Modularised Passenger Seats

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Industrial Ergonomics

Degree Project
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Preface

This master’s thesis has been carried out at Scania CV AB, Södertälje, in cooperation with the department of Management and Engineering (IEI) at the University of Linköping. The thesis was performed between June and November 2007 and constitutes the last stage of our Master degrees in Mechanical Engineering.

We would like to thank the following persons that have helped us in different ways with the realisation of this thesis:

<table>
<thead>
<tr>
<th>Name</th>
<th>Title and Institution</th>
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Abstract

The purpose with this master’s thesis, with Scania CV AB in Södertälje as job initiator, has been to develop three different passenger seat concepts with focus on modularisation, functionality and production. The different concepts are: a foldable passenger seat, which is possible to fold away completely, a bench for two passengers, and a resting seat for resting during breaks when the vehicle is parked.

The main tools used during the search for concept solutions have been brainstorming, morphological analyses, and evaluation matrixes. Prototypes have been made in order to visualise the ideas but also for the possibility to test them in a real truck cabin and by that find advantages but also flaws. Final product specifications has been made and with that guidelines for a continued development work.

Experiences gained during this thesis work has been that by using ergonomic data and theories, well thought through designs, and standardised interfaces a good result can be achieved, which fulfils the demands and wishes placed on the future product.
Sammanfattning

Detta examensarbete syftar till att, på uppdrag av Scania CV AB i Södertälje, utveckla tre olika passagerarstolskoncept vilka alla berör områdena modularisering, funktionalitet och produktion. Koncepten var för sig syftar till att lösa problem inom behovsområdena vilolats för föraren, möjlighet till mer utrymme i hytten genom att stolen tar så lite utrymme som möjligt respektive möjligheten att ha fler än en passagerare. Detta resulterade i en helt undanfällbar passagerarstol, en bänk och en vilstol.

De huvudsakliga verktygen som använts under konceptframtagningsarbetet har varit brainstorming, morfologiska analyser samt utvärderingsmatrizer. Prototyper har tagits fram för att visualisera koncepten, men även för att kunna testa dem i en riktig lastbilshytt vilket i sin tur har visat både styrkor och svagheter hos koncepten. En slutlig produktspecifikation har tagits fram och därmed också riktlinjer för ett fortsatt utvecklingsarbete.

Detta examensarbete har resulterat i insikt i att genom att använda ergonomiska data och teorier, väl genomarbetade konstruktioner och standardiserade gränssnitt kan ett bra resultat uppnås, vilket uppfyller de krav och önskemål satta på den framtida produkten.
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1 Introduction

The introduction chapter aims to provide background information related to the design of passenger seats for trucks when the focus is on modularisation, functionality and production. It also defines the scope of the thesis.

1.1 Background

This part of the chapter defines the background of both the company and the problem, and states the problem which is to be solved.

1.1.1 Company Background

The Scania group is one of the world’s leading manufacturers of heavy trucks (above 16 tons) and buses, as well as of industrial and marine engines. They supply after-sales services on all of their products and they have their largest factories in São Paolo, Brazil, and in Zwolle, Netherlands. Most of the development takes place in Södertälje, Sweden. In total Scania has about 33 000 employees around the world of which 13 000 is situated in Sweden. (Scania Official Homepage, n.d.)

"Scania’s vision is to be the leading company in its industry by creating lasting value for its customers, employees, shareholders and other stakeholders”
(Scania Official Homepage, n.d.)

1.1.2 Problem Background

Today Scania has three series of trucks: P, G, and R (see Figure 1.1). The P-series trucks are optimised for regional and local distribution, construction, and various specialised operations associated with locally-based transportation and service. The G-series trucks are designed for customers with special requirements such as tough operating conditions and poor roads. The R-series trucks are optimised for long haulage. The cabins of the P-series are lower than the ones in the G- and R-series, which means that the engine tunnel takes up more space inside the P-cabin. The cabins in the R-series are the highest of the three, and have thereby an engine tunnel which takes the least space. Examples of Scania cabins are shown in Appendix 1.

![Figure 1.1 Cabins of the P-, G- and R-series](Scania Official Homepage, 2007)
Introduction

Long haulage is often customary for truck drivers, which means that they are on the roads for days at a time. These conditions demand that the interior of the cabin is comfortable and functional in all situations. A crucial point is the driver seat, but also the passenger seat is important for the overall impression and functionality of the cabin. The passenger seat can serve as an alternative seat for the driver during breaks, making it easier to separate free time from work. It can also serve as a seat for a second driver, thus maximizing the driving time. Lastly, the passenger seat can hold a passenger, making it possible to bring someone along for company.

Today Scania has three types of passenger seats: a regular seat, a foldable passenger seat and a bench with two seats, which can be seen in Figure 1.2-1.4. The regular seat is available in three versions depending on the level of adjustments: basic, normal and luxury. On the foldable seat it is possible to fold up the seat squab which gives more floor space and it is also possible to fold down the backrest which makes the seat function as a table.

