepts and their detail designing.

Refinement and deliverables: This section presents the design loops, improvements to the concepts and provides the project deliverables.

Results: This section presents the results from the prototype testing and FE analysis.

Discussion: This section discusses the goal fulfillment and reflection of the project carried out.

Future recommendations: This section proposes the work to be carried out required for bolstering the research carried out in this project.

Appendix: This section provides additional information which is necessary for complete understanding of the project.

2. Product development process - Research methodology

This chapter explains the selection of product development process in this project. It further explains about the process in detail. The process is divided into four phases namely; Pre-study, Research and Conceptual analysis, Development, Refinement and Deliverables.

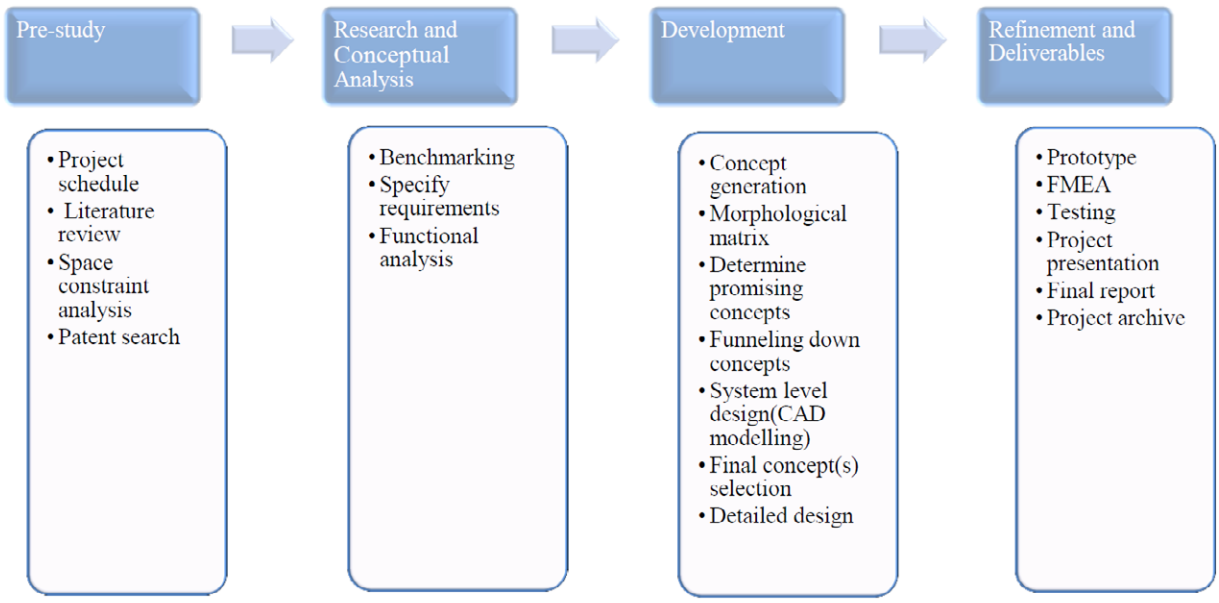


Figure 9: Product development process

Pre-study phase first and foremost involves planning a work schedule for the entire project. One must note that this schedule is subject to alterations in the course of the project. Having set the time goals, the relevant reference material need to be compiled and studied in order to have a thorough understanding of the all the areas and to get a complete overview of the project. The main areas of focus for this phase were the space constraint analysis which gives us the design boundaries and limitations to be followed and a patent search that gives us an insight into the current and future market of RUP mechanisms and other related products.

Research and conceptual analysis phase begins with an analysis of the company/client's business, vision, mission and go deeper into the technology used in the products today. A study on the current solutions available on the market, benchmarking the competitor's solutions along with browsing through various patents pertaining to the project is a very important step as it provides new perspective as well as helps us save time not developing the same solutions. Benchmarking is an effective structural approach to quality engineering and management. It involves investigating industry's best practices, analyzing and evaluating one's own operation for opportunities and implementing an action plan that includes the structure of goals, objectives and operating targets (Boxwell, R.J, 1994). Having done this, the next step is to specify the engineering requirements with definite targets to be achieved. Most of the requirements for this project are well defined as it is derived from the regulation 58 (Refer Appendix D). Following the requirements is the functional analysis which breaks down the main function of the product into smaller independent functions.

The development phase comes next in the project. The first step in this phase is to identify the main functions of the product. This is followed by brainstorming for generating the sub solutions for each function. As Osborn A.F (1957) mentions that the most effective way to generate ideas is through tools such as brainstorming within the project group as well as a cross functional team. A morphological matrix is used to generate various solutions for each of these functions through aggregation of sub solutions. The sub solutions from the morphological matrix are then combined to form complete solutions thus generating numerous concepts. The tools helps the with idea generation and with the flow of creativity when a team gets stuck with a mental block (Ulrich and Eppinger, 2012). These concepts are then funneled down using Pugh and Kesselring matrices. These are decision matrices that help rate multi-dimensional ideas by breaking the decision into various several smaller factors thus facilitating concept selection (Pugh, S. 1996).

The Kesselring matrix has a scoring scale and instead of just rating the concepts, they are scored to give a clearer comparison between the concepts (Johannesson, H. 2013). Also a feature of this matrix is giving a priority rating of the various selection criteria thus making it a more comprehensive tool for funneling down of concepts as well as the final selection of concept(s). After the first phase of funneling down of concepts, a system level design of the same is done by computer aided designing (CAD). This helps us visualize and critique the solutions better which leads to the elimination of weaker solutions and select the final concepts for the last phase design which is the detailed designing. The structural integrity of the models is then verified through finite element analysis subjected to the loads as per the legal requirements and safety factors. Final drawings of the concept(s) are then generated. This completes the final refinement phase and the models are ready for physical prototyping.

Refinement and deliverables phase includes prototyping the final concept(s). The first prototype produced will be an SLS model that is 1:2 in scale and is used mainly in physically verifying the mechanism. Changes to the design are done as and when they are necessary. This is an iterative process involving continuous development with prototyping (virtual and physical), verifying, validating and ratifying the product solution. The prototype is tested and analyzed to check if it satisfies the stated requirements. The models are then subjected to testing and final validation of the concept(s).

Since this is a new product development project, conceptual development and design of the product is to be done from scratch as no such product exists in the market currently and this is what dictates the choice of tools and methodology in this project as indicated above.

3. Pre study of the design boundaries

This chapter is a precursor to the start of the conceptual development process. It is the compilation of data which acts as the theoretical framework of the project. It begins with a short account of how the data was acquired and continues into space constraint analysis and the packaging study. Before the actual development begins, it is imperative to understand the various factors affecting the design and also understand the design boundaries and restrictions one must follow in the project. Since this project mainly involves conceptual development, there are a lot of unknowns and variables. A sound understanding of the problem and all the factors involved hence puts things in perspective. Once the project details are clear, the goals of the project are to be decided by the project team which then has to be integrated in the project schedule.

3.1 Data acquisition

To get an overview of the problem at hand it is very important to gather related information, assimilate it and use it in the development process. Primary data was acquired from the employees of the parent department (Transport and Customer Adaptation) at Volvo. Moreover the research done by the department and compilation of amendments of Regulation 58 formed as a base of this project. Furthermore the information available on the web about the competitor's product was studied.

3.2 Space constraint analysis

In order to understand the packaging space available, which is a vital input for designing RUP mechanism, space constraints were analyzed. This section describes the space available for the functioning of the RUP mechanism and its components. The space available for design of the working of the RUP mechanism was analyzed using CAD models of the RUP-FOSL attached onto the frame of the trucks. Studying CAD models was much quicker, convenient and more accurate as compared to the actual truck components. Hence CAD models were the primary source of the space constraint analysis. To design a new RUP mechanism which complies with these requirements, one has to first study in detail where the current mechanism fails.

When the RUP-FOSL was moved from its outer most position to its inner most position, the intermediate arm clashes with the air bellows of the suspension. From the above analysis, it was observed that the RUP-FOSL can be used only in those trucks with chassis overhang greater than RFL 2545. This mechanism when used in overhangs shorter than RFL 2545 clashes with components under the chassis. The intermediate arm clashes with the air suspension bellow when the RUP is slid into the innermost extremity (see **Figure 10**). (Mahesh, B. 2010)

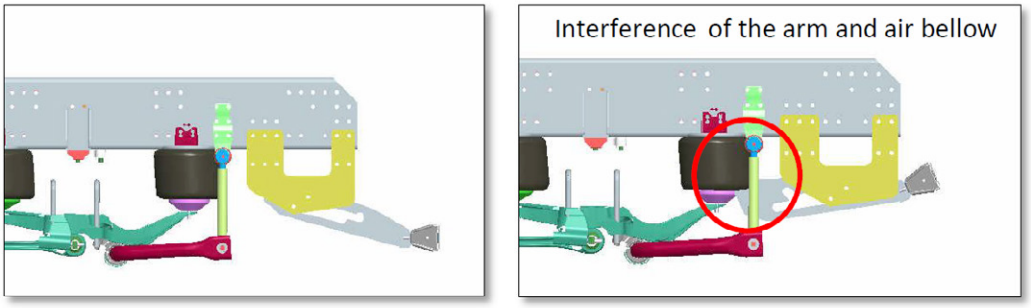


Figure 10: RUP-FOSL at inner extremity (RFL-2545)

In order to understand the placement of all the components on the chassis and also study the dimensions along with all the possible positions of the towing member packaging analysis was done. CAD model of the chassis frame mounted with all the components was studied. It was understood that the towing member was not a component that is designed by Volvo and also that the positioning of the towing member is subject to customer adaptation. This meant that there is no single position of the tow coupling member but instead three different positions. A packaging CAD model that showed all possible positions of the tow member was analyzed. The distance available from the end of the frame and the air suspension was studied. This played a vital input to decide the length of the intermediate arm during development phase. Moreover to understand the width of the RUP mechanism, the distance between outer surface of the chassis frame and tow coupling bracket was analyzed. (See figures 11&12)

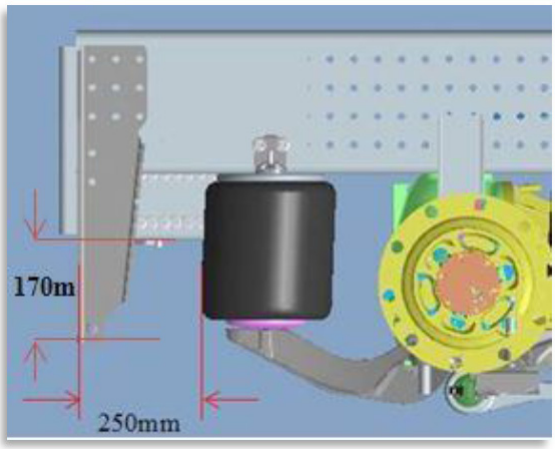


Figure 11: Distances between the RUP bar and tow coupling bracket and air bellows

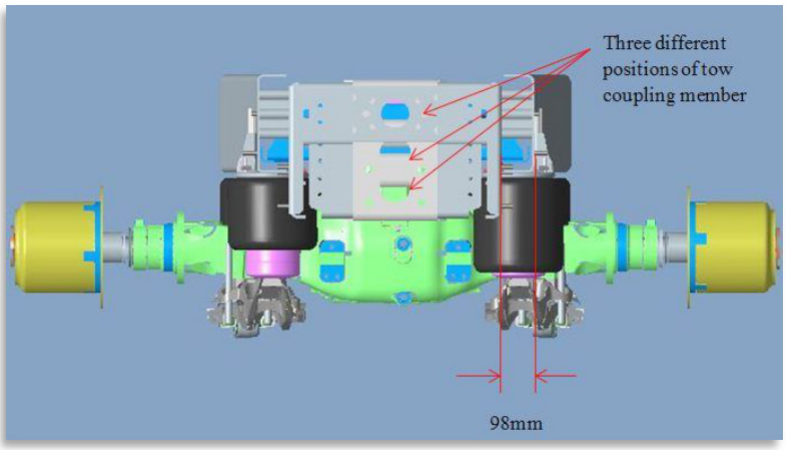


Figure 12: Distance between outer surface of chassis frame and tow coupling bracket

3.3 Conclusions

The space constraint analysis reveals the various dimensional constraints that a designer has to face while designing this particular product. The main findings of this analysis are as follows:

- Chassis lengths to be designed for <= RFL 2545
- Distance between end of the chassis to the air bellows = 250mm
- Number of free hole rows available on the frame = 6 (50mm apart)
- Distance between the lowest tow coupling member and the RUP bar = 170mm
- Minimum length available between the towing member chassis frame = 98mm

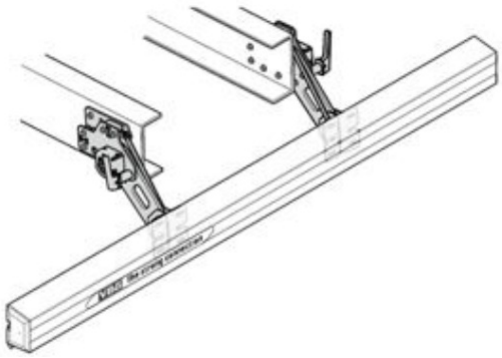
4. Research and Conceptual analysis

This chapter explains the research phase of the project. Before the development of the product can begin, a sound theoretical knowledge, history of the project work, the legal framework that the product is subjected to, the contemporary work that is being done in the field either by the competitors or the parent company and other relevant work being carried out in the particular field are to be studied.

A study of the various RUP solutions, patents and concepts from Volvo as well its competitors that were available in the market was conducted. The RUP family available in the market today was divided into four generic classes for easy understanding as mentioned earlier.

4.1 RUP solutions available in the market

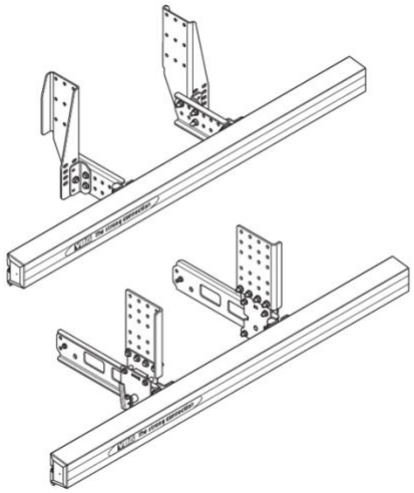
Though generic classes of RUPs were identified, it was important to research further into the variants offered by the various players in the market. Following RUP manufacturers' products were studied and. The focus of the project was to study the movable (elevating or slidable, or both elevating & slidable) solutions.



4. 1. 1 VBG

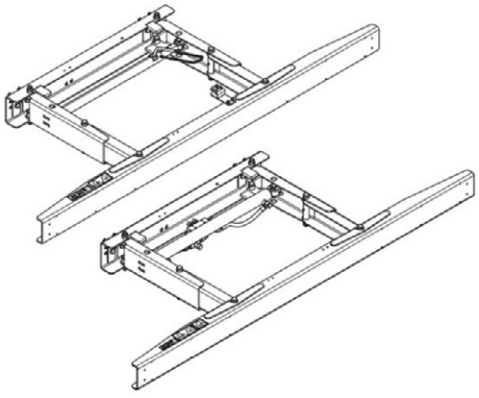
VBG elevating solution
allows the RUP bar to elevate from its working position (current position)

Figure 13: VBG elevating RUP



VBG Slidable Solution
This mechanism allows the RUP bar to slide in towards the truck chassis.

Figure 14: VBG Slidable RUP



VBG retractable solution
This solution allows the user to pneumatically retract and extend RUP bar with the help of linkages.

Figure 15: VBG retractable RUP

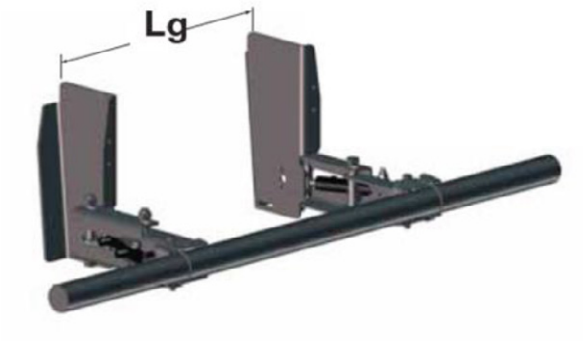


Figure 16: Pommier Retractable RUP

4. 1. 2 Pommier

Pommier retractable solution allows the RUP bar to retract inward i.e. towards the chassis

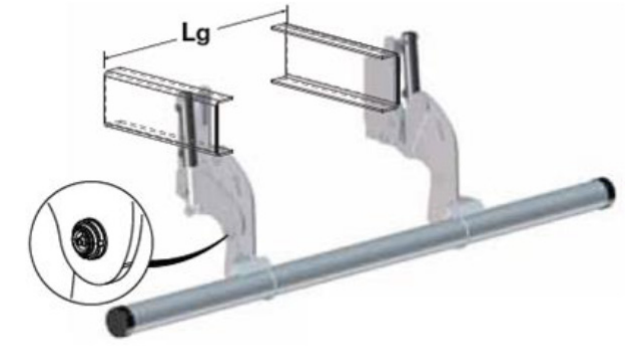


Figure 18: Pommier elevating RUP

Pommier elevating solution
allows the RUP bar to elevate from its working position (current position)

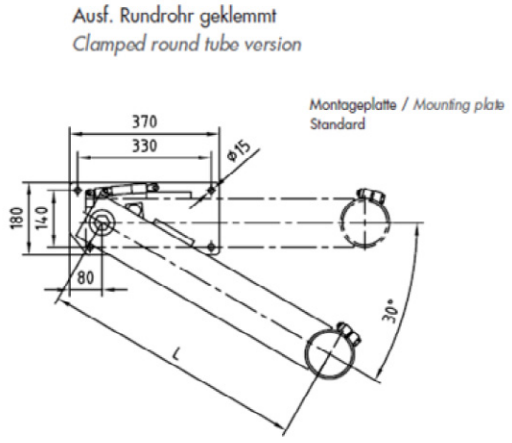


Figure 17: WAP elevating RUP

4. 1. 3 WAP

WAP elevating solution
allows the RUP bar to elevate from its working position

Figure 19: Meiller elevating RUP

4. 1. 4 Meiller

This solution allows RUP bar to elevate from its working position

Figure 20: Wagnfabriken Foldable RUP

4. 1. 5 Wagnfabriken

This solution allows the RUP bar to be folded in when the tail lift mechanism is in use.

Figure 21: Gehab slidable RUP

4. 1. 6 GEHAB

This solution from GEHAB allows the RUP bar to slide in towards the chassis.

Figure 22: Palfinger extendable RUP

4. 1. 7 Palfinger

The following solution from Palfinger allows the RUP bar to be hydraulically extended and retracted.

Figure 23: Mercedes-Benz foldable RUP

4. 1. 8 Mercedes-Benz

This solution from Mercedes-Benz allows the RUP bar to be folded in.

Figure 24: Mercedes-Benz foldable RUP

4. 1. 9 ORY

This solution from ORY allows the RUP bar to slide in towards the chassis.

It was observed that the movable solutions available in the market today are specialized solutions catering only to a particular variant in a particular brand and cannot be implemented universally. It was also discovered that even though majority of the market used fixed RUP, there were numerous foldable, telescopic and even slidable solutions offered by Volvo as well as some of the its competitors and these were a strong benchmark against which the new design can be pitted and also a good base upon which new ideas can be generated.

4.2 Patents research

Patent research helped unearth a lot of material on the current state and maturity of the RUP solutions in the market and helped understand the market better. The patent search was conducted and compiled by the Patent information specialists, Suzanne Molander at Volvo GTT. Patents related to the front, rear and side underrun protection devices were included. Out of these, the relevant ones were picked out and documented for this report. (Refer Appendix D)

The authors have studied the related patents to gain in depth understanding of the product to be developed and in order to not infringe upon the existing ideas. The following patents were worth the mention.

- Volvo Lastvanar AB-WO2013095201A1:
  Impact beam for underrun protection arrangement for heavy vehicle e.g. truck has support surfaces arranged in three dimensions adapted to cooperate with corresponding three dimensional surfaces on the vehicle in a rigid form lock.

- Volvo Lastvagnar AB-SE 0104419-7:
  A method of moving underrun protection as well as arrangements for underrun protection of vehicles

- Daimler AG- DE102012006839A8:
  Underrun guard unit for rear of vehicle, particularly commercial vehicle or trailer, has fixing units with retaining element that extends parallel to underrun guard element, which is eccentrically connected with one of two cross bars.

Thus this study provided a good overview of the work and the developments being carried out on the underrun protection device

5. Requirements specification

In a product development process, the knowledge acquired from the pre study and the benchmarking has to be translated into engineering terms as design requirements. This is done in a requirement specification sheet wherein the various design requirements along with relevant information necessary to fulfill them are listed. This acts as a guideline for a design engineer in a new product development.

The sole purpose of the requirements specification is to declare the objectives of the product that has to be developed. In this project, the majority of the design requirements are very crisp as it comes from the Regulation 58-03 (Refer Appendix C). The rest were standards that had to be upheld from Volvo's brand image point of view. The requirements were categorized broadly into functional, legal, performance and maintainability and attributes of the product. Further information such as the current value, target value, stakeholders and verification method were provided for each of the requirements. With the regulation 58 and Volvo standards as a background, the following requirement specifications were formulated. (See table 3)

The targets for each specification are as listed below. It was inferred that the main stakeholders of the project were the customers, Volvo GTT, suppliers for Volvo and the bodybuilders who work with Volvo. The main verification techniques used in the project were CAD models, FE analysis, expert analysis and prototype inspection.

Table 3: Requirement specification

Requirement Category	No.	Requirements	Current (Reference is the FOSL)	Target	Stake holders	Verification method
Functional	R1	Mechanism to be implemented in the side plate.	Available	To be installed	Volvo	CAD
	R2	The RUP mechanism should not obstruct the tow coupling member.	Does not obstruct	Avoid obstruction	Bodybuilder Volvo Suppliers	CAD SLS Prototype
	R3	The RUP mechanism should not clash with the components under the chassis	Clashes with air bellows in air suspended trucks	Avoid clash with all component	Volvo	CAD SLS Prototype
Performance	R4	Mechanism should fit all chassis heights	No solution available within range 911mm to 1348mm	To be designed within the range 911mm to 1348mm	Volvo's Customer	CAD
	R5	Mechanism should fit all chassis lengths	No solution for RFL2195 (shortest chassis)	To be designed for RFL 2195	Volvo Bodybuilder and Customers	CAD
	R6	Distance of the installation from rear of the vehicle	<400mm before crash	<300mm before crash <400mm after crash	Customer	CAD(Before crash) Basic FEA(After crash)
	R7	Provide quick release operation	Available	To be installed	Customer	CAD
	R8	Easy to operate	No additional aids	Include additional aids	Customer	Expert assessment
	R9	Increase departure angle	20	30	Customer	CAD Prototype
	R10	The force applied by the operator for varying the RUP position	<40daN	<40daN	Customer	Basic FEA Full scale structural steel prototype
Maintainability	R11	Easy to maintain	Minimal maintenance	Minimal maintenance	Customer Volvo(After sales)	Expert assessment
Legal	R12	Load withstanding capacity of the RUPD	P1=50kN P2=100kN P3=50KN	P1=100kN P2=180kN P3=100KN	Customer Volvo	FEA
	R13	Difference in distance from rear before and after the crash	<120mm	<100mm	Customer Volvo	FEA
	R14	Installation height for air suspension trucks	<550mm	<450mm	Customer Volvo	CAD
	R15	Installation height for the leaf suspension trucks	<550mm	<500mm	Customer Volvo	CAD
Attributes	R16	Low weight	35 Kg	<= 35Kg	Customer	Basic FEA
	R17	Low cost (tooling +development of new parts)	-	-	Customer	Expert assessment
Aesthetics	R18	Concept should be aesthetically appealing	-	-	Customer	Expert assessment

The requirements mentioned in **Table 3** will further dictate the functions that the RUP should have which is described in the subsequent chapter.

6. Functional analysis

The requirement specification gives the design engineer the information needed to model and design the product and generate various concepts. But there is a need for these requirements to be translated into functions to analyze and evaluate concepts thus helping the funneling down/combining and improving concepts and help in the flow of the product development process.

The following are the main functions of the product that is to be developed through this project. These are formulated to have a base in order to start brainstorming for sub solutions.

- Support RUP bar
  (The mechanism should be able to support or hold the RUP bar in position)

- Attach to chassis
  (the mechanism should provide an attachment point to the chassis taking into account the spatial constraints)

- Able to vary departure angle
  (the solution must provide an option to vary the departure angle of the RUP)

- Easy to move
  (The position of the RUP should be varied with minimal effort from the user)

- Avoid interference with tow coupling member
  (The RUP should not be in the way of the tow coupling to facilitate the attachment of a towing member)

- Avoid interference during tipping
  (The RUP should not be in the way when the truck is tipping towards the rear)

- Quick to modify
  (The foldable/slidable operation must be performed as quickly as possible)

- Movable without clash
  (The folded/slid mechanism must not clash with any part fitted in the chassis)

The functions listed above were used as criteria to evaluate the concepts through the concept selection matrices i.e. Pugh and Kesselring matrices. Though these functions are all important, their weights with regard to this project vary and become important while evaluating concepts. Hence appropriate weights are associated to these functions before scoring them in the matrices.