1.1.3 Problem Statement

The purpose of this thesis is to develop three different concepts for the passenger seat for Scania trucks. The concepts should focus on functionality, modularisation and production concerning the seats. The three concept areas are as follows:

- In the future one can see the need for increased functionality of the passenger seat. The main function for this seat is that it should serve as a passenger seat for one person and be able to be folded away completely or simply foldable with an additional function. This thesis will investigate the possibility to add more functions at the same time as increasing the open space in the cabin in order to ease movements in the cabin.

- In order to have more than one passenger Scania has a bench where two persons can be seated relatively comfortable and safe. The functionality and design of the new concept should be improved, making it safer and more comfortable but should also offer possibility for storage.

- The passenger seat can function as a resting place for the driver during long haulage breaks. To best accommodate this need, a separate seat with different functions is to be developed. This resting seat should offer good support and a comfortable seating position.
1.2 Scope and Definitions

To achieve a good result in a project one needs to have restrictions so that the work, needed to solve the project assignment, will be consistent with the given project time. The restrictions made in this thesis are as written below.

The thesis will not result in final product solutions but will instead end in prototype solutions. Nevertheless, the project can be considered as a first step in the product development. This restriction is due to the numbers of assignments in relation to the project time.

The main market will be Europe, which among other things will affect the anthropometric data.

There will not be any calculations done on the dimensioning of the seats; for example if they can withstand the forces during a crash. This is mainly because of the time limit but also because it is not included in the project assignment.

The ergonomic features as well as the main functions of the seat will be done in this thesis but the appearance will only be done generally. This is because it is not included in the project assignment.

Some important definitions, often used in this thesis report, are explained in Figure 1.5.

![Figure 1.5 Definition of terms used in this thesis](image-url)
1.3 Disposition

This thesis report is divided into a number of chapters. The first chapters give a background and a theoretical base for the thesis work and are followed by an explanation of the methods planned to use. The methods are explained on a rather basic level and might be left out by the readers that are already familiar with the product development process. Then the methods which were used are presented and after that the results. During the concept generating process many brainstorming sketches and concepts were developed, but because of this great amount only a selection of them are shown in the report. After the result, a discussion is given where the results but also the thesis work are analysed. Finally, the conclusions of the thesis work are presented.

Due to company specific reasons parts of the thesis and its result will only be published internally at Scania and have therefore been moved from the report to appendix. By the same reasons not all concepts and matrixes are shown.
2 Research Questions and Purpose

This chapter states the purpose of the thesis along with its main research questions, which defines the thesis and shows the main focus.

The purpose with this thesis is to develop concepts for passenger seats in Scania trucks. Three different passenger seats will be developed: a foldable passenger seat, a resting seat, and a bench. The focus of the thesis is placed on the modularisation, the functionality, and the production of the seats.

The main research questions that will be dealt with are:

- How should the seats be designed to be both functional as well as be able to support an ergonomic seating position?
- How can the seats support the driver’s and passengers’ need for relaxation?
- How can the manufacturing and assembly of the seats be solved so that they are simple as well as fast?
- How should the modularisation of the seats be achieved and to what extent?
- How can the passenger seats contribute to the realisation of Scania’s product identity?

The aim with the thesis and the expected result, after answering the research questions, are as follow:

- To review current theories applicable to the project goals.
- To develop functioning concepts for each of the seats.
- To manufacture prototypes for each of the seats
3 Theoretical Frame of Reference

The theoretical frame of reference introduces the information needed to realise this thesis project. The selection of what is included in this chapter is an intentional choice and will act as a depot for this thesis report.

3.1 Ergonomics

According to Pheasant (1996), the word ergonomics comes from the Greek words for work (ergos) and natural law (nomos). The science of ergonomics was founded at a conference in 1949 and is an interdisciplinary science which studies how a work is performed, which tools are used, the place where a work is performed, and the psychosocial aspects of the working environment. Ergonomics has several branches such as cognitive ergonomics and anthropometry. Ergonomic theories can also be used to determine optimal seating position for different situations.

3.1.1 Anthropometry

Kroemer et al. (2001) states that the science of anthropometry deals with the measurements of the human body meaning the size, shape, strength, and working capacity of a human. Anthropometric data tells us about the variety of human measurements based on documented studies. Pheasant (1996) uses anthropometric studies which give numbers of, for instance, the stature of European males or the reach of Asian women. Because reliable anthropometric studies are rare and seldom deals with all parts of the population the data used is often old, as Kroemer et al. (2001) state. This creates a danger due to the fact that measurements of the human body have changed over the years. People today are generally larger than their ancestors, probably due to a change in nutrition and hygiene habits.

Pheasant (1996) writes that, in order to design a seat suited for a large international target group one must first decide which design limits to have and which appropriate tables of anthropometric data to use. The recommended design limits are the 5th percentile (5th %ile) of women and the 95th percentile (95th %ile) of men. This means that one designs with 95% of the population in mind. Different parameters should either follow the upper or the lower limit. For instance the space needed to accommodate the head and the movement of elbows and legs should be designed with respect to the 95th %ile of men. The distance to panels or controls should be designed with respect to the reach of the 5th %ile of women. The measurements given by anthropometric data should be corrected to take into account shoes and clothes. The anthropometric data used in this thesis are shown in Appendix 2.

3.1.2 Seating Position

According to Pheasant (1996), when designing a chair or a seat one should consider three things: it should be comfortable to use during a specific period of time, physiologically satisfying, and appropriate for the task that is to be performed. Although no chair or seat is comfortable after a longer period of time some are perceived as uncomfortable faster than others. There are some aspects to consider when trying to achieve an optimal seating position and some of these aspects are further explained below.

The height, depth, and angle of the seat squab, which are defined in Figure 3.1, are all important parameters when designing a seat. If the seat is too high, pressure will be placed on the backside of the thighs which could cause impaired circulation leading to swollen feet and discomfort. On the other hand, a too low seat may cause the user to flex the spine in order to
have an optimal angle between the thighs and the trunk which causes the discs in the spine to deform. If the seat squab is too deep it will be hard for the user to stand up. The user will also have a bad posture due to the inability to lean properly against the backrest. If the seat squab is tilted rearwards from the horizontal the user achieves good contact with the backrest and is prevented from slipping out of the seat. A too large angle makes it more difficult standing up and sitting down.

The backrest with its dimensions and angle, defined in Figure 3.1, has a great influence on the seating position and its effects. The higher the backrest is the better it will support the weight of the trunk, thus relieving the discs in the spine of additional pressure. The backrest should follow the shape of the spine, especially in the lumbar region where extra support might be needed. When the backrest is reclined it carries more of the trunks weight thus relieving the discs in the spine of some pressure. To conclude the Pheasant review (1996), he writes that with an increasing angle of the back a corresponding tilt of the seat or a high friction material must follow to prevent the user from sliding down.

![Figure 3.1 Definition of seat dimensions. Seat height (A), seat depth (B), backrest height (C), seat squab angle (α) and backrest angle (β). (Based on figures from Pheasant, 1996)](image)

There are several other ways to improve the seating position, for example by the use of headrest, armrests, or with the surface of the seat. The European Union Law (2007) states that the main purpose of a headrest is to limit the rearward displacement of the passenger’s head in relation to the rest of the body; this in order to minimize the risk of damages on the cervical vertebrae in the event of an accident. The headrest must not have any hard edges or irregularities that might increase the risk of injuries in an accident. The headrest may or may not be a part of the backrest. Pheasant (1996) writes that armrests support the seating position and acts as an aid when standing up or sitting down. The upper surface of an armrest should either be padded or not go as far back as to the bony part of the elbow where several nerves are easily accessible. It is important to have a good pressure distribution in the seat to avoid putting extra pressure on soft tissues. To achieve this Pheasant (1996) recommends that; the seat should be plane rather than shaped, the foam of the seat should be firm rather than soft, and the material should be rough and porous to aid stability and ventilation in the seat.

All these aspects are recommendations based on studies made by different scientists, but they should be critically analysed and balanced against the needs and demands on the seat in question. The need for armrests might for instance be overshadowed by a limitation in space and the surface material, which might be optimal from a seating position point of view, might be too expensive. Nevertheless, when designing a seat one should always consider the seating position and strive to find an optimum.


3.1.3 Automotive Seating

Reynolds (1993) writes that a seat in a vehicle should be seen as a structure to support the body rather than as something that should fit with the design of the rest of the vehicle. Automotive seats can be separated into two different categories: performance and touring. Performance seats are firmer than touring seats and have more supporting contour as well as several functions for the user to adjust. All automotive seats should at least be adjustable horizontally and vertically as well as in the inclination of the back.

The design process of a driver seat is different compared to that of a passenger seat. This because there are differences in demands due to the tasks the driver and the passenger performs.

For an automotive seat the transportation of water and vapour through the seat upholstery and the other materials of the seat are important. If the moisture is not transported away but rather gathers in or on the seat the user experiences a degree of discomfort. Therefore the material of a seat should be chosen with regards to its ability to transport moisture, this according to Reynolds (1993).

Kroemer et al. (2001) declares that the backrest of a seat for automobiles, as well as for aircraft, is often designed to follow the shape of the spine. This means that the back is concave at the bottom, to make room for the buttocks, convex slightly above, to fill out the lumbar bow, then rising nearly straight but reclined to support the trunk, and then convex again at the top, to follow the bow of the neck (see Figure 3.2).

![Figure 3.2 Profile for automotive seat and reclined seat](image)
3.1.4 Reclined Seating

According to Kroemer et al. (2001), a reclined seat has as its main function to support the body during periods of rest and relaxation. In doing this it should relieve the body of as much stress as possible. An upright backrest cannot support any of the trunks weight and because of this the compressive forces between the discs can be from 350 up to 660 N. If the backrest is reclined these forces decreases, since part of the trunk’s weight is now carried by the backrest. The presence of lumbar support reduces the compressive forces further. A protrusion of 5 centimetres by the lumbar decreases the compressive force with nearly half its original value.