7. Development

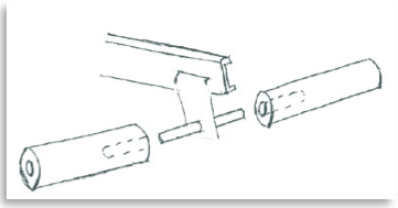
This chapter exemplifies the process of developing a product right from ideation to detailed development stage. Numerous iterations of combinations and refinements of concepts and funneling down of concepts leading to the final selection, is part of this chapter.

7.1 Generation of sub solutions

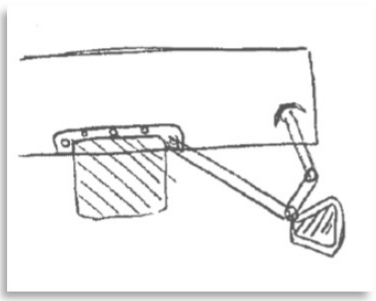
In order to generate a wide range of sub solutions and to explore possible solutions, concept generation was carried out. The purpose was to brainstorm as many concepts as possible based on the stated requirements specification (discussed in chapter five). This is a stage where initial brainstorming was conducted to generate concepts satisfying various functions as mentioned earlier. Numerous ideas were generated for each function. These ideas on sub solutions were put into a Morphological matrix (Refer Appendix A).

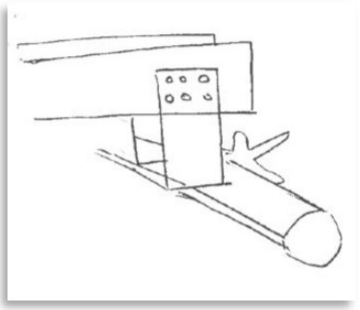
The functions mentioned in chapter 6 were used as criteria to generate sub solutions, some of which are shown below.

1. Support RUP bar

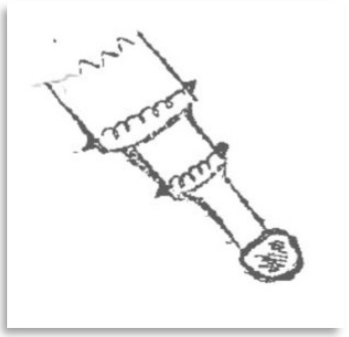


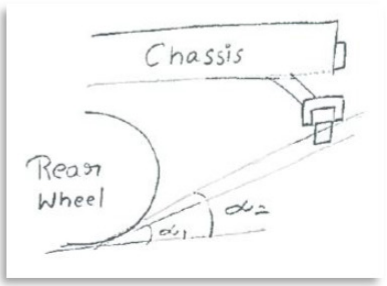
2. Attach to chassis



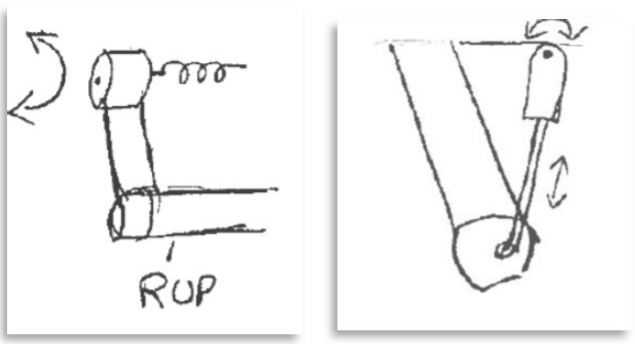


3. Able to vary departure angle

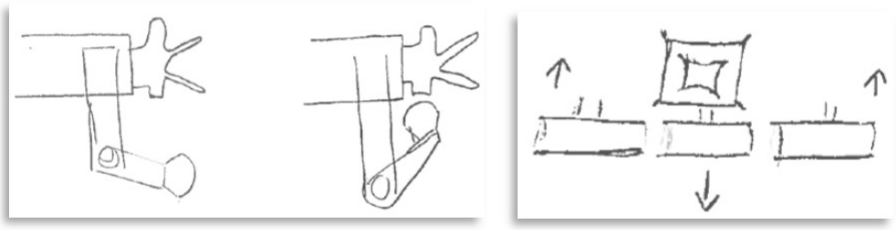




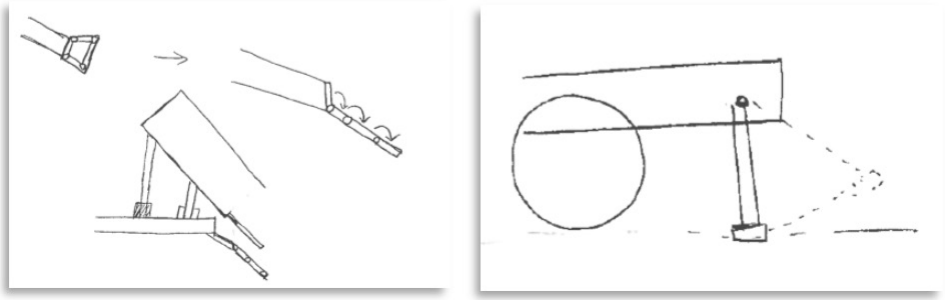
4. Easy to move



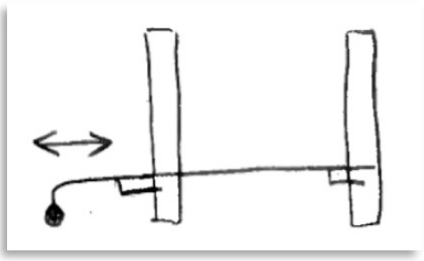
5. Avoid interference with tow coupling member

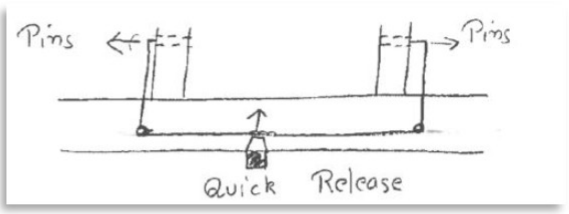


6. Avoid interference during tipping operation

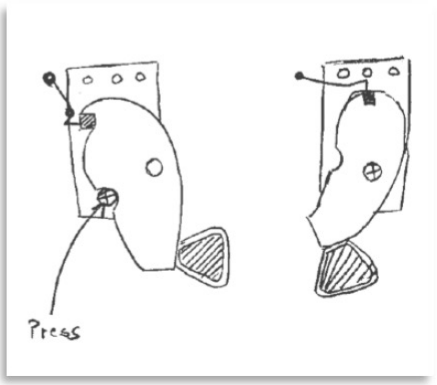


7. Quick to modify





8. Movable without any clash with surrounding components



7.2 Morphological matrix

The purpose of using Morphological matrix in this project is to facilitate the combination of sub-solutions to generate possibilities (concepts) including highly unusual ones by combining the sub solutions for every defined function. Tom Ritchey (1998) defines morphological matrix as a method for identifying and investigating the total set of possible relationships or "configurations" contained in a given problem complex. Also to the right of each element in the column, there is a row containing the possible ways of achieving those parameters. This matrix became the tool to generate complete solutions by combining different sub solutions for every function (Refer Appendix A).

7.3 Determine promising concepts

The second round of brainstorming was conducted in order to combine the various ideas generated in the previous brainstorming session and generate complete concepts after putting the sub solutions into the Morphological matrix. One sub solution is picked out for each function to make a meaningful aggregated combination and thus generate a concept.

In total eleven concepts were generated and their detailed descriptions along with the positive and negative aspects of each of them are described below. One of the concepts generated was guide profile from the morphological matrix and the morphological matrix for the same is shown in the figure 25. Other concepts were similarly generated.

Concept 1- The guide profile

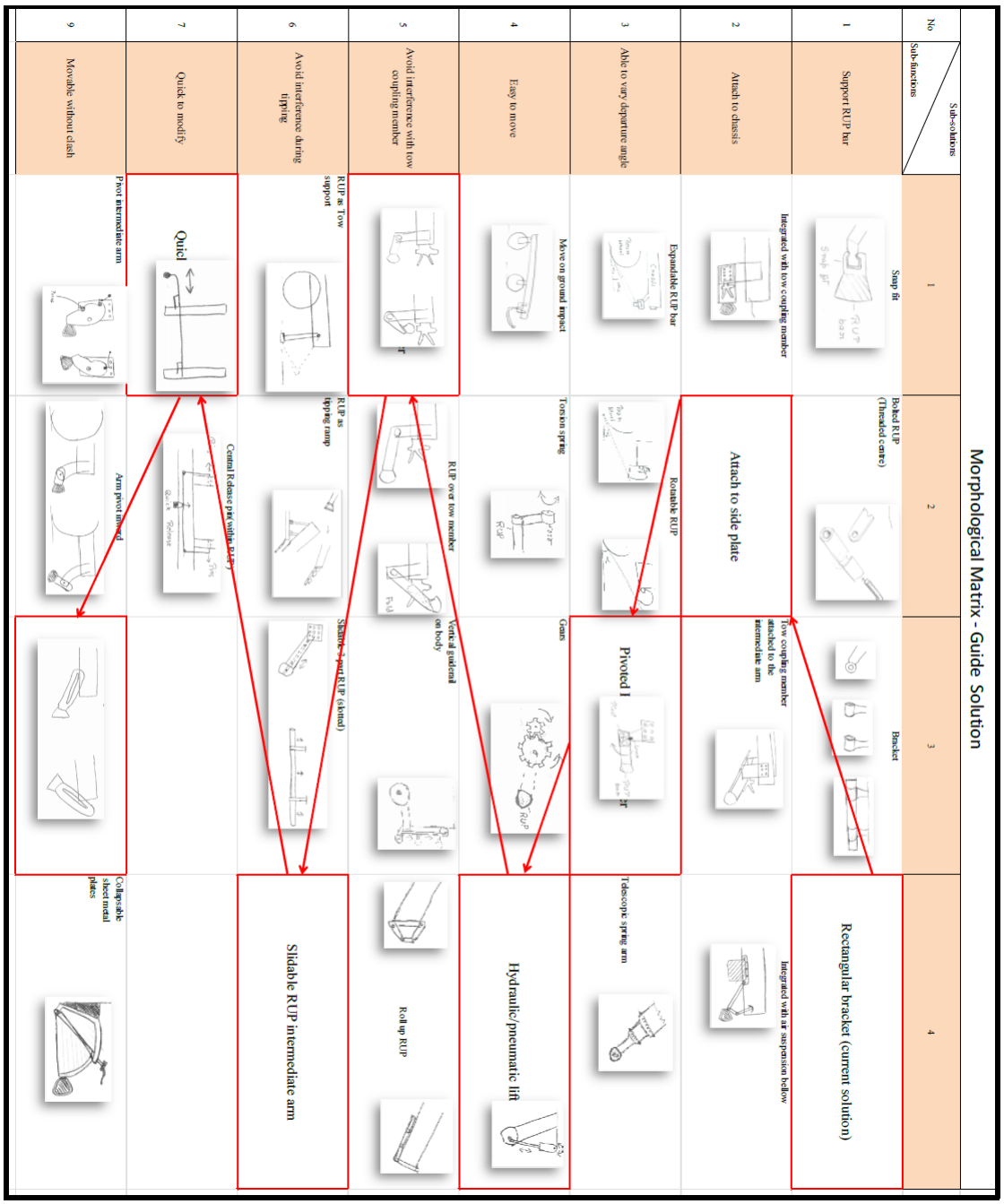


Figure 25: Morphological matrix of the guide profile

Through the combination of sub solutions as shown above, the guide concept was generated.

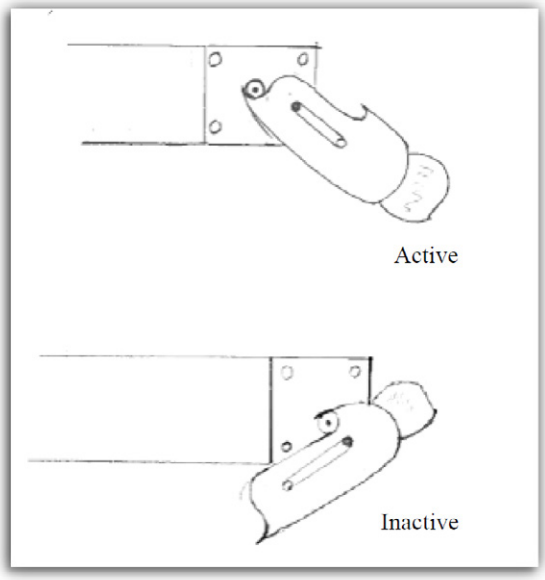


Figure 26: The guide profile

Features

This concept has a guide profile which will act like a stopper when in active position (top sketch) and as a support for intermediate arm when the RUP mechanism is folded (bottom sketch). The length of the intermediate arm is chosen such as to avoid the clash of RUP mechanism with the tow coupling member during the folding motion.

Advantages

- Common fixed stopper in the middle of the connecting plate
- A guide way profile that helps to rotate and retract the RUP close to the chassis

Drawbacks

- Sharp profiles are not conducive for manufacturing, usability and maintenance
- No easy to move option available in the current solution
- Only two steps of departure angles
- Extra stoppers may be necessary for stationary positions
- Complex geometry

Concept 2- The Stopper

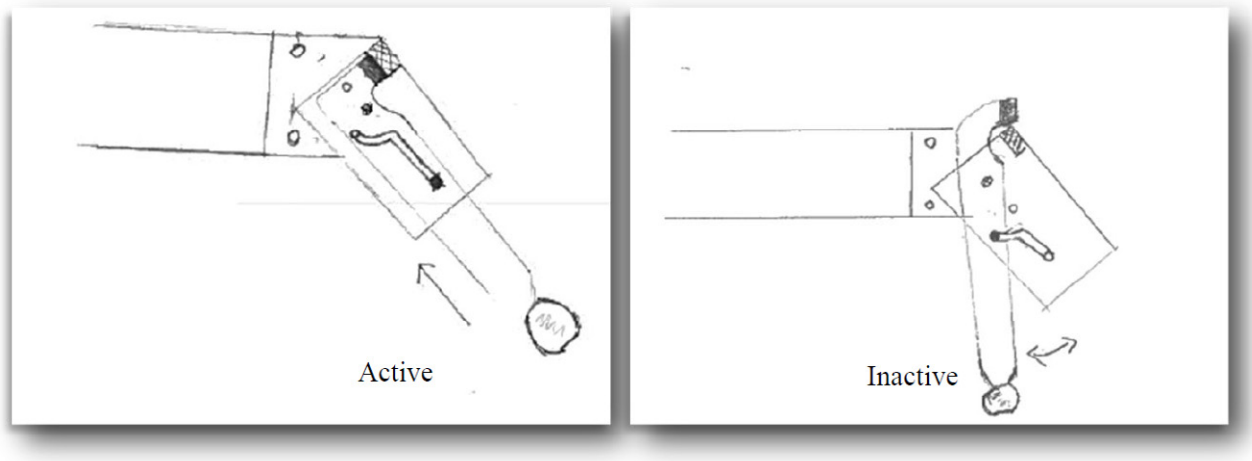


Figure 27: The Stopper

Features

This concept has a guide slot in the intermediate arm. A stopper has been provided to support the intermediate arm during impact. To operate the RUP mechanism, user has to remove the quick release pin, push the intermediate arm along the guide slot and put the quick release pin back in place.

Advantages

- The path is designed such that the intermediate bracket is pulled back as well as rotated thus avoiding the clash with surrounding parts e.g. air suspension
- Stopper provides extra resistance to any impact load on the RUP thus holding it in position rigidly

Drawbacks

- The guide slot makes the plate weaker in bending
- Limited space to maneuver due to space restrictions on the intermediate plate

Concept 3- The Plug

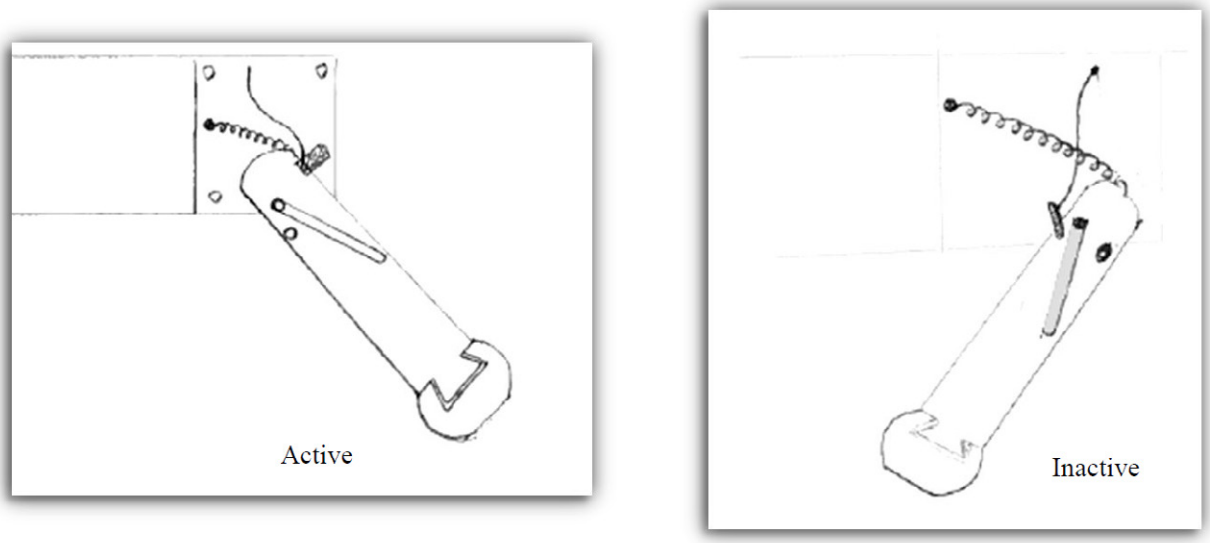


Figure 28: The Plug

Features

The quick release plug is provided to keep the intermediate arm in active position and in folded position when inactive. This concept has guide slot in the intermediate arm. The RUP bar has a feature to snap with the intermediate arm which makes the assembly and disassembly of the RUP bar very efficient. A tension spring helps in folding of the arm when the quick release plug is released. This makes it possible for the user to operate the RUP folding mechanism without much physical force.

Advantages

- Snap fit/removable RUP bar-intermediate arm interface
- Easy to operate due to tension spring
- Arm rotates about the pivot joint
- Two holes and a single quick release pin giving the arm two resting positions

Drawbacks

- The pivot joint is the only load bearing point which makes the arm weak on impact loading

Concept 4- The C-Arm

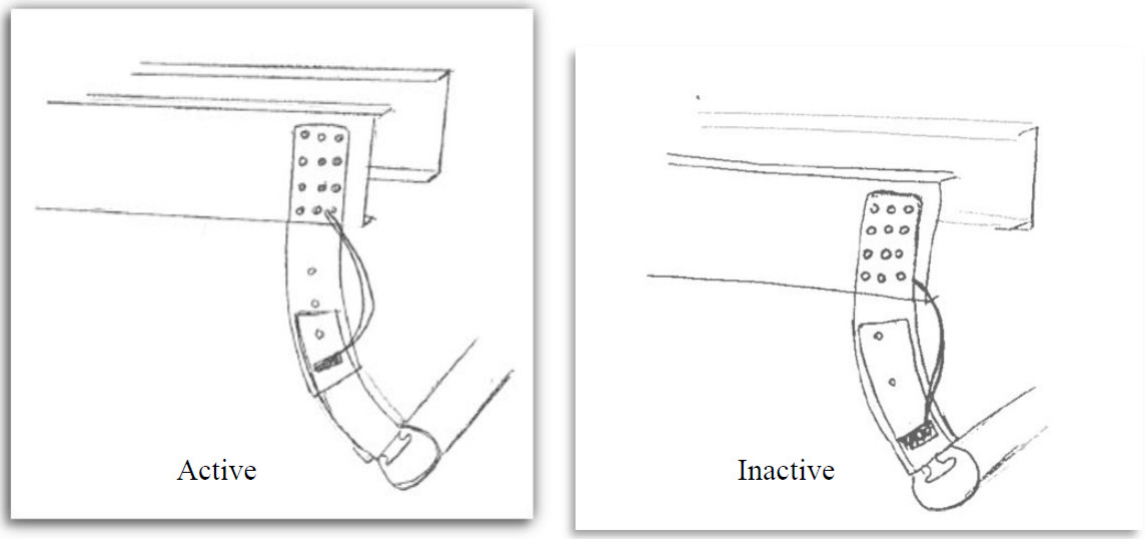


Figure 29: The C-arm

Features

The C-arm concept has an intermediate arm and connecting plate in the shape of the alphabet 'C'. This allows the motion of intermediate arm inwards and upwards simultaneously. This in turn helps in avoiding clash with surrounding parts mounted on the chassis. A quick release pin helps keep the intermediate arm in active and inactive positions.

Advantages

- A curved intermediate plate
- Secondary arm that slides within the intermediate bracket making the telescopic movement possible.
- Quick release pin helps to stop the bar at various positions.
- Occupies less space
- Elevates the RUP bar while retracting it at the same time.

Drawbacks

- No assistance for easy usage.
- Needs accurate geometry check in order to guide the intermediate arm precisely

Concept 5- The limb

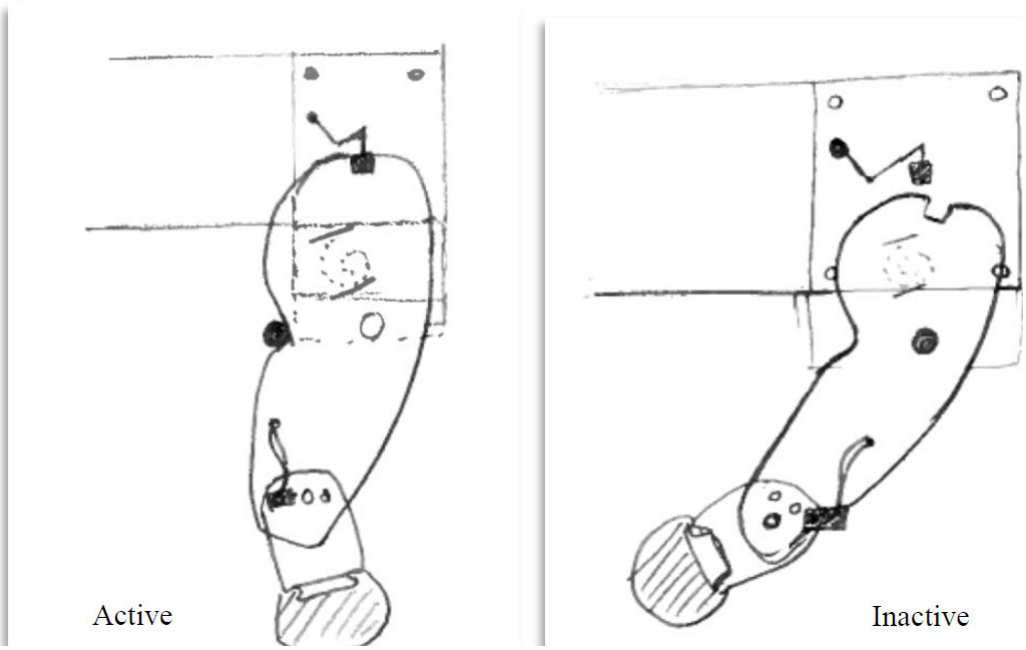


Figure 30: The Limb

Features

This concept has a limb (intermediate arm) equipped with a stopper at the top and two hole slot for keeping the limb in position with the help of a quick release pin. The limb also has several holes at lower end to adjust the RUP bar at varied departure angles.

Advantages

- Rotatable arm with a torsional spring at the pivot
- Detachable stopper to take impact loads
- Quick release pin with 2 resting positions
- Adjustable/rotatable RUP bar for extra variance in the departure angle

Drawbacks

- Too many moving components weaken the structure.
- Able to rotate only in one direction due to torsional spring.

Concept 6 – The threaded telescope arm

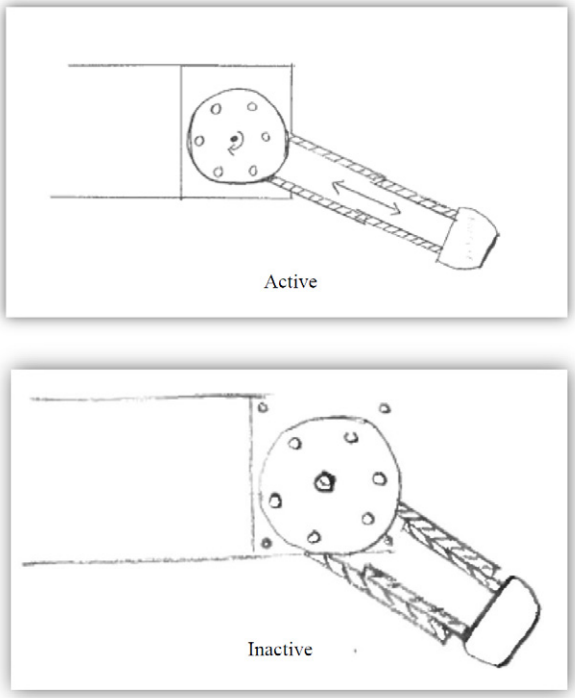


Figure 31: Threaded telescopic arm

Features

This concept has a telescopic arm that slides within the intermediate arm. RUP bar is attached to the intermediate arm. Since this is a telescopic solution it is a well packaged design. The angle of intermediate arm with the chassis is chosen so as to avoid the interference of the tow coupling member and the RUP bar during the sliding motion.