To achieve an optimal angle between thighs and trunk and to reduce the risk of the user sliding down, the seat should be tilted (Pheasant, 1996). An inclination of 20º-30º of the backrest from the vertical and a, up to, 24º tilt of the seat from the horizontal are recommended by Kroemer and Grandjean (1997) and shown in Figure 3.2. To support the head and the neck properly it is recommended that the upper part of the backrest should be inclined 10º forward and be supplied with an adjustable pad (Pheasant, 1996).

3.1.5 Seats for More Than One Person

Sometimes there might be a reason for having two or more seats joined together in one unit. This can save space since the width of a 95th %ile couple is less than twice the 95th %ile individual. This because of the odds of two persons from the 95th %ile meeting random and sharing a bench is, according to Pheasant (1996), 1 in 400. Table 3.1 shows the space needed for a specific number of people sitting in a row; both the mean values and the 95th %ile value.

<table>
<thead>
<tr>
<th>Number of persons</th>
<th>Width required (mm)</th>
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<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>1</td>
<td>480</td>
</tr>
<tr>
<td>2</td>
<td>960</td>
</tr>
<tr>
<td>3</td>
<td>1440</td>
</tr>
<tr>
<td>4</td>
<td>1920</td>
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</table>

3.1.6 Comfort and Discomfort Regarding Sitting

Eklund wrote in his dissertation 1986 that comfort and discomfort are frequently used parameters in ergonomic studies, but that comfort is not a well-defined concept. It can refer to perceived feelings of either comfort or discomfort, but is most often a mix of both. Scientifically there are evidences that the concepts of comfort and discomfort are affected by different variables and should therefore be judged on separate criteria. Discomfort is associated with pain or tiredness caused by a physical constraint on the body and will increase over time. Melzack argued that if a person experiences pain when sitting, it is a reaction of the body indicating the need for relief, for example in the form of movement or change in posture (as cited in Eklund, 1986, p. 47). Comfort on the other hand is based on feelings of well-being as well as aesthetic impression (Helander & Zhang, 1997). Kroemer et al. (2001) writes that a user easily can identify features in a seat that results in feelings of discomfort, but by simply avoiding these features a comfortable seat is not guaranteed. All contributing factors to both comfort and discomfort must be taken into consideration.
As cited in Eklund (1986, p. 47) Branton states that the stability of the seat contributes to the feeling of comfort or discomfort. For a seat to be perceived as comfortable it should, according to Kroemer et al. (2001), also allow the occupant to shift position and the main features of a seat should be easy to adjust; allowing movements, individual preferences, and differences in body dimensions.

Comfort and discomfort are still diffuse parameters and although some research has been made in the area there are no commonly accepted definitions. The parameters are subjective and one person’s opinion of what is comfortable might not be shared by another. Nevertheless there are factors which can be identified as contributing to the perceived feelings of comfort and discomfort and these should be dealt with in order to increase the feeling of well-being as well as decrease the risk of work related injuries caused by a recurring strain on the human body.

3.2 Automotive Safety

Since the beginning of automotive history, safety has been an important subject in order to prevent injuries during accidents. Research has been made and over the last decades vehicle safety has increased enormously but in spite of this, 1.2 million persons worldwide are killed in road accidents and 50 million are injured every year (World Health Organisation, 2004). One needs to confront the problem from all directions; safe cars need to be manufactured, a good infrastructure needs to be built and maintained, and the road users need to take responsibility in the traffic.

Safety can be divided into two features: active and passive safety. Passive safety is safety which is built-in in the construction, for example an optimised crash structure of a vehicle and airbags. Passive safety does not change behaviour depending on the crash scenario, but behaves in the same way regardless of the severity of the crash. Active safety relates to systems which help avoiding accidents, for instance Advanced Driver Assistance Systems (ADAS) that includes, among other things, Anti-lock Braking System (ABS).

Death in traffic occurs mostly for the least protected road users like pedestrians, mopedists, and motorcyclists (Nationalföreningen för Trafiksäkerhetens Främjande [NTF], 1998). In the first six months of 2007, 30 per cent of all traffic related deaths in Sweden occurred in combination with heavy vehicles (NTF, 2007); vehicles with a total weight above 3.5 tons. This means that manufacturer of heavy vehicles needs to not only consider the occupants inside the vehicle but also all other road users. In the case of Scania the main focus is on active safety. But Scania consider active safety to be what decreases harmful effects on humans and material values outside the vehicle and prevents accidents from happen while passive safety is what protects the passengers inside the cabin (Rabenius B., 2007). Because of this the passive safety has not been chosen as one of the prioritised groups in the Product Identity (see chapter Appendix 3); even though it is something they do work with.