Advantages

- A disc shaped intermediate bracket for a wide range of departure angles
- Doesn't require much lifting force to operate as the arms are threaded
- Departure angle can be varied to the exact requirement

Drawbacks

- The thread needs to withstand large shear forces during the impact loads on the RUP
- Cumbersome to operate

Concept 7- The ring

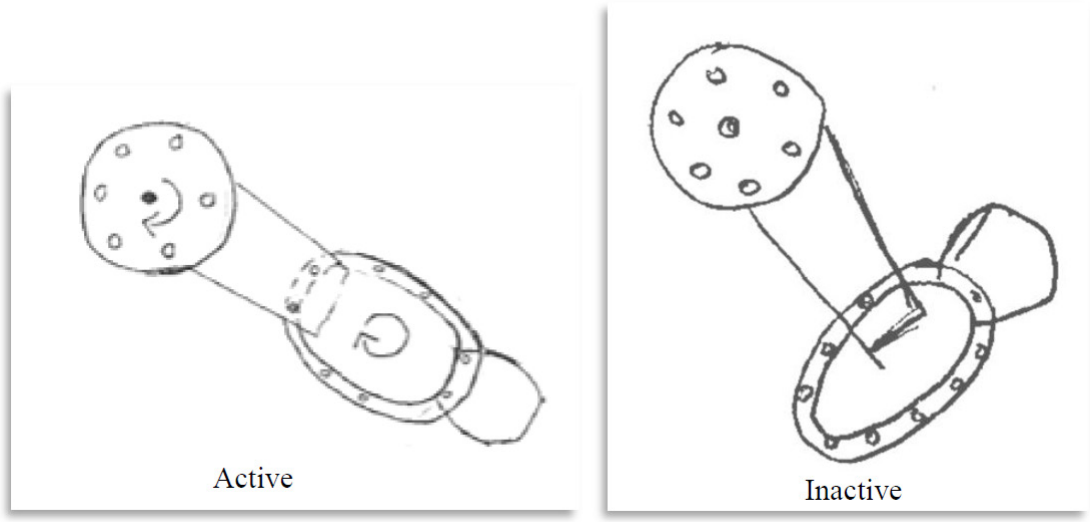


Figure 32: The Ring

Features

This particular concept has two circular plates with holes at the periphery. The intermediate arm in this concept is in the form of a circular plate. Holes are provided on both circular plates to give flexibility in departure angle.

Advantages

- Two identical circular plates reduce development cost
- Rotatable connecting plate for high variance in departure angle

Drawbacks

- Ring arm may not withstand forces.
- Complex geometry and tricky geometry assurance.
- No aid to ease the usage for the customers.

Concept 8- The lever

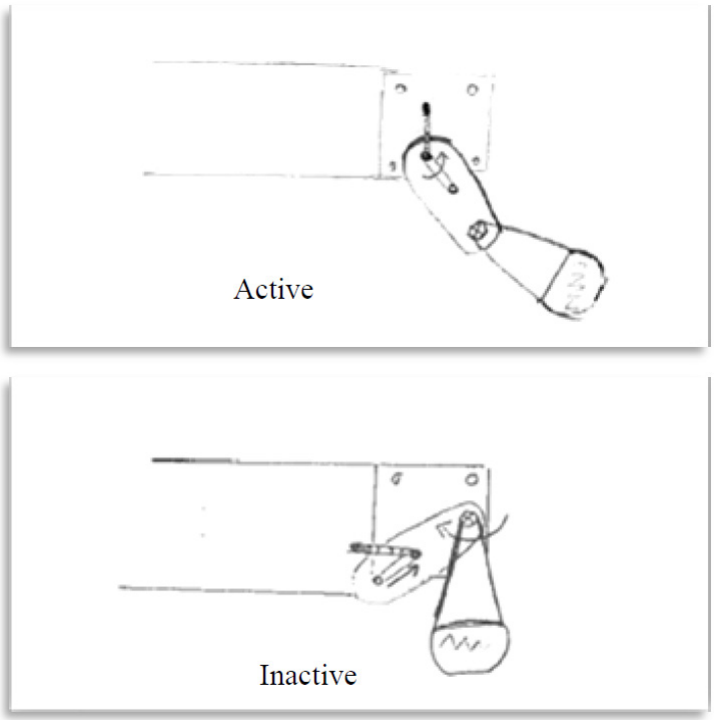


Figure 33: The Lever

Features
This concept has an intermediate arm split into two parts. The split arm allows folding the RUP mechanism as shown in the second sketch.

Advantages
- Two part intermediate bracket
- Rotatable lever for easy maneuvering
- A slot to pull the device even closer to the chassis to avoid clash with tow member and tipper

Drawbacks
- Split arm members decrease the strength of the device
- Additional stoppers are needed to support the device
- Slotted area is susceptible to shear forces

Concept 9- The epic roller split (Van Damme)

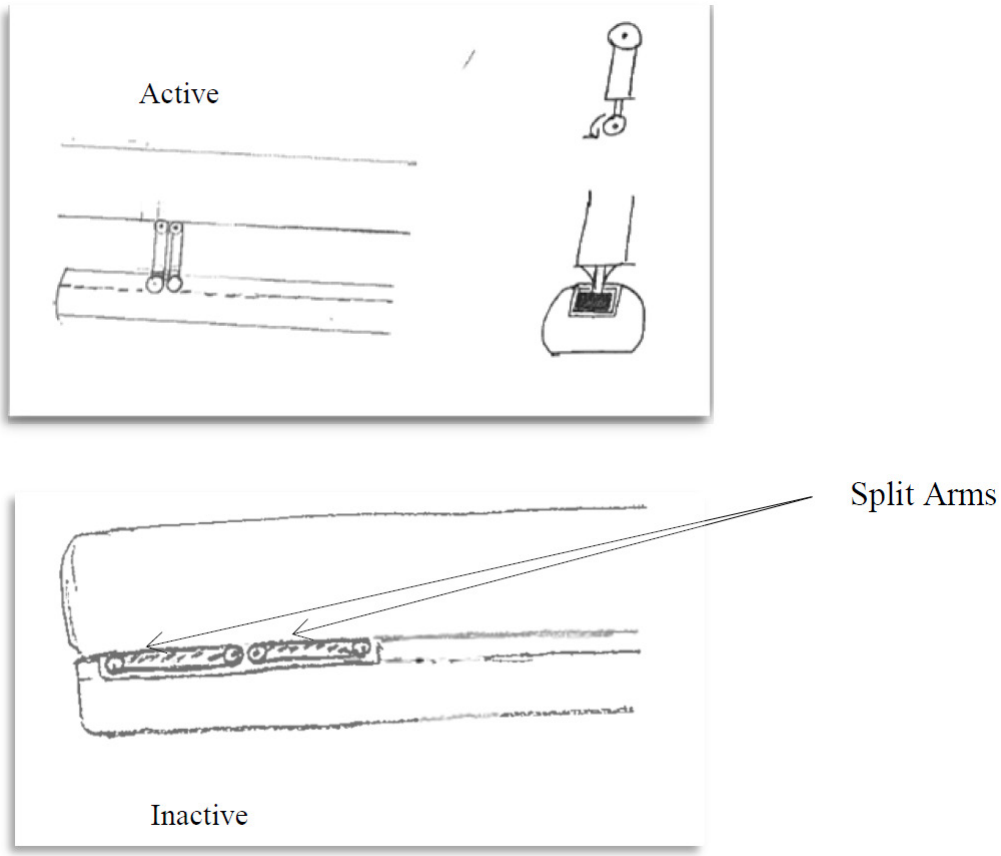


Figure 34: The epic roller split

Features

This concept has an intermediate arm which is attached to a slide on one end and hinged to the chassis on the other end. The sliding mechanism allows the intermediate arms to split and this take the RUP bar towards the chassis. As the name suggests, this concept has been inspired by van Damme and Volvo's 'Epic Split'.

Advantages

- Intermediate bracket is split into two
- Slidable and rotatable mechanism integrated with the RUP bar
- Brings the RUP closer to the chassis without any arm moving out of place
- Very compact packing

Drawbacks

- Guide way included in the RUP may affect its strength
- Rollers need to be pinned down strongly at the stationary positions

Concept 10- The two way foldable

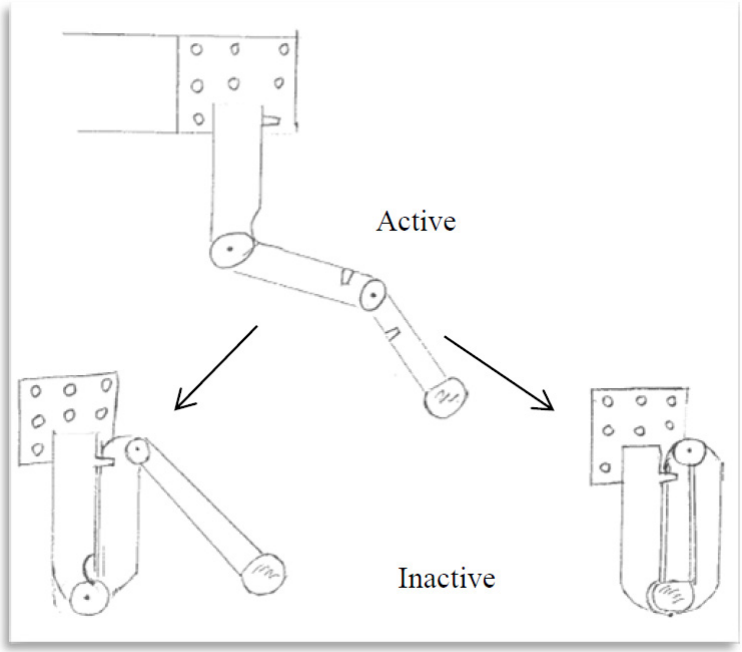


Figure 35: Two way foldable

Features

This concept features an intermediate arm which has a joint on both ends. These joints enable the RUP mechanism to be folded. The folding mechanism allows flexibility to increase the departure angle.

Advantages

- Three part intermediate bracket
- Two way foldable RUP mechanism with the RUP bar foldable (left) and packaged (right)
- Common wedge on the upper arm to keep the folded arms in position
- Two resting positions gives a greater flexibility in departure angle

Drawbacks

- Three parts makes the arm structurally weak
- Complex geometry checks have to be conducted

Concept 11- The triple RUP

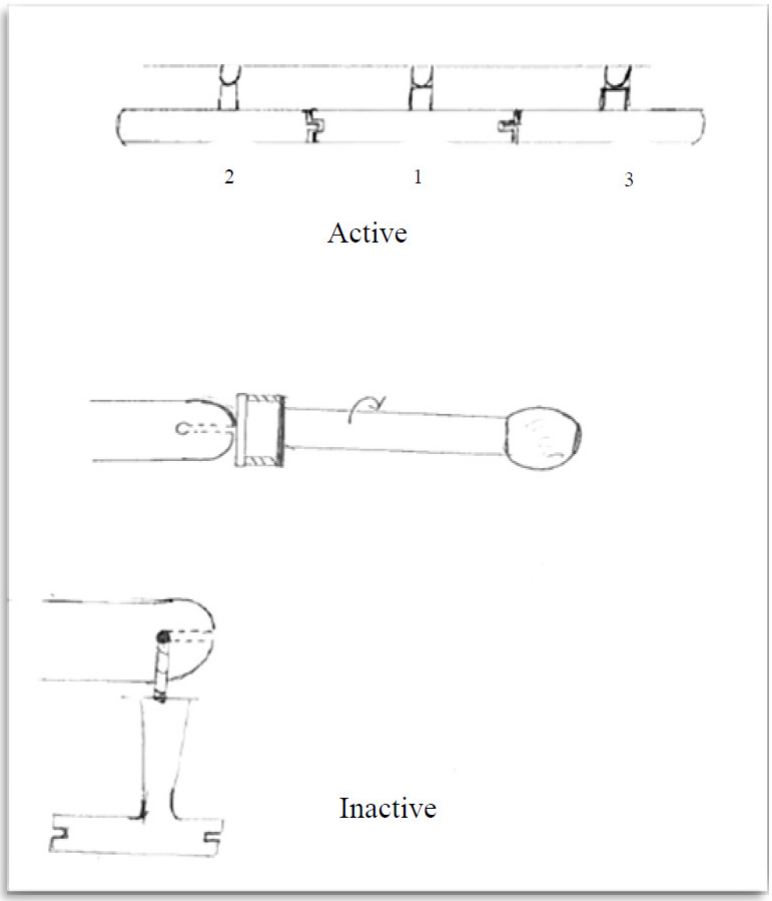


Figure 36: The triple RUP

Features

This concept has RUP bar split into three parts (1,2,3). These parts are connected to the chassis with a hinge joint. This joint enables parts 2 and 3 to fold out leaving part 1 free to rotate to the underside of the chassis thus getting out of the way. This concept can be seen as a collapsible RUP bar.

Advantages

- Three part RUP bar that can collapse which means it occupies less space
- Slotted connecting arm and a spring loaded pivot point that fits into position on correct orientation
- Two degrees of freedom in terms of rotation for each part. One to dismantle the RUP and one to place the bar under the chassis.

Drawbacks

- Orientations of the bars and the geometry assurance have to be perfect
- Length of the bar hanging beyond the chassis after folding it in has to be minimized
- Bar should be of appropriate length so it doesn't interfere with the parts under the chassis and also have an adequate ground clearance

7.4 Funneling down concepts

Concept selection tool helps to make decision on the concepts generated. In this method the concepts having multiple features can be ranked quantitatively. In this project, weighted decision making matrix is used. The concepts are expected to satisfy several criteria as mentioned in the matrix which have been weighted based on the importance it holds for this particular problem definition (discussed in chapter 1.3).

The concepts above are the earliest drafts. The refinements that were made after receiving feedback from Volvo were put into the concept selection matrices. The current RUP- FOSL (foldable and slidable) solution is used as datum or reference for rating the concepts.

7. 4. 1 Pugh matrix

This is used as a screening tool in order to select the best suited solutions for further development. This is done by formulating selection criteria initially. These criteria originate from the demands on the specifications and wishes of the stakeholders. Furthermore, values are assigned for each concept after evaluating the design. The different concepts are compared with a reference solution which is usually the current solution. Pugh matrix selection is based on whether the concepts are better (1), equal (0), or worse (-1), as compared to the reference solution, the RUP-FOSL which is scored as neutral or 0 in every function. In this project, a total of eleven concepts were generated. The concepts generated were compared with nine selection criteria.

The concepts which scored a positive score are the concepts which are better than the current solution. These concepts were taken forward for further improvements and screening. The concepts that scored lower than the reference were modified to overcome their shortcomings with regard to that particular function and thus improved their respective scores.

Table 4: Pugh matrix

Pugh Matrix

				Alternative Concepts											
Sr. No	Criteria	Weights (1-10)	FOSL	The Stopper	Plug	C-Arm	Limb	Threaded telescopic	Ring	Lever	Guide Profile	Van Damme	Two way foldable	Triple RUP
1	Avoid clash during operation	10	0	1	1	1	1	1	1	1	1	1	1	1
2	Withstand impact loads	8	0	0	-1	0	-1	-1	-1	-1	0	-1	-1	0
3	Compactness	6	0	1	1	1	1	1	1	1	1	1	1	-1
4	Assembly	7	0	0	0	1	-1	0	0	-1	1	-1	0	-1
5	Cost efficiency	5	0	0	0	1	-1	1	1	-1	1	-1	-1	-1
6	Easy to operate	8	0	-1	-1	-1	-1	0	-1	1	-1	0	-1	0
7	Aesthetics	5	0	-1	1	1	0	1	0	-1	1	0	-1	-1
8	Change in departure angle	7	0	0	1	1	1	1	1	0	1	0	1	-1
9	Simplicity in design	8	0	1	1	1	-1	1	1	-1	1	-1	0	-1
10	Ease of Maintenance	6	0	0	1	1	-1	0	1	-1	1	-1	1	1
	Final score			11	26	46	-19	33	26	-15	46	-18	3	-22

7. 4. 2 Improvements from Pugh Matrix

Once the concepts have been put through the selection tools, it is important to take a step back and reflect on the choices we have made and process we have followed in doing so. Once the negative points of each concept were well established, the process of combining various concepts began thus improving their rating in the selection tools.

The Pugh analysis highlighted the weaknesses of the initial concepts. Later the process of strengthening the concepts began by tackling the weak areas of each concept. It is important to know the weaknesses at an early stage to save precious time during the detailed development phase. The changes made to the initial concepts are as follows:

Concept - Stopper

This solution is a combination of the Plug concept and Stopper concept. The shortcomings in both these concepts resulted in a low score for the pair. The stopper was on good at varying its departure angle whereas the plug was not good at withstanding impact loads. Hence a combination of the two solutions yielded a much more complete solution overall.

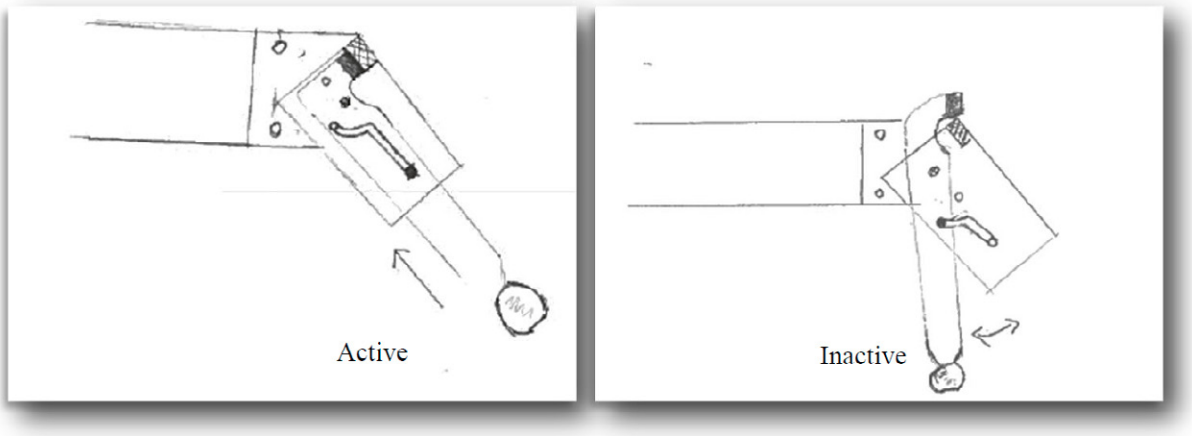


Figure 37: The Stopper

Concept - The C-Arm

The C-Arm initially scored low in the load capacity and the ease of operation. This initial concept was improved by adding bushings at the periphery of the connecting arm plate in order to improve the ease of operation. This also allowed the center arm to traverse properly within the C-section of the base plate and the since concept was susceptible to impact, the guide slot within the center plate was removed.

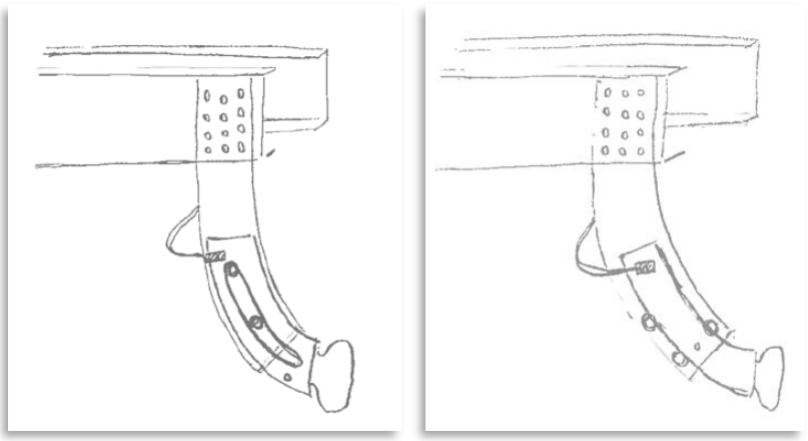


Figure 38: (Left) C-arm with guide slot, (Right) C-arm without guide slot but with guide rollers

Concept - The Guide

The guide concept scored low in the load carrying capacity. To improve this, guide profile was closed and turned into a slot rather than an open ended one.

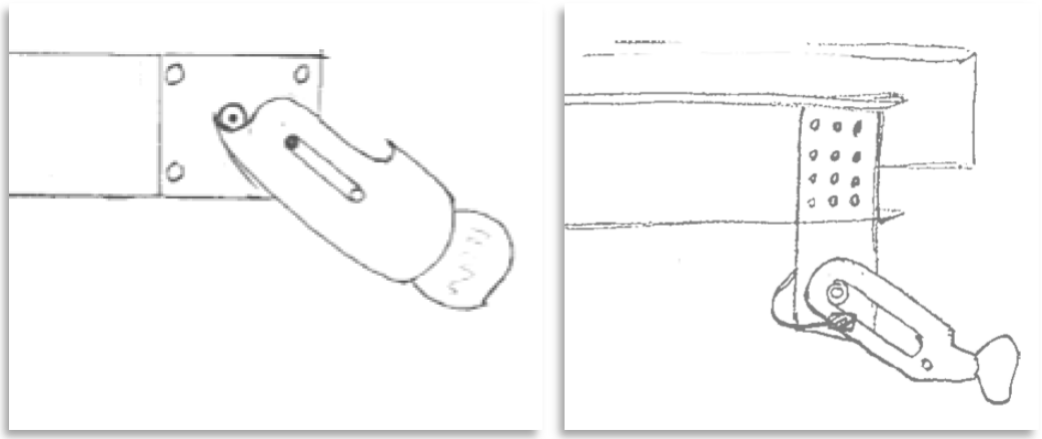


Figure 39: (Left) Open guide slot, (Right) closed guide slot

Concept - The threaded telescope arm

The threaded telescopic arm scored low on the load capacity because of the threading was modified to add flaps for stoppers with adjustable departure angle. Threaded arm was thus modified. Refer **Figure 40** below

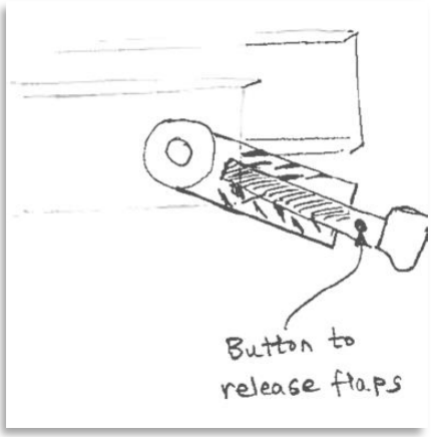


Figure 40: The threaded telescope arm

7. 4. 3 Kesselring matrix

Kesselring matrix is a tool used to score different concepts after the Pugh screening (Johannesson, H. 2013). Once the concepts were funneled down and refined from the Pugh matrix, seven concepts were still in consideration and from these, four of them were selected for system level design phase where they would be designed using CAD software so a thorough assessment can be made . The following section shows the funneling down of several concepts to four and brief justifications for the decisions made with the help of the Kesselring matrix.

In this method, weights are assigned to each selection criteria and the ideal solution is considered to be a solution which has highest score on a chosen scale for every selection criteria. Further values are assigned to all concepts for each of the selection criteria. Therefore, to get the score for a particular concept one has to sum up the product of the weights assigned to selection criteria and the values assigned to each selection criteria in comparison with the ideal solution for that concept. After comparing the scores the best possible solutions emerge as winners. These solutions are further developed in the later stages of the project. (Refer table 5)

The criteria were weighted and the concepts were rated with regard to each of these criteria as shown in the above table. We can see that four concepts namely, Telescopic, Plug-Stopper, Guide and C-Arm stand out from the rest with higher scores and these were the ones chosen to proceed to the system level design phase.

Table 5: Kesselring matrix

Kesselring Matrix

				Alternative Concepts									
Sr. No	Criteria	Weights (1-10)	Ideal	The Plug-Stopper	C-Arm	Limb	Threaded telescopic	Ring	Lever	Guide Profile	Van Damme	Two way foldable	Triple RUP
1	Avoid clash during operation	10	10	7	9	8	8	6	6	8	9	6	6
2	Withstand impact loads	8	10	8	9	6	7	6	5	8	4	4	7
3	Compactness	6	10	6	8	6	7	7	7	7	9	6	5
4	Assembly	7	10	7	7	7	7	7	7	7	7	7	7
5	Cost effeciency	5	10	8	7	5	6	7	7	8	3	7	6
6	Easy to operate	8	10	7	7	8	8	8	7	6	8	6	7
7	Aesthetics	5	10	7	7	6	8	5	5	8	7	5	5
8	Change in departure angle	7	10	7	7	8	7	8	8	8	6	8	3
9	Simplicity in design	8	10	7	8	6	6	7	6	8	6	7	5
10	Ease of Maintenance	6	10	7	7	6	7	6	6	8	5	7	6
	Final score		700	497	540	472	500	471	447	531	459	439	403
	Percentage		100	71	77,1429	67,4286	71,428571	67,28571	63,86	75,857	65,571	62,714	57,5714
	Comments												

7.5 System level design

In the steps prior to this stage, the project team was focused on the core product and its main functionalities. It was based on prospective design rather than in-depth detailing. At the system level design stage, the focus is on the detailed architecture of the product with focus on adding details to and additional functionalities to the product. The product architecture defines the product in chunks, or the primary functional systems and subsystems, and how these systems are arranged to work as a unit. (Riley, R.Q, 2014). Parts that are readily available as standard parts and those that have to be newly designed are mentioned in this section.

Concept: Stopper

The Stopper concept consists of two plates, the back plate that is mounted onto the chassis and a front plate that sandwiches the center arm in-between. There are two stoppers, one for the active and another for the inactive position. Also included are two bushings on the center arm.

The concept as the name suggests has a stopper (depicted in blue) for providing support during active position. The bushing which is inside the guide slot will facilitate the motion and is also the pivot point of the arm (depicted in orange) and the bushing which is provided outside the guide slot will help to support the arm active position and also guide the arm into the inactive position.

As the arm is pushed up, the depression in the arm locks itself in position and the head of the arm rests on the upper stopper. This means that in the inactive position, the arm is pushed upward and backward. It is held in this position with the help of a quick release pin. The pin is spring loaded and is operated by a button that releases the pin.

The two stoppers also act as spacers to hold the two plates at the appropriate distance.

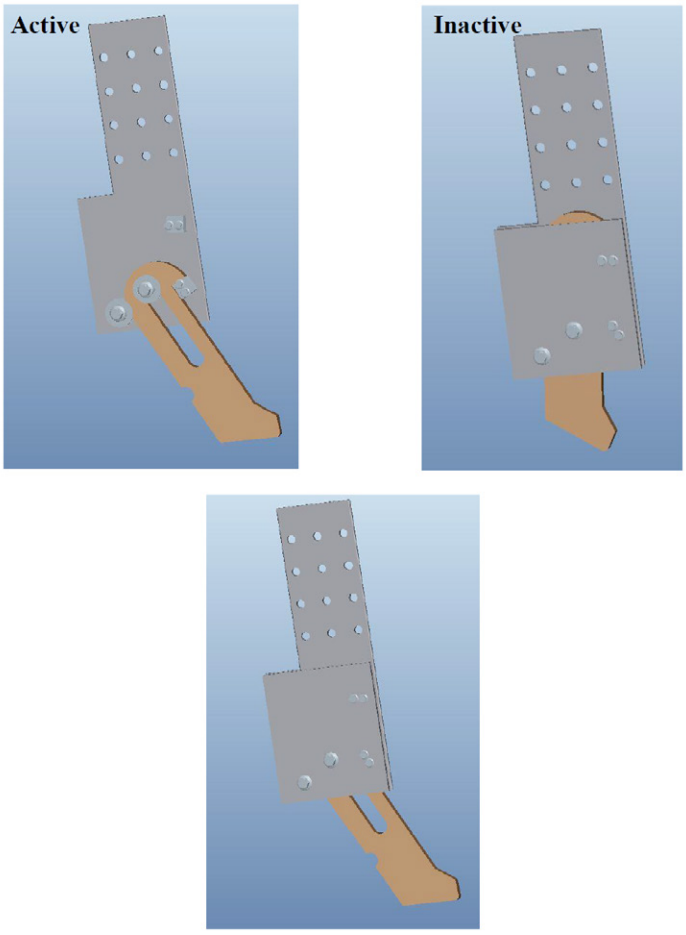


Figure 41: Stopper

Concept: C-Arm

This solution like the Stopper is also a sandwiched solution with a back plate and a cover plate sandwiching a center arm between them. Unlike the Stopper however, the C-Arm follows a curved or a 'C' path when is it pushed up from an active to inactive position. Apart from this, the C-Arm has 3 bushings, a spacer and two quick release pins.

The center arm of this solution has a curved profile and a curved head that can rest on the bushing in its active position thereby giving it increased support. It is locked in position by the bottom quick release pin.

When the arm has to be pushed up, the user must release the pin and push the arm up. The arm is guided by the bushings on either side of it. When the hole on the arm matches the one on the plates, the upper quick release pin has to be pinned in. This keeps the arm in its inactive position. The lower pin can also be pinned on to give it extra stability.

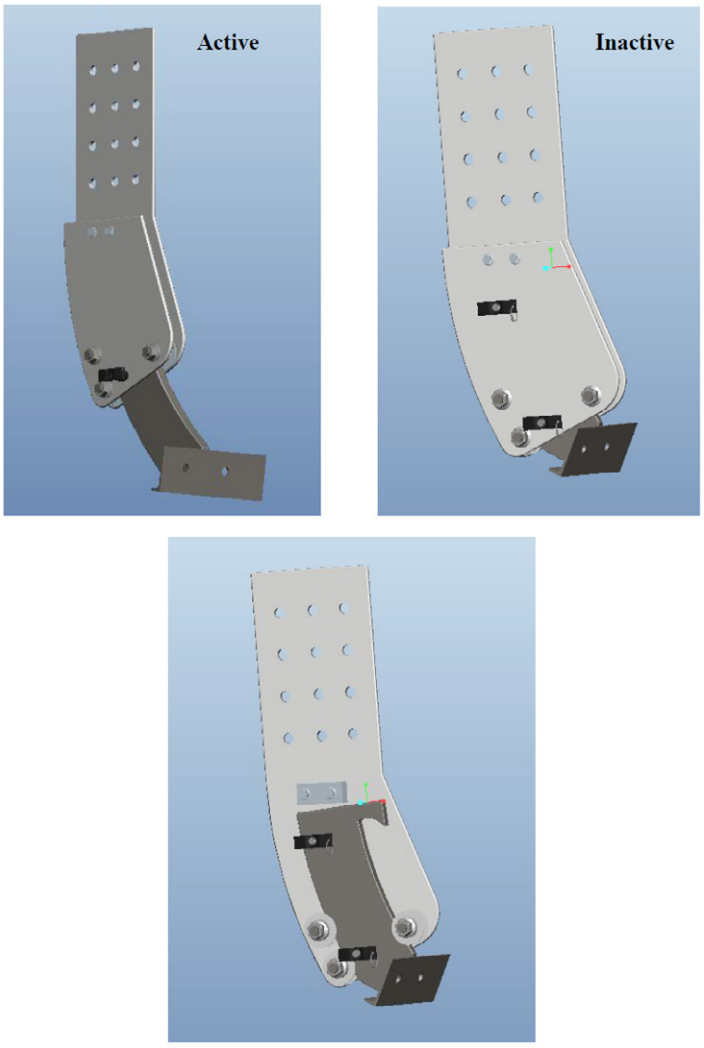


Figure 42: C-Arm

Concept: Telescopic

This solution consists of a telescopic arm (in blue), a sleeve cum back plate into which the telescopic arm collapses and a button (in orange) to engage and disengage the arm.

In its active position, the button is at the lower of the two holes on the sleeve. The arm is lowered into position and is held in position by the button. The rear side of the sleeve has a slot (not seen in pic) that helps guide the arm and also keep it stable during action.

When the button is pushed down, the arm is disengaged and is free to move along the guide and a wedge is built at the edge as a safety feature to prevent the arm from sliding down and out of the sleeve. As the arm is pushed upward, the button engages itself again on aligning with the upper hole on the sleeve. This is the inactive position of the telescopic solution.

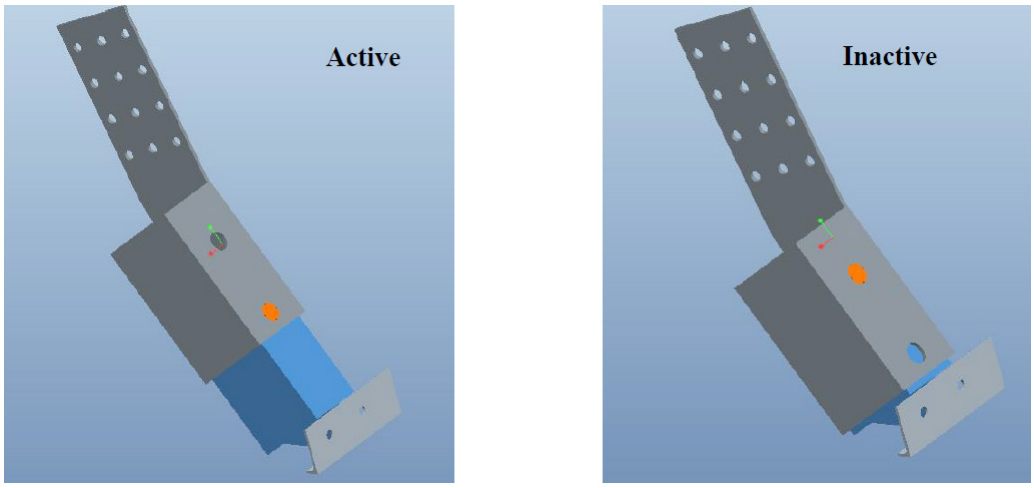


Figure 43: Telescopic

Concept: Guide

The guide solution consists of a back plate similar to the rest of the solutions. There is also a bushing and a circular stopper. The actual arm has the guide or a slot from which the name is derived. A quick release pin (not seen in pic) is included as well.

The center arm has a semi-circular depression into which the circular stopper is inserted thus preventing the arm from clockwise rotation and also prevents upward movement on impact. The quick release pin on the other side of the stopper arrests the arm in anti-clockwise rotation.

The quick release pin is released and the arm is free to rotate and when the guide matched the pin hole, the pin can be fitted back into position thus turning it into a makeshift bushing that helps the arm stabilize and guides it into its inactive position.

Even though system level design involves looking at the product as a whole and not focused heavily on the individual component, it was decided that CAD models of the concepts would be better in terms of visualization, functional understanding and for further improvements. Hence the four concepts were refined slightly and designed in the CAD software as seen above but many details were yet to be added. This in depth understanding was necessary as the four concepts above were to be narrowed down to two final concepts in the final concept selection step. These two would go on to the detailed designing stage.

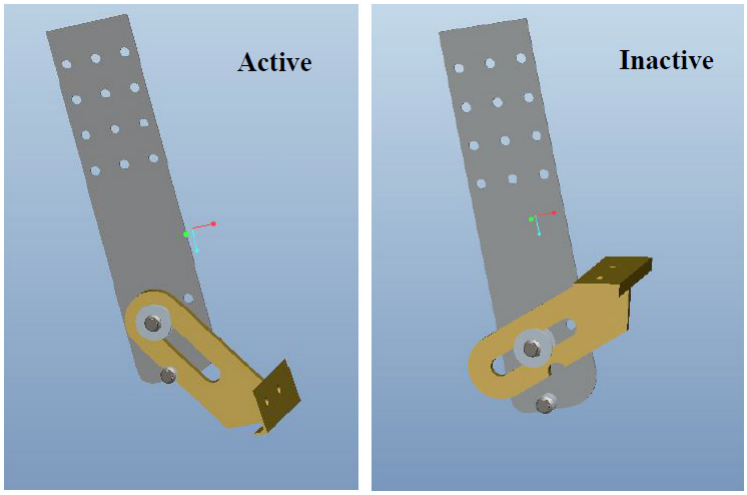


Figure 44: Guide

7.6 Final concept selection

The elimination of two concepts was done using a Kesselring matrix. The criteria used for rating the concepts were similar to the previous matrix barring two new criteria, tooling cost and cost of development of non-standard components.

The tooling cost is calculated according to the new tools required to manufacture the product apart from the ones already available at Volvo for current production needs. Cost of new components is the cost of components that have to be designed and manufactured specifically for the new product and not available in Volvo's current inventory. Aesthetics of the product is a difficult criterion to rate as it is quite subjective. Hence this rating was done using a focus group that consisted of experienced Volvo group professionals who have experience in this field.

The resulting Kesselring matrix is as shown below.

The matrix results in the elimination of the Stopper and the Telescopic concepts owing to the scores they received. This means that the C-Arm and Guide are the concepts that go through to the detailed design stage and are chosen as the final concept for this project.

Table 6: Kesselring matrix for final concept selection

Kesselring Matrix Final Selection

				Alternative Concepts			
Sr. No	Criteria	Weights (1-10)	Ideal	Stopper	C-Arm	Telescopic	Guide profile
1	Avoid clash during operation	10	10	7	8	8	7
2	Withstand impact loads	8	10	7	7	4	7
3	Compactness	6	10	5	7	8	7
4	Assembly	7	10	6	7	6	8
5	Easy to operate	8	10	8	8	7	8
6	Change in departure angle	7	10	7	6	6	7
7	Simplicity in design	8	10	7	5	5	8
8	New component cost	8	10	7	8	5	9
9	Tooling cost	9	10	8	7	5	8
10	Aesthetics	5	10	5	9	7	8
11	Ease of Maintenance	6	10	7	5	6	7
	Final score		820	562	575	496	627
	Percentage		100	68,53658537	70,12195122	60,48780488	76,46341463
	Comments						

7.7 Detail designing

Detail designing is a phase in which every component is focused on individually and as a whole and necessary details and engineering go into every one of them (Riley, R.Q, 2014). The details are implemented in the three dimensional solid CAD models of the concepts. Each component is designed for manufacturing and should be ready enough to send forward for prototyping.

The CAD models for the two final concepts were not done in a single shot but in loops as the norm in industrial product development. The concepts were designed, tested, analyzed and redesigned to overcome the shortcomings and fare well in the tests. The following text explains the design test loops that the guide and the C-arm concepts passed through till they were ready to be prototyped physically.

Concept: Guide

In the first cycle of detail designing as shown in the figure above, the main focus was to bring up the maturity of the concept from a conceptual level to a practical level. The following are the main detailed additions to each of the components of the concept in this loop.

Back plate

- The extra material has been added to accommodate the quick release pin.
- Position of the pin has been lowered to avoid the arm clashing with the towing member when it is in the inactive position.(E)

Arm

- The slot has been shortened to reduce stress concentration around it and to make the arm more stable (A). This reduces the probability of the arm splitting upon collision.
- Two holes are provided in the arm for two different inactive positions.
- A gas spring is designed and mounted on the plate to help in the ease of motion of the RUP mechanism.

Add-ons

- New quick release pin is designed for the concept.

In the second design cycle of the guide concept, the focus was to make the product ready for prototyping. This needed a more scientific approach as at this stage; the design changes that needed to be done were not obvious to the naked eye. As a first step, a quick-fire finite element analysis was conducted. The purpose of this simulation was to find the hotspots in the design that might experience high stresses or deformation and make changes to the design accordingly and hence the actual value of the experienced stresses weren't as important as finding the weak areas at this stage of the development. The software used was Inspire (Beta)

Boundary conditions used for the FEA simulations:

- Material used is structural steel on all parts
- The hole rows on the back plate used for mounting the concept were arrested in all DoF (Degrees of freedom)
- 180kN force normal to the RUP interface plate as this is the worst case scenario (P2 load-Refer table 1)

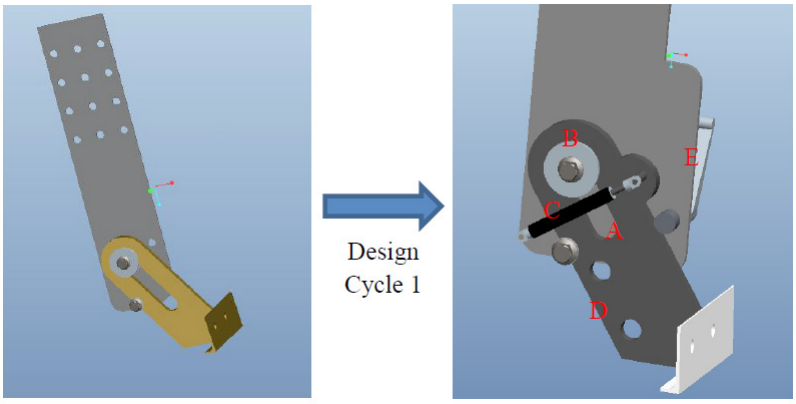


Figure 45: Guide (Design cycle 1)

Von-misses stress and deformation experienced by the arm were the significant results from this test. The portion encircled in the figure above shows the area of the arm that needed attention. On careful analysis of the hotspots, it was concluded that major stress concentration occurred in the areas close to the slot and the holes and this portion needed to be reinforced. Taking these observations into considerations, the following design changes were made.

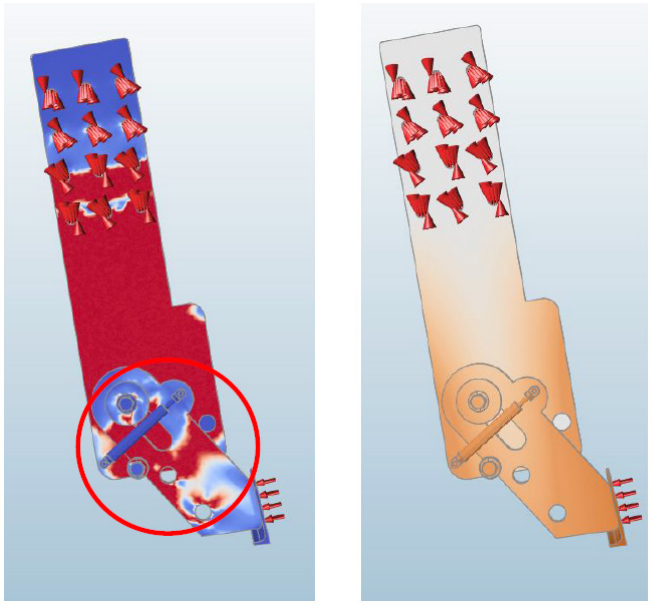


Figure 46: Guide (FEA results for stress and deformation)

Back plate

- Better finish on the plates with fillets added everywhere and sharp corners eliminated for better durability and manufacturability (A)
- A wedge added onto the back plate to limit the arm from rotating further and to keep it aligned to the hole (B)

Arm

- A single, smaller hole instead of two holes which were deemed to be unnecessary.
- Better finishing of the arm with rounded edges.

Add-ons

- Standard quick release pin was used to match the smaller hole and also to eliminate the cost of a brand new part.

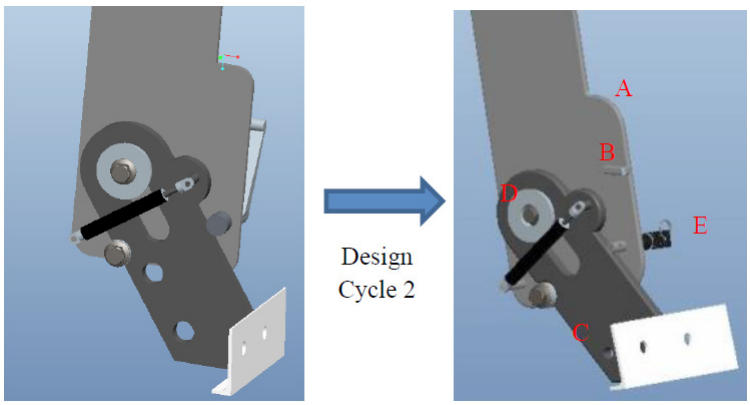


Figure 47: Guide (Design cycle 2)

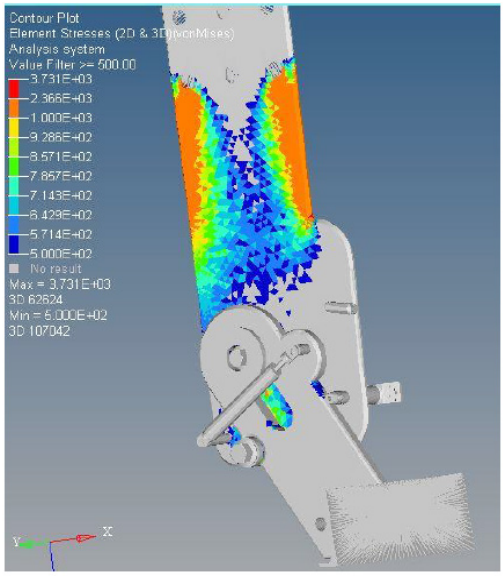


Figure 48: Guide (Final FEA results)

The final model was then put through another finite element analysis for verification. This time around a more thorough testing was done. The software used was Hyperworks (Basic FEA workbench) which is more sophisticated in terms of meshing and the algorithms used to solve the equations. The same load case and boundary conditions were used. The material on all parts was Steel (AISI 304). The results of this analysis are seen in the figures below:

For the ease of understanding, the range of forces depicted in the above figure is >=500MPa. Steel AISI 304 has a yield stress of 520MPa which means it is safe on collision below this range. The main focus of our analysis is the arm of the solution which is most likely to fail and as this arm shows no signs of stresses over the safety limit, the solution is deemed safe.

Concept: C-Arm

The C-Arm concept has one cycle of design changes and two verification stages (FEA)
The first design cycle was a combination of design changes that were made from observations and also from the finite element analysis.

FEA: Loads and boundary conditions

- All holes in the back plate were arrested in all DoF.
- A force of 180kN applied on the RUP interface plate(P2 as mentioned in table 1)
- Material for all parts was structural steel
- Software used was Inspire(Beta)

The basic software was used to run quick simulation and identify the problem areas in the solution. This and keen observations on the models lead to the following design changes

Back plate

- Better finishing with rounded edges and elimination of sharp corners.

Arm

- The curvature on the head of the arm was modified at this stage for two reasons. One was to fit the round bushing/stopper on which it rests when in the active state and the other is a result of the FE analysis which showed stress concentration due to a steep angle of the curvature and demanded a smoother curve and more material to be added at that region.(B)
- Better finishing of the arm especially along the edges which showed some hot spots due to sharp corners.

Add-Ons

- Single quick release pin instead of two as two pins meant more work for the user in changing the position of the arm. Moreover the extra pin provided little improvement in terms of strength and stability.(A)

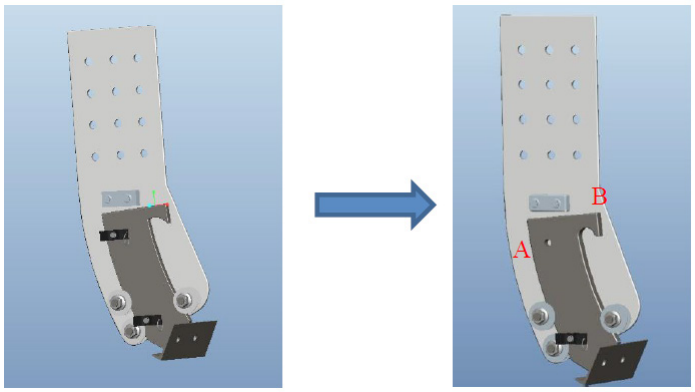
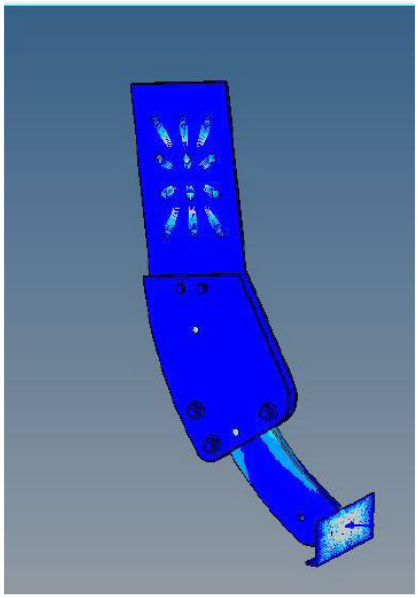


Figure 49: C-Arm (Design cycle)

Figure 50: Guide (Final FEA stress plot)



The final FEA was conducted as a verification step to validate the design changes that were made in the design cycle. The loads and boundary conditions remain the same. The software used was Hyperworks for a more sophisticated analysis. The material for all parts was chosen as Stainless steel (AISI 304). The results of this analysis are shown in the plot below.

Figure 51: C-Arm (Final FEA Stress plot)

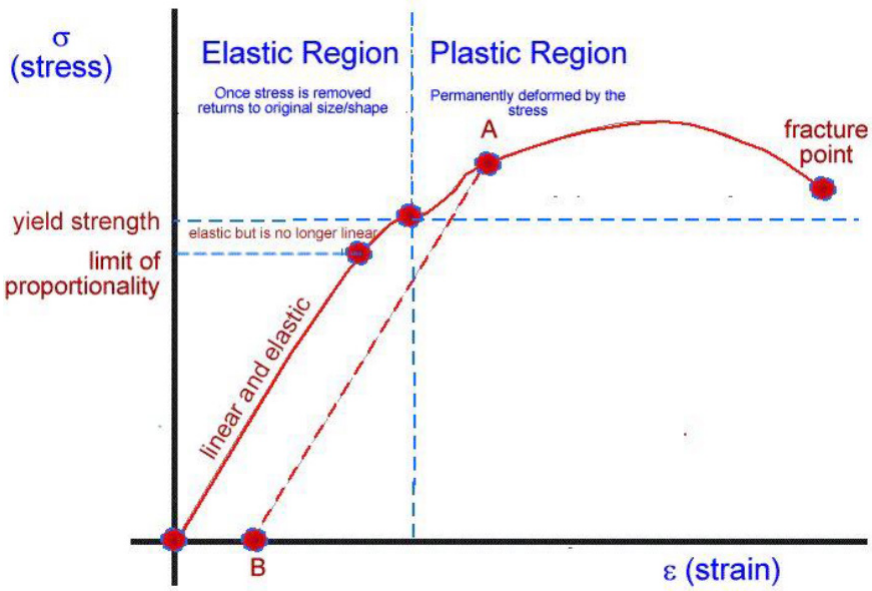


Figure 52: Stress-Strain curve for steel

To sum up this phase, much better and much more complete solutions were generated as a result of this phase. One must note that the Finite element analysis conducted here is a linear static load case only due to license restrictions of the software. So the FEA is used as a tool to detect critical regions in the design and not to test the strength of the material. Hence the high values of stresses that are seen in the results are not realistic as the material would enter a non-linear region of elasticity and further into plastic region much before reaching these values of stresses as seen in figure 50. Hence a more reliable condition to run an FEA simulation would be to conduct a non-linear load case and run the complete model with all the forces P1, P2 and P3 (refer **Table 1**) in their appropriate positions

7.8 Modularity and Flexibility of design

To address the requirement of the concept being designed flexibly so as to fit various chassis heights, the side plate has an inherent design feature such that it can be easily modified. The side plates will be produced with various set of lengths (see **Figure 53 & Figure 54**) to address to meet this requirement.