The work in this thesis only considers safety for the passengers and thereby the focus will be on passive safety, both according to traditional and to Scania’s safety thinking. According to Letho (1993), a crash is a violent and rapid deceleration and the environment of a cabin needs to be created with this in mind. The environment must enable the human body to withstand the forces that will occur during a crash. The prevention of a fatal crash and the increase of occupant safety include energy absorbing steering columns, instrument panel and other interior padding, side door beams, and increased car mass and crush space.
At a crash the occupants in the cabin get a relative movement in relation to the vehicle. This relative movement continues until an initial contact is made with some of the equipment of the seat; for example the seat belt; or the interior of the cabin; for example the wind screen or the instrument panel. Letho (1993) also states that in order to minimize the amount of damage the movement of the human body should be kept to a minimum during as long time as possible and the objects of the interior should be kept from hurting the occupant.

The worst case scenario from the truck driver’s point of view, regarding different types of crashes, is a crash with a complete truck against a trailer back (Lindquist, 2007). Letho (1993) writes that general guidelines indicate that a crash is survivable if the acceleration of the human body is 50 Gs or less and lasts for less than 0.1 seconds. Because of this, 50 Gs or more is often the companies’ limit for what the seat should withstand during a crash at 40 km/h. A passenger seat needs to be developed according to these demands so that safety will be applied also for the passenger.
3.3 Methodology

The theoretical basis for some methods that can be used during a product development is presented below. In chapter 5 Method, a more specific and detailed explication is given of the methods used in this thesis, while this chapter explains their purposes.

3.3.1 Modularisation

The basis of modularisation is, according to Johannesson et al. (2004), to divide a product into modules with standardised interfaces. The formation of modules takes place due to company specific reasons such as same subcontractor or “carry-overs”, meaning components which are highly unlikely to change and are used in several other products and carried over to the next generation of products.

Scania CV AB (2003) states that the interfaces between modules can be in the form of contact interfaces, space interfaces, or information interfaces. Contact interfaces are joints which can transfer, for instance, loads or forces. Space interfaces defines restrictions in space to components which are close but not in contact. Information interfaces defines protocols, information context, and signals for different components and modules. Modularisation is one of Scania’s specialities; Scania does not have a structure with regards to year model or vehicle type but rather a dynamic component structure. By starting with the customers needs Scania can assemble the appropriate vehicle from their selection of components.

Johannesson et al. (2004) name Scania as one of the forerunners in this field, which sometimes is called “mass customisation”. In this way one competes with the use of standardised modules, which can have infinite combinations at the same time as keeping the costs down. Other positive effects of modularisation are shorter development processes, improved production quality, and less risk-taking during new developments.

3.3.2 Functional Analysis

In order to get a better understanding of the connection between the stated demands and the desired functions of the product, Johannesson et al. (2004) suggest that one can make a functional analysis. The analysis is a method for dividing a problem into smaller parts, while making it possible to apprehend the connection in between the different parts. A functional analysis can be visually expressed with a tree structure, as shown in Figure 3.3.
3.3.3 Axiomatic Design

Poor design may result in failures which can have severe effects; people have been killed as a result of faulty design, for example as with the nuclear power plant accident in Chernobyl. Poor design practice can result in design faults, but also in high costs and long delivery times. According to Suh (1990), design faults can be an effect of many things: incorrect or excessive functional requirements, wrong design decisions or an inability to recognize faults early in the process. A result of axiomatic design, developed by professor Nam P. Suh, is that one knows which functional requirements that are important and that one does not fulfil more requirements than necessary. Axiomatic design has a scientific approach to design and has as its base two axioms which are, according to Suh (1990, p. 47):

Axiom 1  \textit{The Independence Axiom}
Maintain the independence of functional requirements.

Axiom 2  \textit{The Information Axiom}
Minimize the information content of the design.

Suh (1990) states that the axioms aid the creative process of design and enables good design solutions to be identified and separated from less acceptable solutions. Axiom 1 deals with the relationship between the functional requirements and their design parameters and Axiom 2 deals with the complexity of the design. According to axiomatic design, functional requirements should be independent of each other and each be linked to a design parameter. If functional requirements are dependent on each other they are equivalent and should thereby form a single functional requirement. By doing this, excessive functional requirements are avoided and the risk of taking the wrong decision is reduced. Axiom 2 states that the information content of a design should be minimized in order to have an as uncomplicated design as possible. This means that integration of several functions in the same part is to be preferred because it reduces the information content. To use the same part on as many places as possible in a design, for instance by using the same type of screws on several places in a product, also reduces the information content.

Suh (1990) also states that from these fundamental axioms many corollaries can come as a result. For instance; one corollary can be that the use of standardised parts is recommended if the parts fulfil the functional requirements. Corollaries can more easily, than the axioms, be used in actual design situations.

Axiomatic design is a scientifically based method for design and the basic ideas are so fundamental that it is applicable on all areas of design. This is a clear advantage to other methods which often have primary areas where they work best and then have to be more or less modified to suite a specific situation. By following the axioms of axiomatic design, faults can be avoided to a higher extent and costs as well as delivery times can be reduced.
3.3.4 Systematic Construction

During the development of a new product, methods are often used to systematise and ease the work. According to Johannesson et al. (2004, p. 108), the construction process is built up of the following steps:

- Product specification
- Concept generating
- Concept evaluation
- Detail construction
- Production adaptation

Johannesson et al. (2004) also write that dividing the development work helps to focus the work on the main problems. The division eases the generating and analysis of a great amount of concepts and clarifies the decision process.