Even though the side-plate is different for different chassis heights the RUP mechanism remains constant. Thus by increasing the common parts within the RUP variants, Volvo can take advantage of economies of scale and thus lower the production cost.

In the **Figure 53**, L1, L2 and L3 indicate variable lengths of side plate to fit different chassis heights. These lengths are just an example of how the concept can be varied in dimension without having to redesign or modify the mechanism. Another advantage is that most of the parts remain the same apart from the side plate's length. This greatly decreases the inventory cost of Volvo.

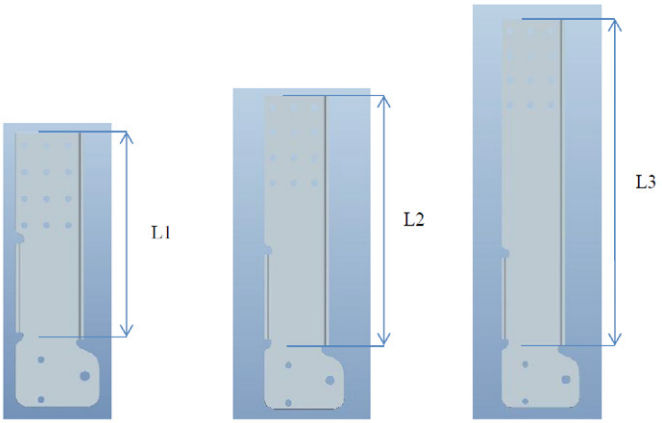


Figure 53: Guide Concept: Different lengths of side plates to fit various chassis heights (L3 > L2 > L1)

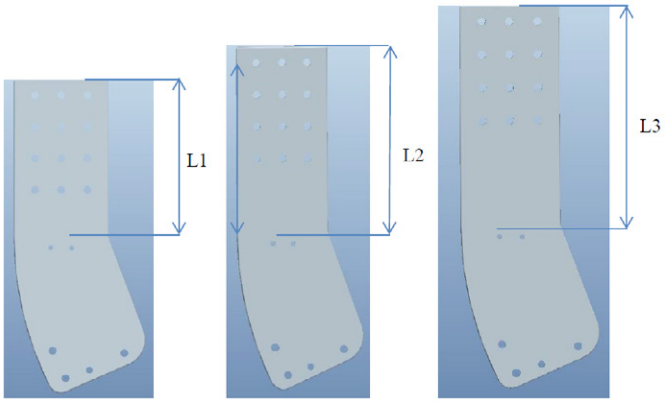


Figure 54: C-Arm Concept: Different lengths of side plates to fit various chassis heights (L3 > L2 > L1)

8. Refinement and deliverables

This chapter takes the reader through the product development phase of testing and refinement. As mentioned before, there are five main deliverables at the end of the project. The testing related to FEA, prototypes and inputs from the FMEA (Failure Mode Effect Analysis) is part of this chapter.

8.1 Prototype

Ulrich (2012) describes prototypes as an early approximation of a product in the development. The following section describes the physical prototypes created in the project. The SLS prototypes were made after the number of concepts were narrowed down to two. These prototypes were tested for proper physical functionality. Functional analysis of the SLS models provided many inputs which were used to further develop the concepts.

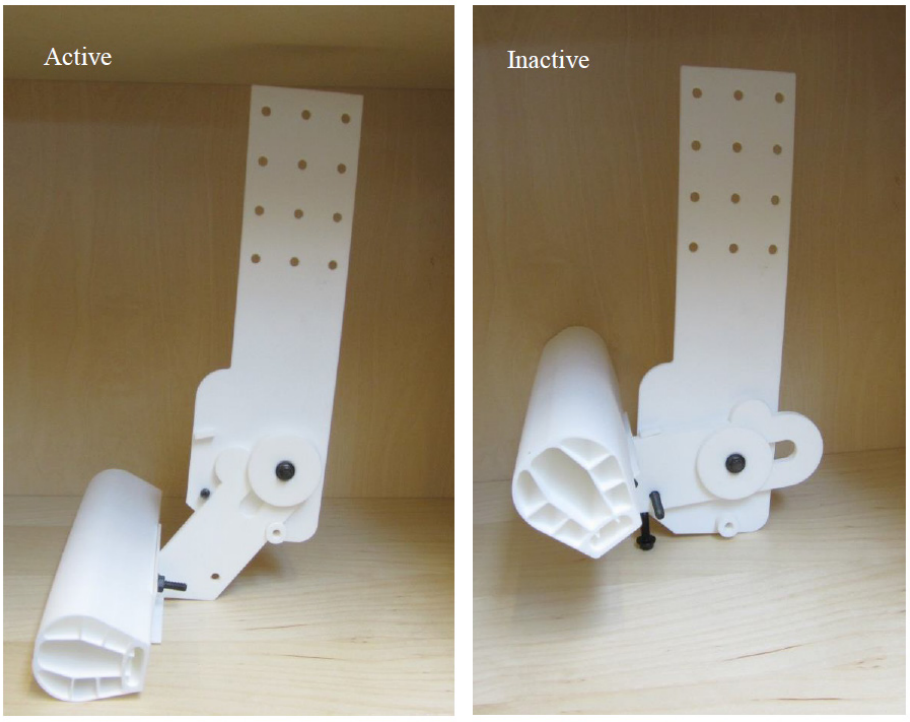


Figure 55: Active and Inactive state of the SLS prototypes

8. 1. 1 Functional Analysis: Guide

The guide concept was tested and checked if it performs as per the design expectations. The intermediate arm during transition from inactive to active position was getting stuck at the support bush (see **Figure 56**) and it was evident that the suitable design changes has to be made in that area. Moreover the intermediate arm in inactive position did not have any mechanism to hold the arm in position and it had a tendency to tilt downwards due to gravity. These inputs were used to further develop this design.

8. 1. 2 Functional Analysis: C-arm

The C-arm concept was also tested for its functioning. The intermediate arm during transition from the active to inactive state was not guiding properly within the rollers. Also it became evident that the intermediate arm can be guided inside in many ways and not just one which was again due to improper rolling support. In active position the intermediate arm has a tendency to tilt due to gravity and the weight of the RUP bar because the arm was not getting arrested properly. All these inputs were used to develop it further and most importantly in determining the final solution. (See **Figure 58**)

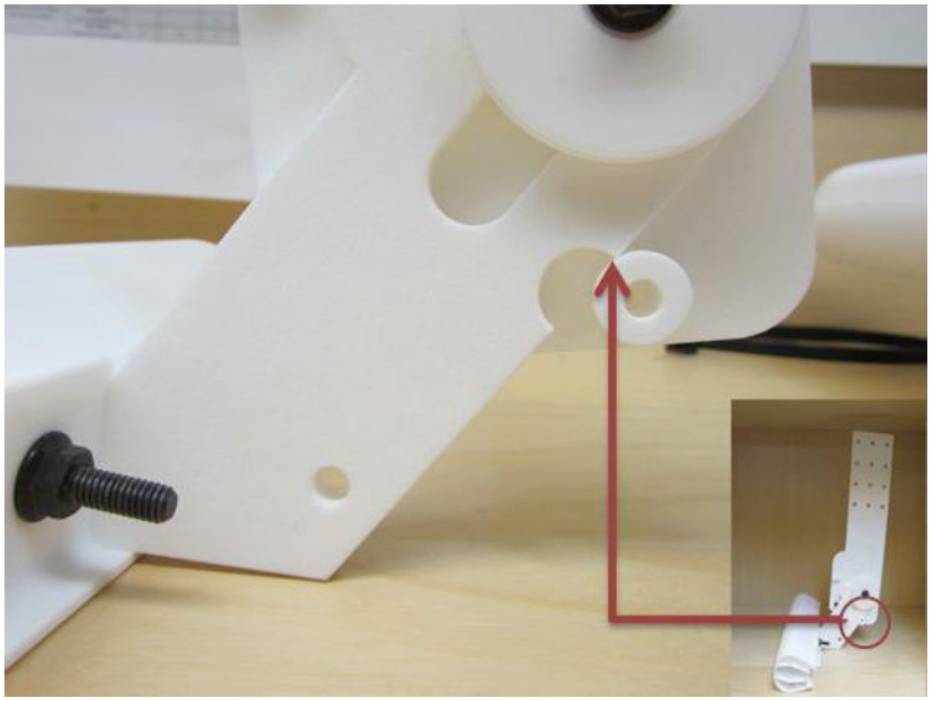


Figure 56: Clash of the semicircular cutout and the bush

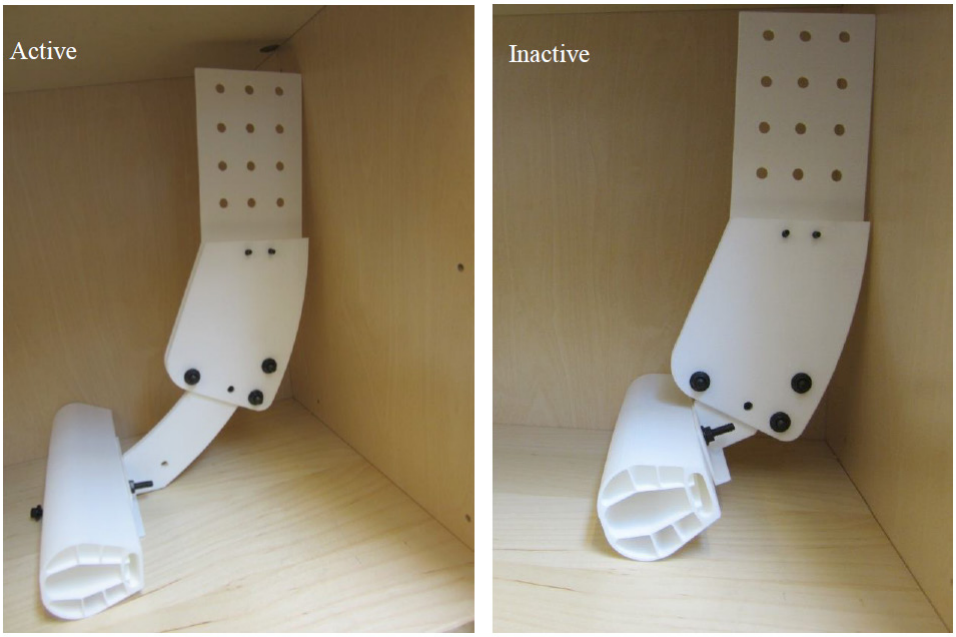


Figure 57: Active and Inactive state of the SLS prototypes

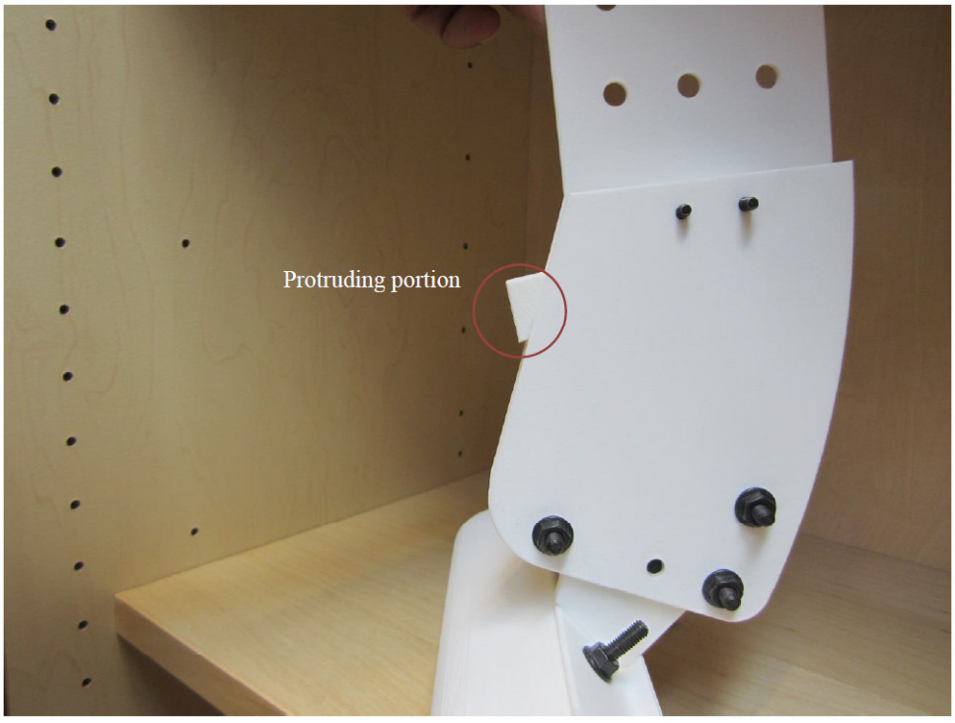


Figure 58: Protrusion of intermediate arm in inactive position

8.2 FMEA

Failure Mode and Effects Analysis is a method used to analyze the modes through which the product has a tendency to fail. Failures are any errors or defects, especially ones that affect the customer, and can be potential or actual (American Society for Quality, 2004). It is also important to find out why the failure would occur and then investigate the consequences if this failure would actually take place. Furthermore the each possible failure modes are rated with respect to its probability of occurrence, probability of detection and severity. With these steps done, a RPN (Risk Priority Number) is calculated. These calculated RPN values will highlight the weak links in the solutions which can lead to failure. This is the strength of this method, to have a tool that can assess the risk and severity of a break down between different solutions. (Institute for Healthcare, 2004)

In this project FMEA was performed on the Guide and C-arm concept. The FMEA performed on the Fixed-RUP was used as a reference since both concepts have sub-parts similar to the Fixed RUP solution. The Fixed-RUP is the non-movable solution of Volvo GTT which is currently in use and the concepts generated in this project will be trying to replace it wherever required.

The C arm solution received rating of more than 125 RPN (Risk Priority Number) value for two aspects. One was regarding the possible problem that the intermediate arm does not get properly guided between the rollers. Another problem anticipated was about the possible tilting of the intermediate arm due to improper guiding and uneven weight distribution. On the other hand the Guide concept did receive high rating for intermediate arm tilting downwards, in inactive position. But the rating was less than 125 RPN since the design was modified to include flange to stop the intermediate arm from tilting. Guide concept emerged as a better solution than the C-arm solution. (Refer Appendix E)

8.3 Conclusion: The winning concept

The functional analysis of the two prototypes helped to narrow down concepts to one final concept.

In FMEA the RPN values for both the Guide and C-arm concepts were compared. This comparison suggested that the Guide concept was better in terms of probable design failures. This proved to be a vital input along with the functional analysis of the prototypes, in determining one final solution.

Taking inputs from both functional analysis of prototypes and FMEA, guide concept was declared winner. Moreover it was more a complete solution in terms of its readiness for further development. Thus the guide solution was further developed based on the improvements which surfaced after analyzing its prototype functioning and inputs from FMEA.

Figure 59: Winning concept-The Guide

8.4 Final Prototypes

The final deliverables of this project were the two physical prototypes. One is a half scale SLS model of the finalized guide concept. The other was a full scale metal prototype of the same.

8. 4. 1 SLS prototype

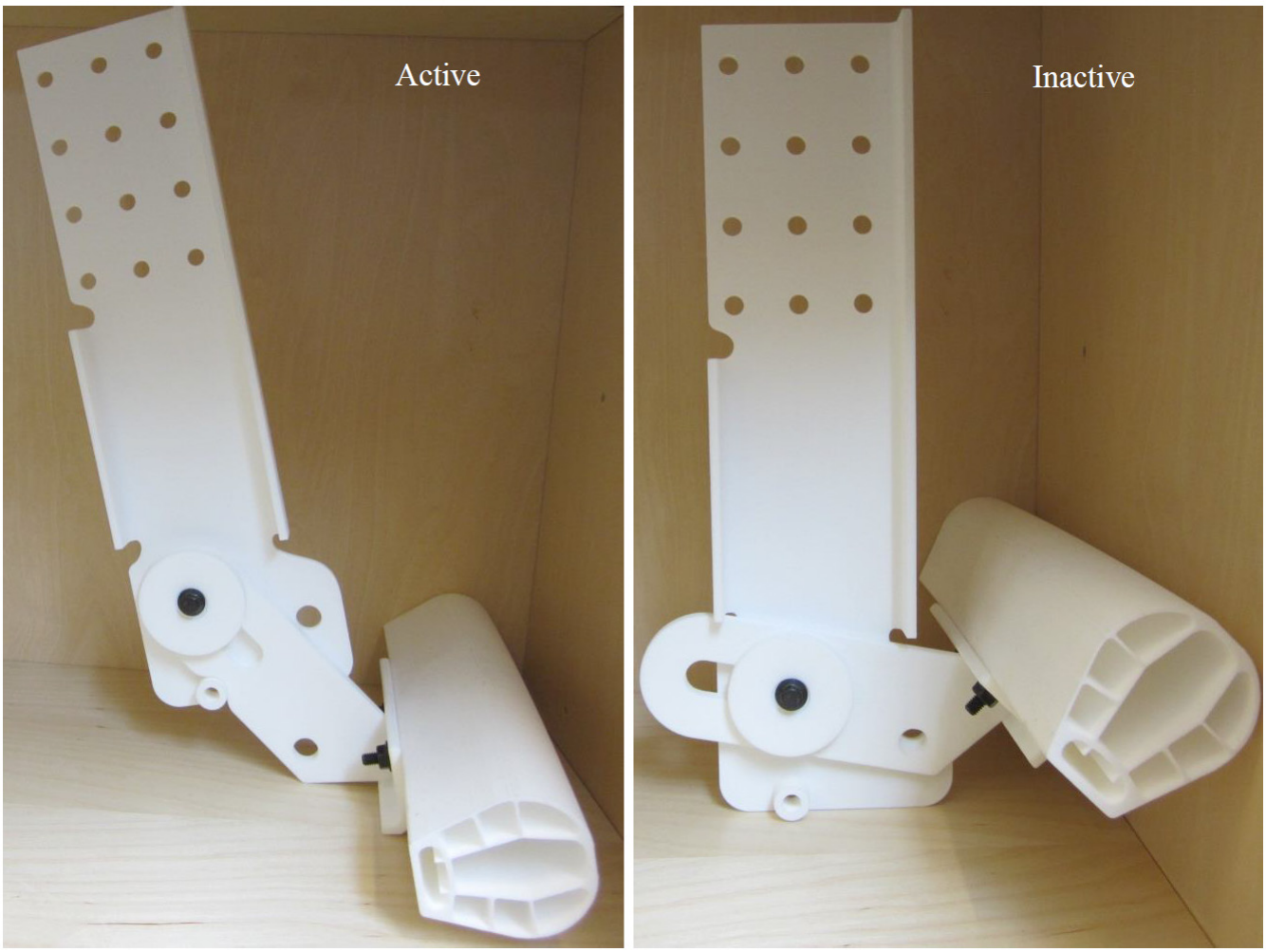


Figure 60: SLS prototype active and inactive positions

8. 4. 2 Full Scale prototype

The full scale prototype of the Guide solution was manufactured from sheet metal and the main aim of this prototype was to see the bracket fits onto the chassis and subject it to further physical testing in the future.

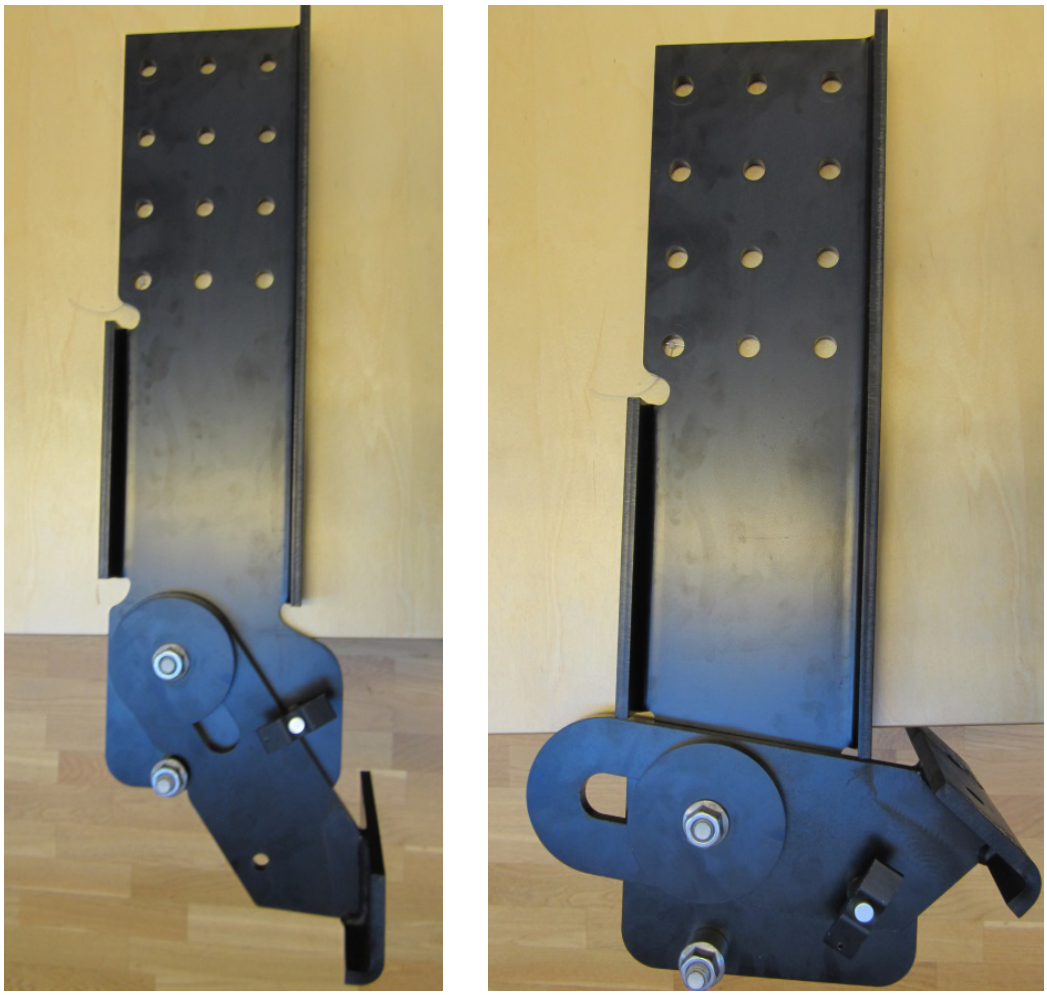


Figure 61: Full scale prototype in active and inactive positions

Figure 62: The Guide fitted to the frame of the truck

9. Results

This section gives the complete set of results obtained from the testing phase. These results help us to look back into the initial requirements and verify that if all of them are fulfilled

The above table gives a complete overview of the requirements and an assessment of which of the requirements have been successfully fulfilled. Those requirements which have been fulfilled, those not fulfilled and those which require further research is the part of the discussion in this chapter.

Table 7: Requirement verification table

Requirement Category	No.	Requirements	Current (Reference is the FOSL)	Target	Stake holders	Verification method	Status
Functional	R1	Mechanism to be implemented in the side plate.	Available	To be installed	Volvo	CAD	Verified
	R2	The RUP mechanism should not obstruct the tow coupling member.	Does not obstruct	Avoid obstruction	Bodybuilder Volvo Suppliers	CAD SLS Prototype	Verified
	R3	The RUP mechanism should not clash with the components under the chassis	Clashes with air bellows in air suspended trucks	Avoid clash with all component	Volvo	CAD SLS Prototype	Verified
Performance	R4	Mechanism should fit all chassis heights	No solution available within range 911mm to 1348mm	To be designed within the range 911mm to 1348mm	Volvo's Customer	CAD	Verified
	R5	Mechanism should fit all chassis lengths	No solution for RFL2195 (shortest chassis)	To be designed for RFL 2195	Volvo Bodybuilder and Customers	CAD	Verified
	R6	Distance of the installation from rear of the vehicle	<400mm before crash	<300mm before crash <400mm after crash	Customer	CAD(Before crash) Basic FEA(After crash) Physical testing	Not verified by physical testing
	R7	Provide quick release operation	Available	To be installed	Customer	CAD	Verified
	R8	Easy to operate	No additional aids	Include additional aids	Customer	Expert assessment	N/A
	R9	Achieve good departure angle	34°	30°-34°	Customer	CAD Prototype	Verified

	R10	The force applied by the operator for varying the RUP position	<40daN	<40daN	Customer	FEA Full scale structural steel prototype	Not verified by physical testing
Maintainability	R11	Easy to maintain	Minimal maintenance	Minimal maintenance	Customer Volvo(After sales)	Expert assessment	Verified
Legal	R12	Load withstanding capacity of the RUPD	P1=50kN P2=100kN P3=50KN	P1=100kN P2=180kN P3=100KN	Customer Volvo	Basic FEA Physical testing	Not verified by Physical testing
	R13	Difference in distance from rear before and after the crash	<120mm	<100mm	Customer Volvo	Basic FEA	Verified
	R14	Installation height for air suspension trucks	<550mm	<450mm	Customer Volvo	CAD	Verified
	R15	Installation height for the leaf suspension trucks	<550mm	<500mm	Customer Volvo	CAD	Verified
Attributes	R16	Low weight	35 Kg	<= 35Kg	Customer	Basic FEA	Verified
	R17	Low cost (tooling + development of new parts)	-	-	Customer	Expert assessment	Verified
Aesthetics	R18	Concept should be aesthetically appealing	-	-	Customer	Expert assessment	Verified

Functional requirements which included mainly the ability of the concept to operate without interfering (R2 and R3) with neighboring components have been fulfilled.