On the other hand, Hubka (1982) points out that there are several models for the product development process and its different stages, but they are all dependent on several factors such as nationality, industry branch, workplace, working conditions, objectives, and general assumptions. Therefore any model must be fitted to the task and the situation.

Product Specification

According to Johannesson et al. (2004) a product specification is a compilation of the criteria put on the product. The purpose is to find out what should be accomplished with the product development process. This should be done so that the information from the product specification can be used as a help when finding different construction solutions, but also as a reference during the concept evaluation.

The specification is developed from a goal specification to a final product specification. The final product specification describes the demands and needs placed on the final product when the entire construction process is finished. Since it is less expensive to change something on the product in the beginning of the project instead of in the end, the goal specification needs to be as right as possible early on in the project.

To establish a goal specification is to describe all criteria that are relevant for the product, which is, according to Johannesson et al. (2004, p. 110):

1. The criteria given in the beginning of the project which are a part of the conditions both explicitly and implicitly.
2. The criteria established during the analysis and the clarification of the assignment.
3. The criteria that follow construction decisions made during the construction development work.

The criteria related to the expected functions can be divided into two groups: demands and wishes. According to Johannesson et al. (2004), “Demands are criteria that always need to be entirely fulfilled while wishes can be fulfilled more or less depending on the construction solution.” (p. 112). For a construction solution to be a possible solution, it needs to fulfil all demands, but it only needs to fulfil the wishes to some extent.
Concept Generating
The purpose with concept generating is, as Johannesson et al. (2004) state, to generate as many alternative solutions as possible. Starting with the product specification one can find a great amount of possible solutions and if the generating is well-done one will not risk missing any good solutions which means that one can ensure that all functional demands will be observed. Examples of methods for concept generating are brainstorming, analysis of natural systems, morphological analysis, and idea association.

Concept Evaluation
After the concept generating one, hopefully, has many concept solutions that needs to be evaluated in order to find out which one is the best. According to Johannesson et al. (2004), the evaluation of the different concept solutions implies that every alternative will be analysed with regards to its “value” and “quality” relative the demands and wishes in the product specification. The analysis results of the different concept alternatives are compared and a decision is made depending on which concept solution has the highest “value” and “quality”.

Detail Construction
Johannesson et al. (2004) explain that with the help of a detail construction the concepts are made more specific and are developed into functioning products. The goal is to have a complete description of a functional and useable product. This description, the final product specification, contains the descriptions of all the product’s parts and is realised through, for example, CAD-models, drawings, and technical component specifications.

During the detail construction there are several aspects to take into consideration: environmental, ergonomic, semantic, aesthetic, and economic issues as well as manufacturability and safety. Each of these aspects is important to consider when designing a functional and usable product.

Two sides of the detail construction work are the product layout and the product architecture. Both deal with the configuration of the product, but with different aspects. The placement and grouping of physical components and details is called product layout and can be based on geometrical, orientation, or space reasons. The product architecture describes how the part solutions are put together in order to form a product. It describes how the part solutions work together and how their interfaces look. Johannesson et al. (2004) conclude the detail construction with that one can use several types of product architectures: modularised architecture, where components are put together based on company specific reasons, and integrated architecture, where as many functions as possible are realised in the same component to minimise the number of components.

Production Adaptation
According to Johannesson et al. (2004), prototypes are seldom made with the use of regular production equipment since they are manufactured in small numbers. The production methods used are often manual and to enable manufacture in large quantities adaptations has to be made. The specification must be developed and adapted in order to be used for regular production. This means to ensure that the product will be able to be produced and manufactured with the intended equipment and methods. The cost of the production also has to be considered during the adaptation. Both the production and the economy of the product should be considered throughout the entire process, but at the production adaptation stage it is time to change the details, which have been simplified during the prototype development.
4 Product Identity

Many companies have a defined product identity which is used during their product development. According to Olins (2002), the product’s design should correspond to the product identity, which describes the identity of the company. The identity consists of four ideas: who you are, what you do, how you do it, and where you want to go. The more successful a company is with their product identity the easier it will be for the customers to recognise their products, and by that hopefully chose that product above a competitor’s product. Examples of companies that have been very successful with their product identity are Absolut Vodka and IKEA.

Scania is a company that, according to Scania’s Official Homepage (n.d.), wants to position them as a premium brand where the brand values are: pride and trust. The brand values together with Scania’s core values; customers first, respect for the individual, and quality; are what form the basis for the company and its future work. Scania has a more defined product identity, which is described in Appendix 3, but this is confidential information only available in the internal report.
5 Method

This chapter is a chronological presentation of how the realisation of the thesis was planned. Figure 5.1 describes the structure of the thesis, starting with the assignment which defines what should be done during the project and ending with the final product. The first phase will be the preparation phase, which consists of the feasibility and the elementary study. The feasibility study is more all-round while the elementary study goes deeper into the areas that are most important for the project’s assignment.

![Figure 5.1 The phases of the product development. The phases planned to execute in this thesis is within the broken line.](image)

The next phase in the process will be when all material and information from the preparation are implemented in the product development. Pre- and final prototypes will be made as well as final product specifications. The production adaptation should be done in a product development but will not take place during this thesis. The systematic construction can, and should, be iterated but due to time limitations this will not be done.

During the entire thesis project documentation will take place, mainly through this report.

5.1 Feasibility Studies

According to Johannesson et al. (2004), the purpose of a feasibility study is to do an unprejudiced problem analysis and gather background material. The background material can consist of information about the market today, design and technology, but also about new developments.

5.1.1 Information Gathering

Information gathering is, as Mindtools (2007) states, a very effective perspective-widening tool and when gathering information one needs to find both background and task-related data. The process of collecting background data will in this thesis consist of:

- talking to experts or knowledgeable people from areas of interest for the project
- benchmarking
- reading books, newspapers and brochures
5.2 Elementary Studies
The elementary study is a deepening in those areas that are most crucial for this thesis. The information gained at the feasibility and elementary study will be the basis for the entire product development. The areas which will be studied further are product identity, production, and reparability. To get a better understanding of the problem a functional analysis will be used.

To take into account demands which are put on the product, due to the production and reparability, one has to study the production and define the desired extent of the product’s reparability. This will be done by experiencing the production first hand; through fieldtrips and talking to the personnel involved in the processes.

With the use of the method functional analysis the main problems will be separated into smaller parts which makes it easier to see new solutions and demands. For every seat; foldable passenger seat, resting seat, and bench; a tree structure will be established with branches for minor areas and descending levels for details.

5.2.1 Modularisation
When deciding which components should form modules it is important to understand the relations between different modules and products in the entire product range and, in the case of Scania, make allowance for the company’s specific product identity which is described in Appendix 3. According to Johannesson et al. (2004), the main steps in the decision process are: check the customer’s needs and do benchmarking, generate technical part solutions for different part functions, identify possible modules, evaluate the found module division, and finally make a detail construction of the modules.
5.3 Systematic Construction

To ensure that the product development will have a satisfying result the systematic construction process described in 3.3.4 Systematic Construction will be followed. This means that the steps shown in Figure 5.1 will be performed.

5.3.1 Product Specification

The product specification will be based on the demands and wishes from modularisation, safety, product identity, production, reparability, functional analysis, and the given list of functional demands. The criteria will be put together in a product specification, as shown in Table 5.1.

Johannesson et al. (2004) claims that some wishes are more important than others and because of this one can give them weight factors, for example on the scale 1-5 where 5 gives the highest amount of importance and 1 the lowest. It is crucial to be objective while deciding the weight factors. Together with the weight factors the product specification can then be used during the evaluation of the concept solutions.

<table>
<thead>
<tr>
<th>Criterion No.</th>
<th>Criterion</th>
<th>Demand or Wish</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Easy to use</td>
<td>D</td>
</tr>
<tr>
<td>2</td>
<td>Possible to use alone</td>
<td>D</td>
</tr>
<tr>
<td>3</td>
<td>No need for electricity</td>
<td>D</td>
</tr>
<tr>
<td>4</td>
<td>Low production cost</td>
<td>W, 5</td>
</tr>
<tr>
<td>5</td>
<td>Low maintenance cost</td>
<td>W, 3</td>
</tr>
</tbody>
</table>

5.3.2 Concept Generating

A systematic search for a solution will be done and it will be, according to Johannesson et al. (2004, p. 121), divided in following steps:

1. Formulate the problem in an abstract and solution neutral form
2. Make a function analysis of the product’s functions with the division of the product function into part functions
3. Search for solutions to the part functions
4. Combine part solution alternatives into total solution alternatives
5. Sort out the potentially acceptable total solution candidates

The methods which will be used for the concept generating are brainstorming and morphological analysis.

Brainstorming

Johannesson et al. (2004) write that brainstorming is a creative method for finding solutions to part problems. This method should be performed with a group of 5-15 persons where one functions as the leader. The purpose is to come up with as many ideas as possible; idea quantity goes ahead of idea quality. This because one wants the group members to challenge each other and thereby help each other come up with new ideas. There are four main rules for brainstorming:

1. Criticism is not allowed. Comments are not allowed; neither positive nor negative.
2. Obtain quantity. It is important to come up with as many ideas as possible since that increases the possibility to find a really good solution.
3. Go outside “the box”. An unusual solution does not have to be a bad solution.
4. Combine ideas. Combine and complete each others ideas.
Morphological Analysis

After the brainstorming session one has a large amount of ideas that needs to be sorted and put together into total solution alternatives. To minimize the risk of missing a good total solution a morphological analysis will be done, as Johannesson et al. (2004) suggest. The analysis will start with finding the essential parts in the problem statement and with this in mind one can give the part solutions, which have been found during the brainstorming, different grades. The final step in the morphological analysis will be to put together part solutions with good grades into total solutions.