The CAD models of the concepts have been assembled with the exact chassis CAD models and tested for interference with the surrounding parts on CAD and the tests have been successful.

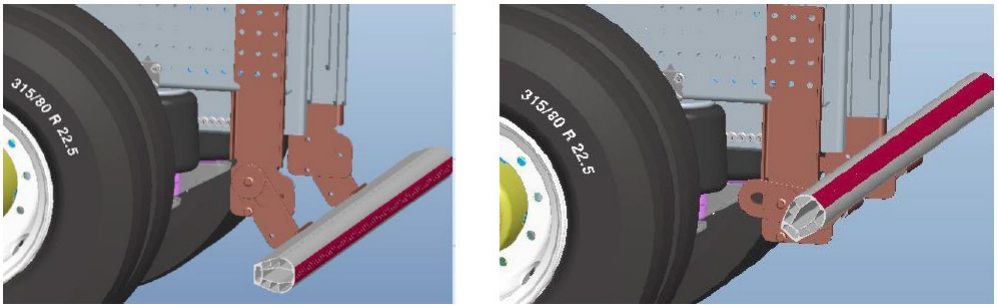


Figure 63: Avoid interference with the components under the chassis

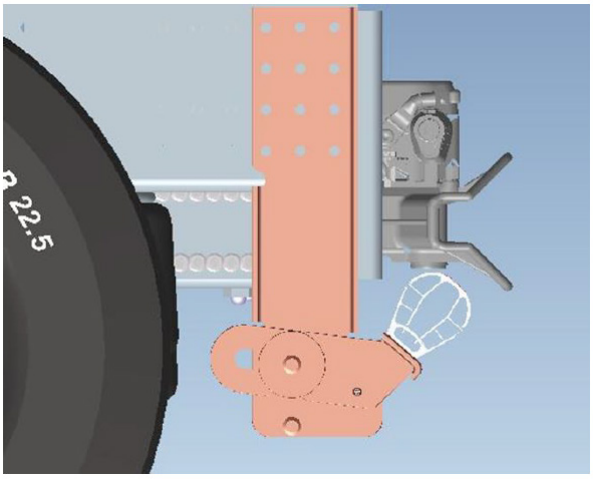


Figure 64: Avoid clash with tow coupling

Performance requirements included the ease of operation, modularity & flexibility of the concept to fit different chassis heights (R4), achieve good departure angle (R9), has been verified using cad models. To fit different chassis heights, the side plate have been designed of different heights without changing the RUP mechanism. Thus the same mechanism can be used on different chassis heights by simply varying the length of the side plate or by using variable brackets between the connecting side plate and the arm of the Guide.

In order to make the concept very easy to operate (R8), a guide slot and a flange have been included in the design. This will allow the user to operate the mechanism very easily. The force needed to operate the RUP mechanism has to be below 40daN which has been fulfilled.

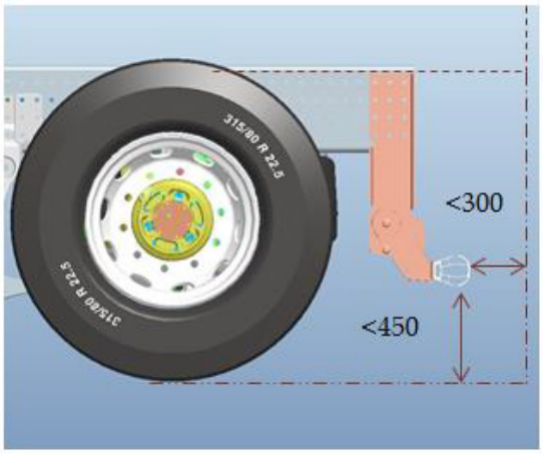


Figure 65: Legal dimensional requirements satisfied

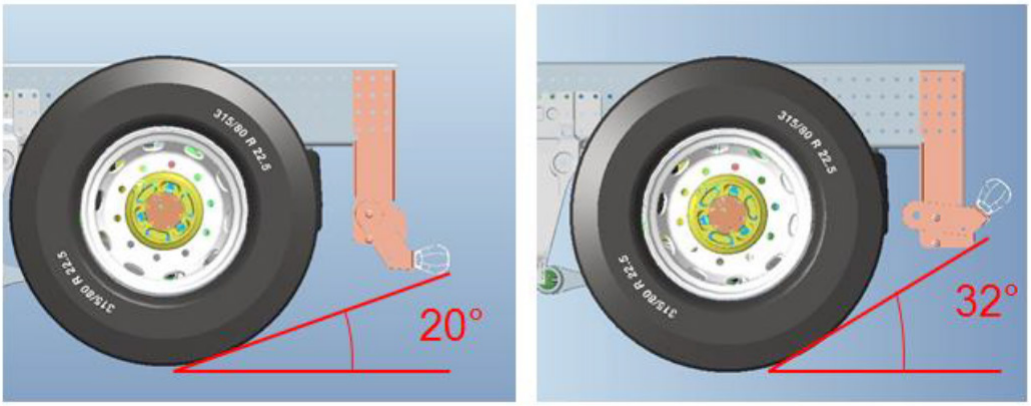


Figure 66: Departure angles achieved with reference measures

Maintainability is one of the important aspects. The final concepts chosen have been selected considering maintainability issue. Moreover the concepts chosen are similar to those which are in use and are quite easy to maintain (R11). This requirement was verified by the experts at Volvo GTT and rated satisfactory.Legal requirements were the critical guiding factors in this projects and one the main reasons behind undertaking of this project. This included load withstanding capacity of the new concepts according to new regulations (R58-03). This requirement has been tested using Basic FEA (Hyperworks) from Altair. Due to software limitations the requirement has been tested under low loads than the actual in order to remain within the range of plastic deformation. A load of 18KN was applied as against 180KN. The hotspots shown by the software indicate the possible stress in the back plate and some small areas on the intermediate plate. These indicate the concept is safe for these load conditions. In order to test the concept for the real impact loads of 180KN and more the CAD models should be further tested and verified using advanced software with accurate load cases. Apart from this, all the dimensional and legal requirements have been verified using CAD software.

Attributes such as low weight of the concept has been fulfilled since the weight anticipated using the CAD software fulfills the requirement and is very similar in magnitude as FOSL solution. The cost of tooling has been one of the aspects of funneling down the concepts and as per the experts in Volvo GTT, the Guide and C-arm solution can be produced cost effectively.

Aesthetics (R18) is one of the important requirements criteria. The expert assessment at Volvo GTT of the proposed concept concluded that the proposed solution should be aesthetically appealing.

The requirements R6, R10 and R12 are to be tested by physical tests such as impact loading for verifying the strength of the concept, its load bearing capacity, the deformation upon impact and also functionalities such as ease of assembly, ease of operation and so on. Since the prototyping of the full scale model was done of a single side only, the complete solution could not be tested as of this stage of the project. And hence these requirements are recommended to be verified through physical tests in the future stages by Volvo.

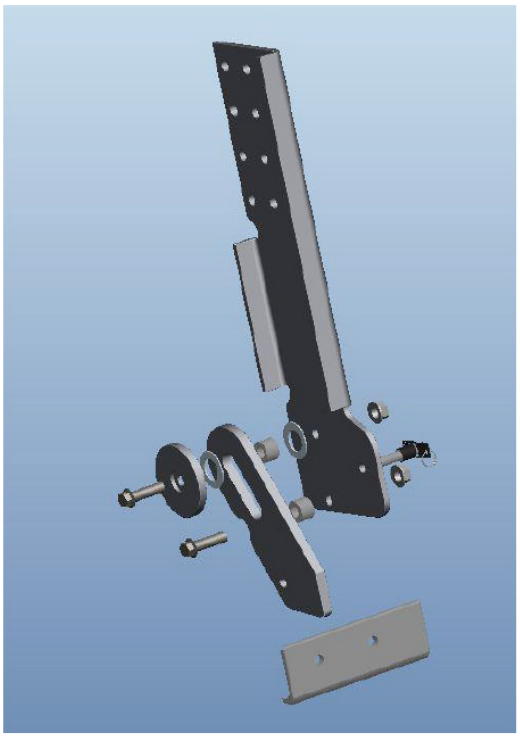


Figure 67: Exploded view of 'The Guide' to show easy maintenance and cost effective

10. Discussion

This section is a critical assessment of the results mentioned above as well as the product development process that has been followed in the course of this project. Their advantages and drawbacks are intended to transfer the knowledge obtained from this project to similar future endeavors thus making the product development process more efficient.

10.1 Approach of the thesis

The first thing to note about this thesis is it is a product development project wherein a new product had to be designed from scratch. This dictated the methodology and the choice of the product development process that was used as a framework to work within. A general process was taken as the base and customized to fit this project.

The planning and pre study phase was rightly the first step wherein the time plan is set and a general background study is made on what has been done in this field and what the authors were expected to deliver in this project. It was noticed very early on that customer requirements, legal requirements and the general boundaries of the project were well established before the work began and no time was spent on collecting the data for setting the requirements. Though the requirements were set, they still had to be put into quantifiable terms for setting clear design engineering guidelines. Hence the team went straight into setting up a requirement specification table. This gave a clear target for each requirement and means to verify them. The stakeholders section helped the authors keep an eye on the stakeholders with respect to each of these requirements which were then translated into functions for brainstorming. Then came the brainstorming to get the ideas flowing for each function. The numerous ideas generated had to be compiled for developing them into complete concepts. A morphological matrix was deemed to be one of the most effective tools for this task. It turned out to be right as many promising concepts came out of this exercise. The concepts were then rated, modified and eventually funneled down using selection matrices such as Pugh and Kesselring matrices. This then led to system level designing and detailed designing which were done using CAD systems. Though it cost more time, this proved most effective for better visualizing and communicating within as well as outside the team. First prototyping (SLS) was done once final two concepts were shortlisted. This gave a realistic feel of the product for the first time and the findings were conclusive enough from testing and the FMEA to choose the final winning concept. The development phase is not as linear as it seems on paper but is an iterative one where a lot of going back and forth is inevitable before progress is achieved and this project was no exception. The final design was eventually frozen and delivered to be prototyped in full scale and SLS which will lead to further development.

The whole project went off smooth and according to plan in terms of time and goals. One cannot help but feel that a design is always incomplete which is an occupational hazard of a design engineer. But one clear area where the authors feel a different approach and perhaps a more effective approach could have been taken is in terms of the number of physical prototypes built. A CAD design can only go so far in bringing out the reality in a product and this is where a real life prototype excels in bringing out the shortcomings if any in the design. Another comment on the project is its level of maturity. Ideally the team would have liked to go further into the development of the product but due to resource and time restrictions, physical testing could not be conducted on the prototype and hence some verification went unfinished. Having said this, no major design changes are expected as a result

of this testing.
In conclusion, the thesis was deemed a success as per the bar set in the beginning as to what a good solution would be. All these requirements were met to the satisfaction of the project team as well as the parent group at Volvo. The further developments recommended as per the following section gives a good guideline of what actions are to be taken in the future development of this project so that a solution is ready to be put into production as soon as the R-58 is passed and no significant time or money is further spent by Volvo in this regard.

10.2 Report design

This being a thesis in the department of product development, the authors have decided it is best to format the report using the same framework as the project as it not only focusses on the results achieved but also gives a detailed step by step account of the project itself.

The chapters to a great extent reflect the process followed in the thesis but this might seem a bit beside the point to someone interested only in the results. But the authors feel that this project is an excellent example of a design engineering and product development project which is what the team at Volvo works on and there are good learning points that can be picked up and used in other projects and hence is worth documenting them. Much of the theoretical material like Morphological matrix, FMEA table, Patent list and so on have been moved to the appendix instead as it might not be as interesting or important as the results from these exercises. But it is a good addition to the report as it makes it more comprehensive and complete. Having said this, it is impossible to record every single step taken in the project because as mentioned before, the project progressed not linearly but with a continuous development and many development loops. This meant that only significant changes were recorded in the report which may make it seem to have lost its continuity at certain places but this is not the case in reality.

A good balance between a practical and a theoretical report had to be achieved and the authors feel that it has been so.

11. Further Development and recommendations

This is the final chapter in the report and it serves a guideline to what further developments are to be done and path to be followed to make the final proposal mature enough to be put in production.it also contains suggestions of features that could be included in the product that would to add value to it.

The following are the areas where further development is required

- **FEA**
  The finite element analysis done on the model as it stands was for detecting the weak points in the design but for a thorough verification, the complete solution has to be analyzed. This includes both left and right side plate with the RUP bar attached to it. Since no changes were made to the RUP bar itself, the standard bar can be used. The analysis conducted has to be nonlinear load case with all the P1, P2 and P3 forces as mentioned in R58 (refer table 1), similar boundary conditions as in the FEA that is already done and with the appropriate material properties.

- **Prototyping**
  Conducting an FEA is not sufficient for the solution to be production ready and hence a physical impact test has to be conducted as is the norm at Volvo for any new product development. For this purpose, a prototype with both sides has to be made with the actual grade of steel material that Volvo uses in their product along with the RUP bar attached to it. Stress and deformation can be thus verified and thereby verifying the requirements R6, R10 and R12 (refer table 7).

- **Assembly and manufacture**
  The Guide solution is designed for assembly and manufacture with Volvo design rules and regulations. Hence the product is mature in that sense but real life test for ease of assembling the solution, mounting it onto the chassis frame, using the proper torque in the screws has to be verified through real life testing.

- **Usability test**
  Tests have to be conducted to ensure the solution is easy and intuitive to use with regards to weight, functioning and maintenance. An estimation of the number of parts to be produced and hence the cost of the product is useful.

The following points are suggestions by the authors to Volvo which will add value to the product. These suggestions are just to have a complete scope of what could be done with the product but they also might be something not implementable due to financial impracticality.

- **Variable departure angle**
  A solution which will give more flexibility to the user in terms of determining the departure angle that is required for specific tasks.

- **Poka-Yoke**
  Apply Poka-Yoke to avoid mounting of wrong RUP part on incorrect truck variant. This can be done either by simple stickers or engravings which indicate wrong combinations or inherent design alterations which prevent them.

- **Gas springs**
  This feature was deleted from the solution as it was deemed useless and costly but is always a good option to have if the customer demands it.

- **Automatic locking**
  The current solution has simple locking pins that have to be manually matched with the hole as this is a standard part but a self-locking mechanism in these pins would be a great addition to the solution.

- **Automatic solution**
  Making the solution work by the push of a button. This is a suggestion for the future and one that may not have scope in the current market but it would certainly add value to the product.

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Appendix

Appendix A: Morphological matrix

No	Sub-function / Sub-solution	1	2	3	4
1	Support RUP bar	Snap fit	Bolted RUP (Threaded centre)	Bracket	Rectangular bracket (current solution)
2	Attach to chassis	Integrated with tow coupling member	Attach to side plate	Tow coupling member attached to the intermediate arm	Integrated with air suspension bellow
3	Able to vary departure angle	Expandable RUP bar	Rotatable RUP	Pivoted RUP with release lever	Telescopic spring arm
4	Easy to move	Move on ground impact	Torsion spring	Gears	Hydraulic/pneumatic lift
5	Avoid interference with tow coupling member		RUP over tow member	Vertical guiderail on body	Roll up RUP
6	Avoid interference during tipping	RUP as Tow support	RUP as tipping ramp	Slidable 3 part RUP (slotted)	Slidable RUP intermediate arm
7	Quick to modify	Quick release	Central Release pin(within RUP)		
8	Movable without clash	Pivot intermediate	Arm pivot inward		Collapsable sheet metal plates

Appendix B: Volvo truck segments

This segment gives a consolidated view on the various truck segments at Volvo GTT and the RUP used in each of them. (Hofvendahl, M. et al., 2013) Since the main focus of the project is on the foldable and slidable RUP (FOSL), only the segments with FOSL have been highlighted.

1. Flatbed truck

   This type of truck can be either rigid or a semi-trailer. It is flat and had a bed like body with sides and no roof which allows for easy loading and unloading of goods. It's mainly used for heavy transport or construction and is equipped with an FOSL or Fixed RUP.

Figure 1: Flatbed truck

2. Slurry tanker

Figure 2: Slurry tanker

   As the name suggests, slurry tankers are used to transport slurry. They are categorized as distribution trucks. They have an enclosed container and are equipped with either Fixed or FOSL RUP. They can be without RUP in some instances.

3. Concrete mixers/pumps

These trucks are in the construction segment. There are 3 variants which are all equipped with either fixed or FOSL RUP.

a. Concrete mixers-Used only for mixing concrete.

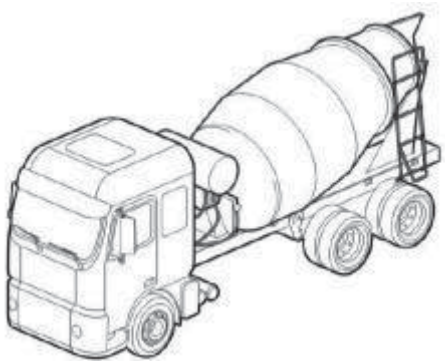

Figure 3: Concrete mixer

b. Concrete pump- Used specifically for pumping mixed concrete for construction purposes

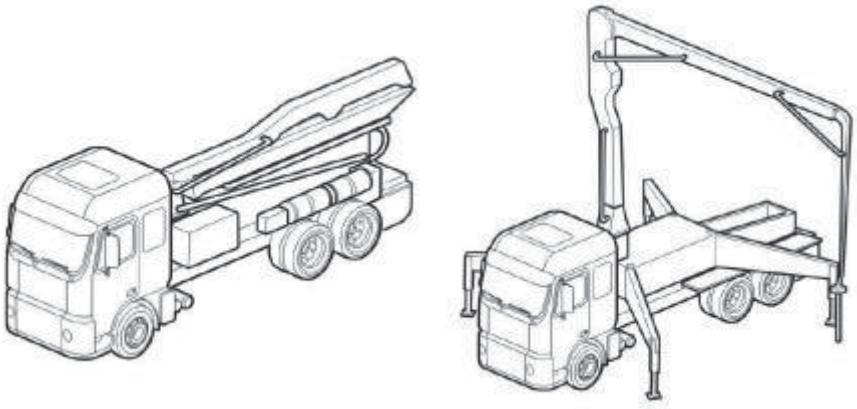

Figure 4: Concrete pump

c. Concrete mixer and pump- Equipped with a concrete mixer that is connected to a pump

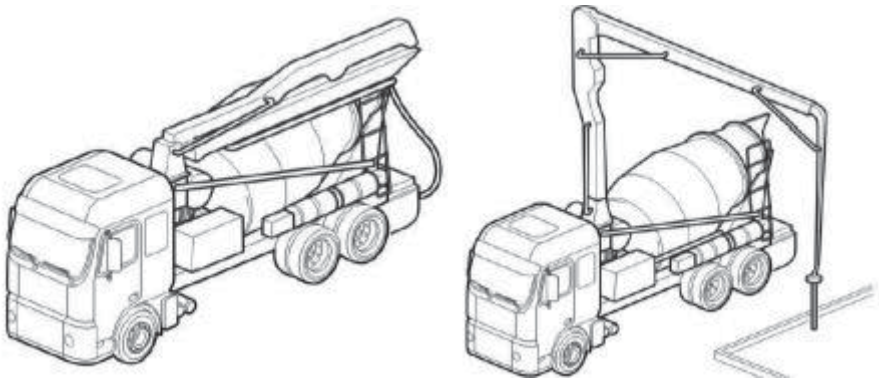

Figure 5: Concrete mixer and pump

4. Tipper body

These are construction trucks that are equipped with tippers that can backwards or sideways. They use hydraulic lifts for tipping purposes and are equipped with fixed are FOSL RUP.

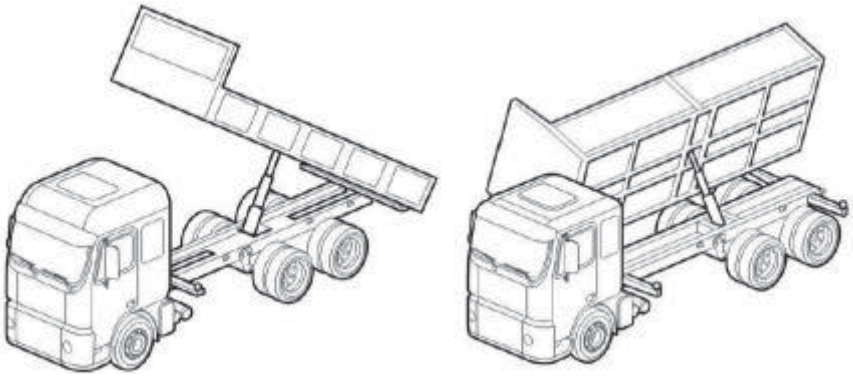

Figure 6: Tipper body

5. Dump body

These are construction trucks are used for carrying heavy loads and are similar to flatbeds with the added feature of dumping the load at a particular area on site. Like the tipper body, they too are equipped with a hydraulic lift for dumping and are equipped with either a fixed or FOSL RUP.

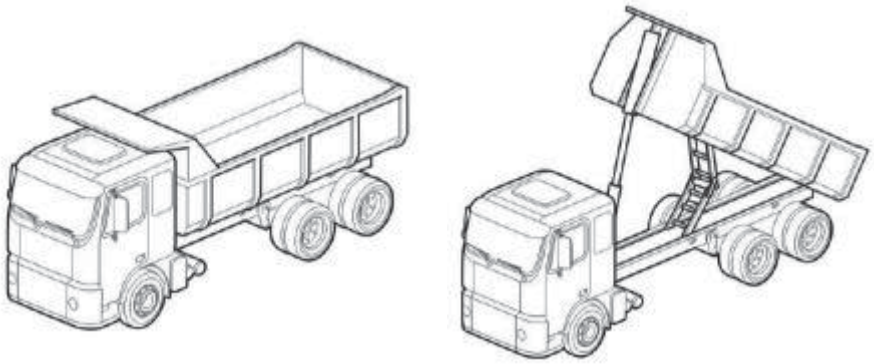

Figure 7: Dump body

6. Hook lift

Hook lift trucks are construction trucks that are equipped with special hooks for the purpose of lifting heavy loads and are equipped also with either fixed or FOSL RUP.

Figure 8: Hook lift

Appendix C: Regulation 58-03

Car velocity before collision: 50 to 70 km/h
Under-ride situation

- Scenario 3
  Truck velocity before collision: 40 to 60 km/h
  Car velocity before collision: 80 to 100 km/h
  Under-ride situation
- Scenario 4
  Truck velocity before collision: 80 km/h
  Car velocity before collision: 120 km/h
  Under-ride situation

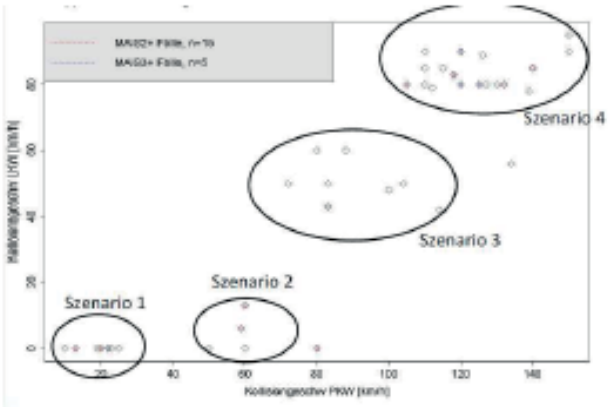

Figure 1: Collision velocities of car (x-axis) and HGV (y-axis) in km/h

The investigation of each case ended with the conclusion that most of the relevant accidents (scenario 2, 3 and 4) show a difference in velocity between the impacting car and the HGV of 40 to 45 km/h.

To have an indication of the force levels during the impact dynamic four tests with 100 % overlap were performed with two vehicle types of the categories small and medium family cars at a test speed of 35 km/h and 56 km/h with each vehicle. For the low speed test the maximum impact force reached 200 kN for the small vehicle and 490 kN for the medium size vehicle. At a speed of 56 km/h the force level went up to 370 kN for the small and 715 kN for the medium size vehicle.

The assumption for the test loads to be applied at the test points P1, P2 and P3 comes from the observation of the accident data showing that a vast majority of accidents happen with an overlap of less than 100 % of the car width. Looking at the geometry of a truck or trailer, the maximum width allowed in the EC is 2.55 m (see Fig. 2).

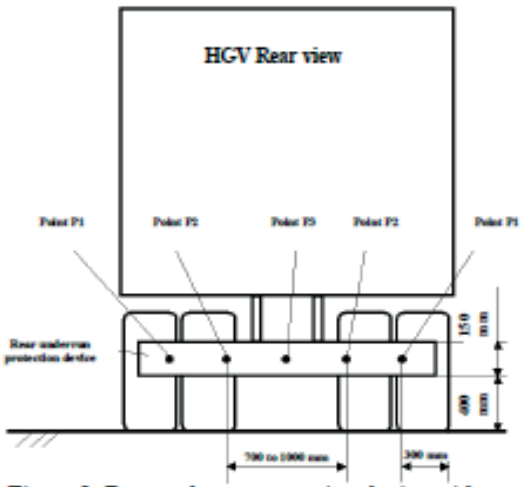

Figure 2: Rear underrun protection device with test points

Taking the width of 1.8 m for an average car shows that for the case of an overlap of less than 100 % only three test points or less on the cross-member of a RUP will be hit. To cover and withstand the forces applied by a car at a

speed of approximately 40 to 45 km/h a total maximum force level of 380 kN is proposed for the three test points P1, P2 and P3. The force levels to be applied at the three test points are as follows (GVW: Gross Vehicle Weight):

- P1: 50% GVW (max. 100 kN)
- P2: 85% GVW (max. 180 kN)
- P3: 50% GVW (max. 100 kN)

These force levels in combination with the reduced ground clearance of the RUP can ensure to hold cars back from under-riding the rear of a HGV and will therefore reduce the numbers of road victims significantly.

To cover current specific technical solutions the proposal made in document GRSG/2011/19 includes a minimum departure angle of 8° for vehicles having a large rear overhang. This ensures that these vehicle types still have access to ferries or loading ramps. The current proposal also covers the specific characteristics of vehicles having platform lifts mounted.

Appendix D Related patents

Title - DWPI	Assignee - DWPI	Abstract - DWPI Novelty	Abstract - DWPI Advantage	DWPI Family Members
Simulated fender-guard integrated heavy vehicle protecting device, has vehicle frame fixed with fixed end of device body, self-lock mechanism used as executing mechanism, and simulated beam used as main bearing component	SUN B	The device has a vehicle frame (1) fixed with a fixed end of a device body. A self-lock mechanism (2) is used as an executing mechanism. A simulated beam (3) is used as a main bearing component.		CN103332158A
Vehicle rear-end collision preventing device has crank rod support pipe that is hinged in right angle position side of crank rod frame and rocker rod by using pin shaft	UNIV HUNAN	The device has a rocker rod outer pipe (4) that is hinged with a vehicle frame (5). A protective beam (9) is provided with a triangular reinforcing rib, and is fixedly connected with a protective beam energy absorbing block (10). The rocker rod tube hinged by a pin shaft is connected with a car bracket. A rocker inner tube (2) is embedded in a swinging rod. A crank rod support pipe is hinged in the right angle position side of a crank rod frame (1) and the rocker rod by a pin shaft. The swinging rod is embedded in the inner tube and the outer tube.	The structure of the vehicle rear-end collision preventing device can be simplified. The passing ability of the vehicle can be ensured. The collision energy can be absorbed to protect collision of vehicle, so that the life and property of the driver can be saved.	CN102689617A
Arrangement of underrun protection device at frame element of passenger car, has legs connected with each other over bar and partially extended toward each other in direction of underrun protection element	DAIMLER AG	The arrangement (10) has an underrun protection device (12) whose underrun protection element (20) is extended in a vehicle transverse direction and secured on a frame element (14) by fastening elements (22). The frame element is provided with two obliquely extending legs (28, 30) in a portion (24), where the legs are connected with each other over a bar (32) and spaced apart from each other in a U-shaped cross-section (26). The legs are partially extended toward each other in direction of the underrun protection element. The fastening elements are made of sheet metal i.e. curved sheet metal.	The legs are connected with each other over the bar, spaced apart from each other in U-shaped cross-section and partially extended toward each other in the direction of the underrun protection element, thus reducing complexity of the arrangement and achieving effective protection against an underrunning of the vehicle. The fastening elements are made of curved sheet metals, thus reducing weight and manufacturing cost of the underrun protection device. The underrun protection element is formed in a circular cross-section, so that stability and rigidity of the underrun protection element can be improved.	DE102012006839A1 | DE102012006839A8
Under-run protection device for trailer of tractor, has horizontal under-run prevention beam with mounting openings correspond to horizontal beam mounting openings, and removable reflective strip corresponds to reflective strip opening	SAPA EXTRUSIONS INC	The device has upright supports having mounting plate (110) with vertical truck mounting holes. Vertical elements (120) non-welded communicates with extruded back mounting plate and horizontal elements (130) that non-welded communicates with vertical elements and back mounting plate. Horizontal elements have horizontal truck mounting openings (125) and horizontal beam mounting openings.	As the horizontal under-run prevention beam has mounting openings correspond to horizontal beam mounting openings, and removable reflective strip corresponds to reflective strip openings in beam, the vehicle can be stopped by the under-run device before the vehicle	US20130249223A1 | WO2013142818A1

		Horizontal under-run prevention beam (140) has mounting openings correspond to horizontal beam mounting openings, and removable reflective strip (145) corresponds to reflective strip openings in beam.	travels under the trailers so that the damage to the under-run device can be reduced. The under-run device that is light weight, sufficiently strong, corrosion resistant and durable can be provided. The under-run device can be manufacture in simple, efficient and cost effective manner.	
Anti-collision guardrail for lorry, has bracket whose two sides are extended outward and bent into arc-shaped hook, where flat part of bracket is connected with middle part of anti-collision rod and mounting hole is provided with bracket	ZHANG JIAGANG LONGJING AUTOMOBILE PARTS	The guardrail has an anti-collision rod provided with a mounting hole. The mounting hole is provided with a U-shaped bracket. Two sides of the bracket are extended outward and bent into an arc-shaped hook. A flat part of the bracket is fixedly connected with a middle part of the anti-collision rod.	The guardrail is simple in structure, and increases buffer area and improves stress buffering effect.	CN202463751U
Impact beam for underrun protection arrangement for heavy vehicle e.g. truck has support surfaces arranged in three dimensions adapted to cooperate with corresponding three dimensional surfaces on the vehicle in a rigid form lock	VOLVO LASTV AGNAR AB	The impact beam (18) includes a length substantially corresponding to the width of the vehicle and a height allowing the beam to function as an underrun protection barrier when mounted to a vehicle. Support surfaces (32) are used for mounting the beam rigidly to the vehicle. The support surfaces are arranged in three dimensions adapted to cooperate with corresponding three dimensional surfaces (25,26) on the vehicle in a rigid form lock.	Both ends of the beam can be curved with a radius such that it even provides for a more positive form lock to resist an impact force. The support surfaces extend along the full length of the impact beam, e.g. by forming a longitudinal ridge. This enables the impact beam to be manufactured at low cost, e.g. by extrusion of aluminum alloy, by hydraulic or roll forming of steel sheet. The impact beam may be manufactured in various designs with different heights, and the correct position of the lower edge of the underrun protection is achievable through the deployment of a single impact beam or of a certain combination of impact beams. The underrun protection arrangement includes an impact beam which makes it possible to provide adjustable ground clearance with an ability to withstand large impact forces.	WO2013095201A1
Vehicle rear part protecting device, has mounting piece connected with protective vertical beams, which are connected with front end of rear beam, where vertical beams are inclined downward	BEIQI FUTIAN AUTOMOBILE CO LTD	The device has a mounting piece connected with two protective vertical beams, which are connected with a front end of a rear beam, where the vertical beams are inclined downward.	The vertical beams incline downward for preventing the vehicle rear part collision and protecting the passenger at the rear part of the vehicle, when the vehicle is driven at night.	CN202368524U
Anti-collision guard fence protecting assembly for vehicle, has guard fence upright post provided with guard fence that supports seat locating pin assembly, where pin assembly comprises locating pin that passes through through-hole	SHAANXI HEAVY DUTY AUTOMOBILE CO LTD	The assembly has a guard fence support fixed on a frame and formed with a sliding groove. The sliding groove is formed with a through-hole placed on an outer side of a base. A guard fence upright post is formed with multiple locating holes and sleeved on the sliding groove. The guard fence upright post is provided with a guard fence, where the	The assembly can slide up and down in a chute so as to realize height adjustment of a guard fence assembly, so that the guard fence assembly is effectively utilized in a vehicle according to different environments.	CN202320177U

		guard fence supports a seat locating pin assembly. The pin assembly comprises a locating pin that passes through the through-hole.		
Rear lower part protecting device for vehicle, has shield that is detachably fixed on mounting board using multiple fixing parts, where shield includes upper part passing through fastening hole and fastening piece fixed on board	BEIQI FUTIAN AUTOM OBILE CO LTD	The device has mounting board (1) and a shield (2) detachably fixed on the mounting board using multiple fixing parts (3). The fixing part comprises a fastening hole (31), the shield includes an upper part passing through the fastening hole, and a fastening piece is fixed on the mounting board. The shield comprises a connecting plate and protection beam (22), where the connecting plate is fixed on the mounting plate by the fixing parts. The fastening hole is formed on the mounting plate and the connecting plate.	The setting of a set of fixed part realizes shield capable of adjusting the position of the shield and the mounting plate, which enables the first lower part protecting device to be in different road. The universality and practicability of the lower part protecting device increases greatly in relation to the fixed position of the mounting plate.	CN202294648U
Device for preventing car from running at back of truck in event of rear-end collision, has swing arm whose one end is hinged with vehicle frame and other end is fixed with baffle	XU Z	The device has a baffle provided at upper portion of a tail frame. An upper block is provided with a thrust on a thrust column and provided with a soft spring. One end of the soft spring is fixedly connected to the baffle and the other end is connected to a swing arm. One end of the swing arm is hinged with a vehicle frame and the other end is fixed with the baffle. Two sides of the swing arm are provided with a reinforcing plate. The lower end of the swing arm is provided with a roller.	The prevention of car from running at back of truck in event of rear-end collision can be performed efficiently. The problem caused by departure angle of the air outlet can be solved.	CN202200931U
Collision prevention device for automobile such as car, has anti-collision frame that is provided with groove-shaped steel plate, and connected with lower section of swinging arm	UNIV SOUTH EAST	The structure has a truck frame (8) that is provided horizontally on two sides of supporting device (1). A hanging arm (7) is provided on the truck frame. The supporting device is respectively provided on the front baffle of a steel pipe. An anti-collision frame (2) is provided with a groove-shaped steel plate. The anti-collision frame is connected with the lower section of a swinging arm (3) which is connected with a fixing seat.	The collision of the automobile can be prevented. The size of the collision prevention device can be reduced.	CN202038262U
End collision preventing device, has collision-preventing frame connected with lower section of swinging arm, where upper section of swinging arm is connected to fixed seat, and steel vertical plate connected with steel ribbed plate	UNIV SOUTH EAST	The device has a collision-preventing frame (2) provided with a groove-type steel plate. A steel ribbed plate (21) is connected on a surface of the groove-type steel plate. A steel vertical plate (22) is connected with the steel ribbed plate. The collision-preventing frame is connected with a lower section of a swinging arm (3). An upper section of the swinging arm is connected to a fixed seat (4). The fixed seat is connected on a rear part of a tail end of a truck frame (8) and the swinging arm. A support plate (5) is connected on a lower part of the tail end of the truck frame.	The device prevents sedan cars from moving into bottom of a truck and prevents a passenger region from collision with a truck tail.	CN102152770A | CN102152770B
Adjustable rear protection device for installing different types of vehicles, has lower bracket plate whose end is fixedly connected with protection rod, where bolt holes are formed at joint of upper bracket plate and lower bracket	CHINA NAT HEAVY DUTY TRUCK CORP JINAN PO	The device has an upper bracket plate whose end is fixedly connected with a longitudinal beam of a vehicle frame. Another end of the upper bracket plate is connected with an end of a lower bracket plate through a bolt. An end of the lower bracket plate is fixedly connected with a protection rod. Bolt	The device is simple in structure, convenient to regulate and reliable to install.	CN201914200U

plate		holes are formed at a joint of the upper bracket plate and the lower bracket plate.		
Rear underrun protection device has nut and bolt that penetrate hole of attachment surface and hole of beam	NISSAN DIESEL KOGYO KK	The protection device (1) has bracket (12) provided in the both sides of a vehicle stand frame edge portion in vehicle width direction. The beam (20) has a hole to which the nut and the bolt are attached. The nut and the bolt penetrate the hole of the attachment surface and the hole of the beam.	The diving of passenger car at the time of collision is prevented and the maximum clearance with a road surface is secured.	JP2012131449A
Underrun protection for mounting at rear side of lorry, has ball head clutch whose ball neck is vertically aligned to ball head in operational position that is provided in road intersection position	MVG METALLVERARBEITUNGS GMBH	The protection (2) has pivotal arms (6, 7) spaced apart from each other at a frame (1) of a lorry, where a pivotal axis (8) of the pivotal arms horizontally extends to a longitudinal axis of the lorry. A ball head clutch (5) is arranged at a rear-end collision profile (3) in the road position. A ball neck of the ball head clutch is vertically aligned to a ball head in an operational position that is provided in a road intersection position. A jaw clutch is fixed at the frame of the lorry in an area position and arranged above the rear-end collision profile.	The ball neck of the ball head clutch is vertically aligned to the ball head in the operational position, thus assembling underrun protection at the rear side of the lorry in a stable manner while increasing the rigidity of construction of the underrun protection.	DE202010012938U1 | DE102011055350A1
Under-run protector attachment structure for vehicle e.g. truck, has under-run protector connected with protector attaching part, and rubber elastically deformed according to fluctuation of protector mounting bracket	ISUZU MOTORS LTD	The structure has a rear under-run protector connected with a protector attaching part (30). A suspension mounting bracket (15) is fixed to a chassis frame (4). A protector mounting bracket (6) is provided with a fluctuation range limiting part that limits a swivelable range with respect to the chassis frame. The protector mounting bracket is arranged between a vehicle body frame and the fluctuation range limiting part. Rubber (7) is elastically deformed according to fluctuation of the protector mounting bracket.	The structure provides dynamic damper function to the under-run protector without impairing original function of the under-run protector.	JP2012101631A
Under-run protector attachment structure of vehicle e.g. passenger car, has rubber mounts that are arranged between chassis frame and upper board portion, and are elastically deformed according to fluctuation of bracket	ISUZU MOTORS LTD	The structure has a front under-run protector (5) which is arranged in the front portion or rear portion of the chassis frame (4), and is extended in a vehicle width direction. The brackets (26,27) are provided with a upper board portion (32) for limiting the fluctuation range with respect to the chassis frame. The rubber mounts (7,8) are arranged between the chassis frame and the upper board portion, and are elastically deformed according to the fluctuation of the bracket.	The dynamic damper function of the under-run protector can be improved without impairing the original function of the under-run protector. The movement at the back of the front under-run protector can be prevented reliably. The original function of the front under-run protector can be ensured.	JP2012101630A
Rear protecting device system for vehicle, has fixing device which is fixedly connected with vehicle frame	CHINA NAT HEAVY DUTY TRUCK CORP JINAN PO	The system has a fixing device which is fixedly connected with vehicle frame. The fixing device is also connected with rotary stretching and retracting device and transverse rod. The fixing device has fixed supports that are connected with corresponding rotary stretching and retracting device. The stretching and retracting device is adjusted in the range from 0-90 °.	The rear protecting device system with simplified structure and less weight is manufactured conveniently at low cost. The protection of the vehicle is provided, by the provision of buffering function in the rear protecting device system.	CN201842045U

Telescopic rear protection device for dumper, has vertical brace connected to longitudinal brace by fixing bolts inserted into vertical brace fixing holes and longitudinal brace fixing holes	GANSU CIMC HUAJUN VEHICLE CO LTD	The device has a longitudinal brace (2) whose rear end is welded with a rear protection cross brace (3). A vertical brace (1) is provided with vertical brace fixing holes. Longitudinal brace fixing holes are formed on a front portion of the longitudinal brace. The vertical brace is connected to the longitudinal brace by fixing bolts (4) inserted into the vertical brace fixing holes and the longitudinal brace fixing holes, where distance between the vertical brace fixing holes is 40 mm.	The rear protection cross brace is retained at different distances from ground by adjusting assembling positions of the vertical brace fixing holes and the longitudinal brace fixing holes so as to retain distance between rear end of rear protection unit and tail end of a dumper. The fixing bolts are drawn out, and a rear protection vertical brake is telescoped upwards and forwards to right position and fixed by the bolts when the dumper needs to run on a road with a bad road condition. The device is simple and convenient to operate. The device improves rear protection strength of the dumper, such that the device is safe and reliable to use.	CN201901100U
Protective device for vehicle, has hollow structured rear protective guard fixed on rear protective mounting rack and provided with rectangular tubular cross section, and sloping support fixed on rear protective guard	BEIQI FUTIAN AUTOMOBILE CO LTD	The device has a hollow structured rear protective guard fixed on a rear protective mounting rack and provided with a rectangular tubular cross section. One part of a folding type stop plate is fixed on the rear protective mounting rack, and another part of the stop late is fixed on the rear protective guard. A sloping support i.e. straight bar, is fixed on the rear protective guard.	The hollow structured rear protective guard provides greater strength and impact resistance to the device.	CN201553116U
Manual fixing tool of manual fixing device used for movable bumper has guide surface which converts rotation operation of control lever into forward and backward movement of piston	HEISEI JIDOSHA YG	The manual fixing tool (1) has control lever which is connected with a piston shaft so rotation of piston can be performed. A protrusion is provided in one end side wall of cylinder. A guide surface converts rotation operation of control lever into forward and backward movement of piston, and is formed in surface that is twisted three-dimensionally.	Provides a manual fixing tool that reduces burden of operator, with improved operability, and performs operation smoothly and easily since guide surface converts rotation operation of control lever into forward and backward movement of piston, and is formed in surface that is twisted three-dimensionally.	JP2011080511A | JP05284236B2
Rear protection reinforcing device for trailer, has transverse rod added with trapezoidal grooved plate, where transverse rod with grooved steel structure is provided with recess on negative side face	QINGTE GROUP CO LTD	The trailer has a transverse rod (2) added with a trapezoidal grooved plate (4). The transverse rod with a grooved steel structure is provided with a recess on a negative side face. The grooved plate is turned upside down in recess of the transverse rod. The grooved plate is located on a connection part between a lower end of a vertical support component (1) and the transverse rod.	The grooved plate utilizes trapezoidal section structure, and is turned upside down in the transverse rod, so as to resist impact by the stretching part and maintain elasticity at the same time, thus improving the strength, and effectively absorbing the impact. The service life of the protection device is prolonged.	CN201472285U
Liftable rear protection device for use in vehicle, has upper support and lower support that are fixed by using fixing pin and fixing hole, and pin holes and connecting holes	GANSU CIMC HUAJUN VEHICLE CO LTD	The device has angle brace (4) having pin, that is fixed on lower wing plate of vertical beam. A rear protecting net support has upper support (5) having connecting hole, and lower support (6) having fixing holes along length direction. The upper end of the upper support is fixed in a vertical beam (8), and the lower end of the lower support	The fixing pin is removed and the rear protecting lower support is lifted to the proper position and fixed by the fixing pin when the vehicle is driven in a bad road condition while the device structure is simplified. Hence the	CN201423996Y

		is fixed in a rear protecting transverse brace (7). The upper support and the lower support are fixed by using a fixing pin (1) and the fixing hole, and pin holes and connecting holes.	operation convenience of the device is improved, and the rear protecting effect, safety and reliability can be improved.	
Rear protection device for transporting car i.e. refrigerated van semi-trailer, has connection components whose rear end surfaces are connected to horizontal piece of rear lower part through elastic component	CHINA INT CONTAINER SHIPPING CO LTD |	The device has an anti-collision bracket assembly fixedly connected to a car rear lower part. Two connection components are vertical to a lower suspending bar, and are fixedly connected to the bar. Upper end surfaces of the connection components extend into a transporting car, and are fixedly connected to a vertical piece of the rear lower part. Rear end surfaces of the connection components are connected to a horizontal piece of the rear lower part through an elastic component e.g. spring steel component. A mounting plate is provided between the upper end surface and the vertical piece.	The device resets an anti-collision bracket, thus ensuring a gap between the lower part of the anti-collision bracket after resetting and ground as small as possible. The device has long service life.	CN201380815Y
Truck for transporting bulk load, has bumper arranged at rear side of vehicle chassis and below tipper element supported by chassis, and overhang section extended rearwards of tilt shaft that connects tipper element and chassis	HYVA INT BV	The truck has a tilt shaft at the end of a tipper element supported by a vehicle chassis (2), to connect the tipper element and chassis, and a bumper (8) arranged at rear side of chassis and below the tipper element. The tipper element has overhang section that extend rearwards of the tilt shaft. The bumper has bumper frames (14,15) and a hinge (12) to connect bumper frames and tipper element, and an adjustment mechanism to extend the distance between bumper and hinge.	The bumper can be located under the rear end of overhang section of tipper element, in drive state of truck, and can be easily moved against the underside of the overhang section, when the truck is unloaded by tilting the tipper element. The bumper frame can be easily used during drive of vehicle, and during tilting of tipper element. The loading and unloading can be easily and quickly performed, without the risk of damaging the bumper and tipper element. The hinge is made compact.	EP2143591A1 | EP2143591B1
Bulk load transporting truck, has bumper located at rear of chassis, where bumper is provided with bumper frames, and hinge connecting bumper frame to tipper body, and adjustment unit extending distance between bumper and hinge	HYVA INT BV	The truck has a chassis (2) for supporting a tipper body, and connected at an end of the tipper body, where the tipper body extends with overhang rearwards of a tilt shaft. A bumper (8) is located at rear of the chassis, where the bumper is provided with bumper frames (14, 15). A hinge (12) connects the bumper frame to the tipper body. An adjustment unit extends distance between the bumper and the hinge, where the tilt shaft and the hinge have the same rotation axis. An actuator (9) is coupled to the tipper body.	The truck allows locating the bumper under the rear end of the overhang while driving the truck and moving the truck against underside of the overhang when the truck is unloaded by tilting the tipper body, and allows the adjustment unit to extend distance between the bumper and the hinge so the truck is prevented from collision, thus preventing the truck from damage. The truck easily utilizes the bumper frame during driving or during tilting the tipper body. The truck has compact design. The truck allows positioning the bumper in a quick manner before starting unloading without damaging the tipper body.	EP2143592A1

Underride protection device for lorry i.e. air suspension lorry, has cross beam pivoted by holder arrangement between driving position and pivoted-forward position in region of rear dual tires of lorry	DAIMLER AG	The device has a cross beam (20), and a holder arrangement (22) for holding the cross beam on a vehicle frame (10) of a lorry. The cross beam is pivoted by the holder arrangement between the driving position and a pivoted-forward position in a region of rear dual tires (16) of the lorry. The cross beam is formed for installation on the tires of the lorry in the pivoted-forward position. A spring element is provided for holding the cross beam in the pivoted-forward position. The cross beam is held in the driving position by a safety element.	The cross beam is pivoted between the driving position and the position by the holder arrangement, thus ensuring that the lorry is universal and convenient in application.	WO2009080187A1 | DE102007062584A1 | WO2009080187A9 | EP2219904A1 | EP2219904B1
Bracket for underrun protection for vehicle, has three bracket portions, one of which is weaker than other bracket portions and forms curvature facing away from nearby steering device	SCANIA CV AB | SCANIA PUBL CV	A bracket (8) of a single plate construction has three bracket portions (30,32,34). One bracket portion (30) is rigidly fastened to an impact absorbing unit (16) or beam and articulately fastened relative to the frame (12) of the vehicle (4). Another bracket portion (34) is rigidly fastened to the frame. The last bracket portion (32) is weaker than the other bracket portions (30,34) and has a curvature (40) facing away from a steering device (18) nearby the bracket. During collision, the bracket deforms away from the steering device.	Steerability of vehicle is not lost even after collision, since, by forming curvature on weaker portion of bracket in direction facing away from steering device, bracket can be deformed away from steering device in event of vehicle collision. Brackets are arranged in mirror image fashion on respective sides of vehicle, making it easier to fit steering device in collision-protected manner on either side of vehicle, depending on whether vehicle is left- or right-hand drive.	WO2009051551A1 | SE200702331A | SE531582C2 | DE112008002755T5
Under-run protector for motor vehicle e.g. truck, has cylindrical reinforcement block arranged and fixed inside hollow portion in front-back direction of vehicle	MITSUBISHI ALUMINIUM CO LTD	The under-run protector has a cylindrical reinforcement block (2) arranged and fixed inside a hollow portion in the front-back direction of the vehicle. The contact plates (3) are attached to the front and back ends of the reinforcement block.	The strength of the under-run protector is improved without increasing the weight of the protector by using the reinforcement block.	JP2009090797A
Parallelogram supported bumper i.e. under-ride protection device, for e.g. bus, has product exhibiting automatic adjustment and/or control of impact forces, which takes places by elastically deformable elements and/or elastomer components	WEIGEL J	The bumper has a product manufactured to exhibit automatic adjustment and/or control of different impact and/or impulse forces. The control of the different impact and/or impulse forces takes places by elastically deformable spring, pneumatic and/or hydraulic elements and/or elastomer components and by flexibly deformable honeycomb structure and/or the elastomer components. The elements and their attachments are arranged in a suspended manner. The elements are protected in a pneumatic and/or hydraulic and/or mechanical manner.	The product exhibits the automatic adjustment and/or control of the impact forces, which takes places by the elastically deformable elements and/or elastomer components, thus reducing distance between the road and the lower edge of the bumper during the vehicle impact, and hence preventing the accident-causing vehicle from turning. The design of the bumper protects public life in traffic, minimizes the damages to property and combines the accessories such as pallet retainers and stowage boxes, with each other in an optimal and economical manner.	DE102007003916A1 | BR200800291A
Lorry, has underride protection-push rod arranged at consoles, formed and bent at attachments of consoles and encompasses consoles, where shanks of protection-push rod are arranged and bent to each other	DAIMLER AG	The lorry has two longitudinal carriers (2a, 2b), at which consoles (3a, 3b) are arranged at an end-side. An underride protection-push rod (4) is arranged at the consoles. The protection-push rod is formed and bent at attachments of the consoles and encompasses the consoles. Shanks of the protection-push rod are	The lorry is designed such that bending of the underride protection-push rod is enabled hardly at the attachments of the consoles without squeezing the volume of the shanks and respective ends of the	DE102007001111A1

		arranged and bent to each other and exhibit different thicknesses. A side of the push rod turned away from the consoles is constantly curved. Inner sides of the shanks are formed as flat and lying at bearing surfaces.	consoles together, so that the under ride protection-push rod exhibits an increased flexural rigidity.	
Protruding prevention apparatus for motor truck, has press cam that supports protruding prevention mechanism in erect posture	FURUKAWA IND MACHINERY SYSTEMS CO LTD | FURUKAWA SANKI SYSTEMS KK	A protruding prevention mechanism (41) and an up-down rotation mechanism (45) are provided in a loading platform (3). The protruding prevention mechanism is moved to fall or erect position by moving the up-down rotation mechanism. A press cam supports the protruding prevention mechanism in the erect posture so that a horizontal splice material (54) contacts a guide frame (44) in an opposite direction and restricts the force acting from back.	The strength of the protruding prevention mechanism is improved, reliably. Shortens the full length at the time operation and hence achieves size reduction.	JP2008149989A | JP04818897B2
Commercial motor vehicle`s e.g. lorry, rear under-run protection device, has percussion unit movable from output or normal position to end or crash position, where percussion unit is guided such that it lies in end or crash position	INFATEC GMBH	The device has a percussion unit (6) movable from an output or normal position to an end or crash position, where the percussion unit is arranged in the end or crash position at a distance below a vehicle frame (3) of a commercial motor vehicle (1). The percussion unit is guided in such a manner that it lies in the end or crash position at a unit supporting the percussion element. A holder (7) is provided between the percussion unit and the vehicle frame.	The device enables the commercial vehicle to take up high collision forces during collision, and effectively prevents the under-run of the commercial motor vehicle.	DE102006056498A1
Side sliding prevention device for carrying truck and carrying truck with such device	CHINESE INT SHIPPING CONTAINER GROUP CO LTD |	This utility model claims a side sliding prevention device for carrying truck and carrying truck with such device, this device includes fixing racks and prevention frames and the clips for adjustable fixation of prevention frames to fixing racks. This device simplifies the installation process and reduces the cost of production design and is easy to be mass produced.		CN200951742Y
Underrun protection system for a vehicle has frame connector that is arranged to be displaced parallel to a horizontal plane upon application of a force	VOLVO LASTVAGNAR AB	A beam (200) is attached to the frame connector (202) for mechanical attachment to a longitudinally extending frame portion (204) of the vehicle. The frame connector is arranged to be displaced parallel to a horizontal plane upon application of a force.	Less depending on where a crashing object hits the beam while still maintaining efficient underrun protection and distribution of crash forces.	WO2008002212A1 |
Chassis`s rear part protecting device for commercial vehicle, has cylinder and springs actuating frame to respective positions, where frame is slid to retracted position so that frame is spaced from obstacle when obstacle is detected	GOUVERNEUR	The device has a rear sliding frame (5) situated at the rear of a commercial vehicle and mounted slidingly with respect to a chassis (1) of the vehicle. A pneumatic cylinder (10) permits to actuate the frame to an active position in which the frame is projected with respect to the rear of the vehicle. Springs (12) permit to actuate the frame to a retracted position in which the frame is not projected with respect to the rear of the vehicle. The frame is slid in the retracted position so that the frame is spaced from an obstacle when the obstacle is detected.	The frame is slid to the retracted position so that the frame is spaced from the obstacle when the obstacle is detected, thus permitting the vehicle to react to the loading and unloading actions without premature wear of a rear chafing block. The configuration of the device permits to avoid the constraints of the part of the vehicle against a building of the obstacle, thus ensuring the movement of the vehicle with respect to the building without the degradation of its nature.	FR2899863A3

			The configuration of the device permits the sliding of the frame without transmitting the impact to the chassis of the vehicle.	
Manual storage-type rear bumper for vehicle, has fixing pin which is inserted in insertion hole for maintaining rear bumper in storing position and adjustment bolt for adjusting ground height position of rear bumper	SHIN MEIWA IND CO LTD	The rear bumper (1a) is maintained in the storing position by inserting fixing pin (3) in insertion hole formed in the base end of the attachment arm (23). The ground height position of the rear bumper is adjusted in the storing position by an adjustment bolt (4).	The ground height of the rear bumper storing position can always be made into maximum by adjusting the amount of rotation of the rear bumper by adjustment bolt. The interference with asphalt finisher can be avoided reliably. The rotation operation between the working position and the storing position can be performed easily.	JP2007290676A
Towing hook positioning structure for vehicle e.g. truck, has towing hook inserted through hook installation attachment of bracket	ISUZU MOTORS LTD	The towing hook positioning structure has an underrun protector (5) extending in width direction fixed to front or rear end of the vehicle frame (4), by a bracket (6). The bracket has a towing hook installation attachment (34) through which the towing hook (8) is inserted.	The deformation of the under-run protector during impact load is prevented. The bracket is shared and increase in weight and number of components are reduced. The attachment operability is improved. The towing hook is attached even to the vehicle without underrun protector, and versatility is improved.	WO2007080677A1 | JP2007186008A | JP04099781B2
Rear protector of truck, particularly for increasing the departure angle of the rear protector when the truck travels rearward	HYUNDAI MOTOR CO LTD	A rear protector of a truck is provided to increase the safety of the truck by forming a protector body of the rear protector adjacent to the ground and making the departure angle small.		KR2007048314A
Vehicle under side protection on impact with a smaller vehicle, especially for a cross country or pick-up truck, has an impact shield plate under the front bumper to be moved by a toggle lever into the protective setting	DAIMLERCHRYSLER AG	The under side vehicle protection (3) under the front bumper (13), especially for a cross country or pick-up vehicle, has an impact shield plate (27) to prevent a smaller vehicle passing underneath on an impact collision. It can be moved from a start position into a shrouding setting by at least one toggle lever (19) linked to a bodywork structure (15). The impact shield has a swing movement on a second bodywork structure (11), with a lock to prevent a backward movement on an impact.	The structure reduces the forces on the bodywork linkage points on an impact.	DE10200601178 6A1
Impact plate for the under side of a cross country or pick-up vehicle, to prevent a smaller vehicle passing underneath it on an impact collision, is held in place in the retracted position without movement by a centering unit	DAIMLERCHRYSLER AG	The protection system for the under side of a cross country or pick-up vehicle, to prevent a smaller vehicle passing under it on an impact collision, has an impact plate (16) moved between retracted and extended positions under the vehicle. It has at least one centering unit (29) to align it in the retracted position, with a centering element (31) in an opening.	The structure holds the impact plate in position without movement or vibration when in the retracted position.	DE10200601178 5A1

Underride protection device for passenger vehicle, has rubber flexible bearing and front plate, which connect inner and outer portions of two-dimensional extensive element to cross bar and longitudinal chassis beam, respectively	VOLKSWAGEN AG	A longitudinal chassis beam (1) defines a crash plane by arranging the transverse elements (10,11), a lateral longitudinal element (9) and a two-dimensional extensive element (8) in front of cross bar (3). A rubber flexible bearing (16) and a front plate (18) connect the inner and outer portions of extensive element to the cross bar and chassis beam, respectively.	Provides compatibility of the impact zones for protecting the occupants of struck vehicle reliably.	US20050275182A1 | DE102004028161A1 | US7461850B2
Protector structure for vehicle, has support arms fixed to ends of each protector bar, and guide biased by compression coil spring and having edge abutting over cam portions of support arms adjacent division position of protector bars	TOYOTA JIDOSHA KK	The protector structure (10) has a main body (22) divided into several protector bars (26). Two support arms (30) are fixed to both ends of each protector bar. A guide (56), which is pressed and biased by a compression coil spring (58), has an edge abutting over the cam portions (64) of the support arms adjacent the division position of the protector bars.	Ensures that uniform reaction force acts on an object or body colliding in front of a vehicle, and ensures minimum impact to the object or body colliding with the vehicle. Provides a simple protector structure that can be simple installed to the bottom portion of a vehicle's front bumper with increase in number of parts. Ensures that the protector main body is arranged and attached to the bottom portion of the vehicle's front bumper without touching the road surface.	JP2005225460A | JP04321289B2
Chassis protection device for a heavy goods vehicle, comprises swivel arms, each of which has at least one telescopic arm section which is movable relative to the vehicle rear	XAVER MEILLER FAHRZEUG MASCHFAB GMBH	The chassis protection device comprises swivel arms (20a,20b), each of which has at least one telescopic arm section (25a,25b) which is movable relative to the vehicle rear. At least one swivel arm can be secured in the pullout position and insertion position by a securing mechanism (45).	The chassis protection barrier is sufficiently low, even for vehicles with a high frame.	DE102004024159A1
Motor vehicle e.g. tourist car and lorry, has anti-embedded bar that is transversally linked to two longitudinal slide rails and moved transversally between upper and lower position in reference plane	POMMIER | POMMIER SA	The vehicle has an anti-embedded bar (10) that is transversally linked to two longitudinal slide rail (1). A linking arm has front (30) and back sections (40) joined mutually with each other, where the front section is joined to the slide rail and the back section is joined to the anti-embedded bar. The anti-embedded bar is moved transversally between an upper and lower position in a reference plane (P).	The anti-embedded bar unit is moved transversally between an upper and lower position in a reference plane, thus reduces the disturbance in unloading the vehicle.	FR2850618A1 | EP1445153A2 | EP1445153B1 | DE602004000697D1 | ES2263115T3 | DE602004000697T2
Mounting structure of side guard rail is provided to offer convenience to a worker in vehicle maintenance by detachably mounting the side guard rail, and to reduce the weight of a vehicle and manufacturing cost	HYUNDAI MOTOR CO LTD	A mounting structure of a side guard rail is provided to offer convenience to a worker in vehicle maintenance by detachably mounting the side guard rail, and to reduce the weight of a vehicle and manufacturing cost.		KR2004023032A | KR483120B
Under-run guard for utility vehicle comprises bumper attached to force-absorbing component with inverted V-shaped groove which crumples when bumper hits obstacle with force exceeding threshold value	DAIMLERCHRYSLER AG	The under-run guard for a utility vehicle (3) comprises a bumper (1) attached to a force-absorbing component (2) with an inverted V-shaped groove (5). This crumples when the bumper hits an obstacle (4) with a force exceeding a threshold value.		DE10144212C1

Hinged guard for truck or trailer side has projections on vertical bars to engage with slots in brackets when raised	NATALI G | NATALI G F	The guard, consisting of vertical bars (1) pivoted in inverted U-section brackets (4) and having a panel or transverse bars attached to their front faces (2), has projections (14) on the sides of the vertical bars which engage with slots (13) in the brackets to hold the guard in its raised position. The bars have elongated holes for the bracket pivot pins (8) and additional holes for locating pins (11) which hold them in the vertical position.	The guard can be raised and fixed in the raised position for improved access to tank, toolbox or other objects fitted under vehicle body.	FR2807984A1 | DE10119249A1 | IT1321485B
Front side structure of motor vehicle, consists of protrusion material protruding beyond bumper reinforcement on lower side of bumper and supported movably by a support	MAZDA KK	The front bumper (8) has a reinforcement (6) installed on the end of right and left front side frame (5). Protrusion materials (10) are provided, so that the end protrudes beyond the reinforcement to the forward direction on lower portion of bumper. The protrusion material is movably supported to the lower side by supports (9), more forward than the reinforcement, when colliding.	Ensures safety of pedestrian, when colliding with front portion of vehicle, by reducing the action position of the protrusion material to the lower side, and prevents a fracture of leg.	JP2001088655A
Commercial vehicle drop-down drive-under protection device has lever arms and guide mechanism for movement of rear bumper bar between raised and lowered positions	DAIMLERCHRYSLER AG	The drive-under protection device is attached to the chassis (1) of the commercial vehicle via lever arms (6) on either side of the vehicle, for movement between a raised inactive position and a lowered active position. The free end of each lever arm is provided with a second lever arm (8) supporting a rear bumper bar (10), with a guide mechanism (19) cooperating with or both lever arms.	The protection device is lowered automatically in the event of an accident to protect the passengers of a following automobile.	DE19928104A1 | DE19928104B4
Deployable underride protection for trailer has pivotable ramp set at rear end of tilt bed and free to rotate rearward relative to transport vehicle according to exerted force when in downward position	TOWMASTER INC	A pivotable ramp (38) that serves as a barrier disposed at rear end of the tilt bed (30) is automatically deployable with respect to the position of the tiltable bed. The ramp is free to rotate rearward relative to the transport vehicle according to exerted force when disposed in a downward position while the tiltable bed is in a transport disposition.	Reduces damage to underride protection especially when trailer is traveling along rough or uneven roads.	US6179544B1
Multipart under-run guard for vehicles with load-lift platforms	BAER G	The individual parts (11,12) which make up the under-run guard (10) are each connectable to a connecting device (17,18) fixed on a support profile of the platform. Each connecting device has a rearward perpendicular flat bearing face (17a,18a) with fastening holes (19,20) of which at least three are set in a row one behind the other in the longitudinal direction of the vehicle.	The protection can be screwed onto the support profile at variable length and only one structural group need be provided for any length.	EP903266A2 | DE19741457A1 | DE19741457C2 | EP903266B1 | DE59806697D1
Removable fixing for vehicle bodywork part comprises clamp with central plane region on edges of which are two branches having re-entrant region holding it on support region and gripping section enabling separation of branches for disengagement	HUTCHINSON | HUTCHINSON SA	The removable fixing for a vehicle bodywork part (30) comprises a clamp (1) having a central plane region (11). On the edges of this region are two branches (5,6) each having a first re-entrant region (16) which enables holding the clamp on a complementary region (26) of a support section (2). There is also a gripping region (17) enabling the separation of the branches in order to disengage the clamp from the support.The clamp has an elastic piece having a base face which rests on the clamp central plane region and borders a	ADVANTAGE The clamp is relatively easy to install and reduces the vibrations.	EP864763A1 | FR2760799A1 | EP864763B1 | DE69802596D1 | ES2167847T3

		proximal region (12) of each of the clamp branches. The elastic piece upper face (38) is abutted on a base face (28) of the support when the clamp is mounted on the support.		
Motor vehicle bumper has lower bumper section attached to support member and movable with it about hinged connection against biassing members	SPEASE D R	The bumper comprises an upper bumper section (13) mounted to the vehicle (1) and having hinged connections (11) and biasing members on it to normally bias an attached vertical support member (9) towards a vertical disposition. The biasing member includes a horizontally disposed spring (15) attached to a pulley having a depending cable (25) attached to the support member.The vertical support member is connected to the upper section hinged connections and vertically depending from it. A lower bumper section (5) is attached to the support member and movable with it about the hinged connection against the biasing members when impacted by an obstruction.	USE/ADVANTAGE For loading carrying trucks where the bumper lower section moves away from the vehicle when impacting an obstruction.	US5673 953A
Rear impact trailer guard for semi-trailers includes collapsible struts formed with joint in mid-portion which allows bumper to move inward toward the tyres of semi-trailer and collapsible strut to move toward frame to move bumper from interfering position w.r.t ramp	US SEC OF ARMY	The guard includes a safety bumper extending horizontally across the vehicle body, the safety bumper being of sufficient strength to withstand the force of impact generated by the impact of a vehicle. There are vertically extending bumper supports located at the rear of the trailer. There are curved legs having one end firmly attached to the trailer frame, and the other end extending towards the rear of the trailer to a point below the trailer frame.The curved legs have a curved aperture formed through it, the curved aperture having a number of roller teeth formed on the lower surface of it and a number of detents formed on the upper surface of it. There are also a number of second arm members corresponding in number to the vertical supports each of the second arm members being associated with a particular curved arm. There are also slotted bars having one end attached to the trailer frame at a point near the rear of the trailer, the slotted bars having a longitudinal slot formed near the end of the slotted bar juxtaposed the curved arm. Finally there are a number of cam pins associated with the second arms, the cam pins having one end firmly mounted in the second end of the second arm, each of the cam pins extending orthogonally to the associated second arm through the curved slot and into the slot in the slotted bar.	ADVANTAGE A gentle force on the safety bumper will cause the cam pin to move along the roller teeth allowing the bumper to retract in toward the trailer frame but when the bumper is struck forcefully, the cam pins will move into contact with one of the detents from the impact force preventing the vehicle from submarining under the semi-trailer.	US5632 518A
Front lower side protector for vehicle e.g. truck has turning pin which laterally and turnably connects protector body to joint bracket attached vertically to tip of bracket through shaft	NISSAN DIESEL KOGYO KK	The protector has a bracket (4) with a base edge fixed at both sides of the front end of a frame (2). A joint bracket (6) is vertically and turnably attached to the tip of the bracket through a shaft positioned on the front and rear axial lines of a vehicle body.The protector body is laterally and turnably connected	USE/ADVANTAGE For protection against collision. Reduces cost of device since shaft with comparatively small dia. can be used. Exchanges bracket and joint bracket only on side where impact	JP83243 62A

		to the joint bracket through a turning pin to which the axial line is vertically positioned.	is received. Minimises damage of bracket.	
Drop down bumper for attachment to rear of truck or transportable container comprises impact protection bar, attached loading rollers, and foldable linkage connecting impact protection bar with frame	WALDSCHMITT T	The drop down bumper comprises a transverse impact protection bar having a first end and a second end. A first loading roller is mounted to the first end of the transverse protection bar. A second loading roller is mounted to the second end of the transverse protection bar.A linkage is movable between a folded position and an extended position. A device attaches the linkage to the frame. A device attaches the impact protection bar to the linkage such that when the linkage is in the folded position the impact protection bar is proximate to the frame, and when the linkage is in the extended position the impact protection bar is moved a distance below the frame.	ADVANTAGE Prevents cars or other small vehicles from riding under the rear of a container being carded on a truck. Is compatible with a wide variety of tilting truck beds.	US5624143A
Side guard for freight motor vehicle has control cylinder that moves guard main body from vertical position to horizontal position	HINO MOTORS LTD	The guard (1) comprises a guard main body that is placed near a side frame (13) of a front-rear wheel axle part. The side guard hinge (5) is attached to a side guard bracket (4) between which the guard main body is placed.The guard main body is moved from a vertical position to a horizontal position using a control cylinder.	ADVANTAGE Improves efficiency of unloading work. Enables use of side step during unloading.	JP8142922A
Movable bumper for vehicles includes bumper rotatably mounted to frame of vehicle, with piston located on vehicle moving bumper moving bumper between first lower portion suitable for highway driving and second elevated position for off road operations	BELL F G	The bumper for mounting on a vehicle is movable between at least a first lower position suitable for highway driving and a second elevated position that is suitable for working conditions. The bumper is preferable rotatably mounted to the frame of the vehicle and means are provided for moving the bumper between the first position and the second position. Piston members which normally may be adapted to lock the bumper in the front lower position for highway driving are connected to both the frame of the vehicle and the rotatably mounted bumper.The piston members are preferably pneumatic and are activated by the vehicles air supply system which is operably connected to the piston member. Activating members such as solenoid valves are connected into the air supply system to cause the piston member to either retain the bumper in the lower highway position or to move the bumper to the elevated working position. Normally the bumper is locked in a first position i.e. the lower highway position. A control unit is operably connected to the activating member to cause the piston means to move the bumper between the positions.	ADVANTAGE Provides vehicle bumper which both conforms to requirements for highway driving and which also may be moved to alternative position to facilitate working operations.	US5520428A

Rotating hinge for cover panel of truck carrier has first member hanging downwards with overhang and second part with concave part to receive overhang when hinge is swung	SHOWA ALUMINUM CORP			JP8028546A | JP03141128B2
Vehicle interruption prevention appts mounted in trailer has attachment part which is provided at lower part of post attaches light emitting part	MARUTO SEAT PILE KK	The appts has a post (2) which hangs from a support body (S).A clamp unit (3) attaches the post to the support body. An attachment unit (5) provided at the lower part of the post attaches a light emitting part (4).	ADVANTAGE Prevents accidents reliably. Has compact structure. Recognizes loading platform of pulled vehicle and pulling vehicle reliably. Improves versatility. Simplifies attachment of light emitting part.	JP7329629A
Vehicle rushing into prevention device has pin part driving mechanism which turns releasing pin part in support arm activating rear bumper of vehicles such as dump trucks	NAKAZATO K	The device installs a support arm (1A,1B) of a right and left couple extending to the rear end of a vehicle. These are placed at the lower side of the carrier frame. It fixes a rear bumper (2) extending to the width direction of the vehicle. It is turned connecting it to the free turn on the base part end of the support arm. The rear bumper is turned upward on the carrier frame through a supporting axle (3). The support arm part opposed to the frame surface of the carrier is formed.Pin parts (5A,5B) advances when the support arm is turned at the lower edge of the carrier frame. The turn movement of the support arm is facilitated through a support arm driving mechanism. It is located in the upper and lower arm of the support arm. The support arm driving mechanism makes the pin part go into the lower turn edge of the support arm. A pin part driving mechanism (71) precedes turning on the support arm making the pin part to be released.	ADVANTAGE Pin part driving mechanism facilitates enough shock absorption and providing cheap and light structure.	JP7228209A | JP03315514B2
A system, method, and apparatus for automotive under-run protective device	TATA TECHNOLOGIES PTE LTD	A SYSTEM, METHOD, AND APPARATUS FOR AUTOMOTIVE UNDER-RUN PROTECTIVE DEVICE	The present disclosure provides an apparatus, a system for a under-run protection device for a vehicle comprising a first beam member extending laterally to the direction of the vehicle, wherein a partial portion of the first beam has a corrugated cross-section. A second beam member mounted on the first beam member positioned and adapted to absorb an impact from another vehicle by deforming when the impact force exceeds a predetermined level, further the partial corrugated cross-section of the first beam member enables reduction in construction/manufacturing material for the said second beam member. A plurality of brackets characterized by	IN201201975I3

			a Lshape, joined to the first beam member at one arm of the L-shape and with the vehicle at other arm of the L-shape.	
Cargo handling vehicle e.g. dump truck, has rear bumper, which can be rotated relative to rear end of vehicle body frame from rear impact position to storage position under box as it declines rearward to dump position	KYOKUTO KAIHATSU KOGYO KK	CARGO HANDLING VEHICLE	Enables load to be dumped out of box without causing accidental contact between rear bumper and dumped load.	JP2008012968A
Cargo handling vehicle e.g. dump truck has rotatable protective shield supported by rear bumper positioned behind rear lamp	KYOKUTO KAIHATSU KOGYO KK	CARGO HANDLING VEHICLE	An exclusive component for protecting rear lamp is avoided by mounting the shield on the rear bumper.	JP2007320490A

Appendix E: FMEA

Main Function / Operation			Date Performed : 08-05-14	Date Time Updated				
PART		CHARACTERISTICS OF FAILURE						
Concept	Function / Part / Operation	Failure mode	Causes of failure	Undesirable customer effects Effects of failure on syst. / part / operation	Po	S	Pd	RPN*
Guide	Side plate	Cracks due to fatigue	Wrong dimension		3	3	9	81
			Wrong design	Difficult to observe	3	3	9	81
		Cracks near screw holes	Wrong dimension		4	3	9	108
			Wrong shape		4	3	9	108
		Deformation	Wrong dimension		4	3	5	60
		Out of position	Wrong combination of side plate and truck variant	Legal requirements	3	6	5	90
			Wrong size of side plate	Legal requirements	3	6	4	72
			Plate assembled in w rong holes		4	5	4	80
		Corrosion	Chafing from surrounding parts		4	3	5	60
	Quick release pin	Cracks	Shear forces	Vibrations	8	5	1	40
		Jam	Dirt	Pin stuck in the hole	4	8	1	32
		Build up edge	Repeated stress at point of mate w ith intermediate arm		3	4	2	24
	Bushing supporting the semicircular slot	Wear	Friction	Undesirable motion of the RUP	6	3	6	108
	Intermediate arm	Arm tilts dow nw ards in inactive position	Loose tolerance and no dampner present		5	6	4	120
C-arm	Side plate	Cracks due to fatigue	Wrong dimension		3	3	9	81
			Wrong design		3	3	9	81
		Cracks near screw holes	Wrong dimension		4	3	9	108
			Wrong shape		4	3	9	108
		Deformation	Wrong dimension		4	3	5	60
		Out of position	Wrong combination of side plate and truck variant		3	6	5	90
			Wrong size of side plate		3	6	5	90
			Plate assembled in w rong holes		4	5	4	80
		Corrosion	Chafing from surrounding parts		4	3	5	60
	Quick release pin	Break	Shear forces		3	5	2	30
	Quick release pin	Jam	Dirt		4	3	2	24
	Side bush w ear out		Wear		5	3	5	75
	Intermediate arm	Arm does not get properly guided.			8	5	4	160
		Arm rattles w ithin the side and top plate	Loose tolerance and no dampner present		8	6	4	192
		Revolving	Top portion of intermediate arm proturdes out from the front		8	6	4	192