5.3.3 Concept evaluation

In order to find a final concept solution one can use more or less systematic and structured methods. The methods which will be used in this thesis are first the Elimination Matrix by Pahl and Beitz and later on the Relative Decision Matrix by Pugh.

Elimination Matrix

According to Johannesson et al. (2004), the Elimination Matrix (see Table 5.2), is the first step when eliminating concept solutions. In difference to the Relative Decision Matrix this one does not consider the wishes and therefore it is good to use this method first in order to delete the obviously not acceptable concept solutions. The solutions that fulfil all demands and those which need more examination to be able, to be judged according to the demands, are the only ones which will pass to the next evaluation step.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Solves the main problem</th>
<th>Fulfils all demands</th>
<th>Realisable</th>
<th>Within the frame of costs</th>
<th>Safe and ergonomic</th>
<th>Fits the company</th>
<th>Enough info</th>
<th>Comment</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2 The Elimination Matrix by Pahl and Beitz (based on Johannesson et al., 2004, p. 133)
Relative Decision Matrix

The second elimination step, according to Johannesson et al. (2004), is the Relative Decision Matrix by Pugh (see Table 5.3). A Relative Decision Matrix is based on the relative comparison between the different concept solutions. The selection criteria depend on the demands and wishes in the product specification.

The selection criteria, with their weight factors, and the alternative concept solutions are placed in the matrix. Every concept solution will be compared to the reference solution, datum, and depending on the order of priority it will finally be decided which concept will be eliminated and which will go to the next selection round.

Table 5.3 Example of Pugh’s Relative Decision Matrix with weight factors (Johannesson et al., 2004)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Alternative</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (ref)</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Wish A (w = 5)</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Wish B (w = 4)</td>
<td>0</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Wish C (w = 3)</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Demand D (w = 5)</td>
<td>-</td>
<td>+</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Wish E (w = 3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Sum +</td>
<td>0</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Sum 0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sum -</td>
<td>16</td>
<td>12</td>
<td>3</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Net value</td>
<td>0</td>
<td>-16</td>
<td>-7</td>
<td>+4</td>
<td>-7</td>
</tr>
<tr>
<td>Order of priority</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Further development</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

The evaluation will be iterated and for every new iteration the concept with the highest number of priority will be placed as the new reference, but before every new evaluation one need to ask some questions: does the result seem reasonable, does the relative judgement which has been made during the evaluation seem correct, and finally should the selection criteria be extended. Johannesson et al. (2004) conclude that the evaluation and elimination will be iterated until the reference solution is considered the best solution, which means that the final concept solution has been found.
5.3.4 Detail Construction

Johannesson et al. (2004) elaborately describes the process from concept to final product specification, as shown in Figure 5.2. The components of a product will be divided into unique parts or standard components which are either developed or accessible externally or internally. For both the unique parts and the standard components a choice will be made to either go by routine, using a component or part which, based on earlier experience, will work, or perform a special treatment on the component in question. The definition of the special treatment resembles the product development process, but scaled down. A unique part which is taken from an existing product without modifications is called a “carry-over” and need no further work before being placed in the final product specification. Unique parts that need to be developed especially can benefit from the making of prototypes, either real or virtual. This ensures that the part will be functional and that it can be tested to some extent.

![Figure 5.2 Detail construction, product architecture and product layout (based on Johannesson et al., 2004, p. 142)]
6 Realisation

The realisation chapter is a presentation of how this thesis has been carried out; how the methods explained in chapter 5 Method have been used and why certain choices have been made. Part results found during the realisation are presented here while final results are presented and elaborated on in chapter 7 Results. The realisation of the resting seat can be seen in Appendix 4 in the internal report.

6.1 Feasibility Studies

The feasibility study was used to receive as much information as possible about the problem area, but also to understand Scania’s organisation.

6.1.1 Information Gathering

The information gathering have consisted of reading books and reports and searches on the internet within the area of, for example, chairs, seating positions, ergonomics, long haulage related injures, but also competitors’ solutions today. Fieldtrips have been made within the Scania organisation, both in Södertälje and in Oskarshamn, to better understand the main problems in this thesis. A fieldtrip to the manufacturer of today’s passenger seat has also been made. The conclusions from the fieldtrips are discussed in 6.2.3 Aspects of Production and 6.2.4 Aspects of Reparability.

6.2 Elementary Studies

During the feasibility study a wide view of the thesis problem was received and through this the areas in need of more information was found. The deepening in the areas of product identity, modularisation, production, and reparability were carried out during the elementary study and was later the basis for the systematic construction. The systematic construction was also helped by a functional analysis which was carried out during the elementary studies.

6.2.1 Product Identity

Since the information about Scania’s product identity is confidential, this part about the realisation of the product identity is also confidential, but can be seen in the internal report in Appendix 3.
6.2.2 Modularisation

The modularisation was built up of steps, as explained in 5.2.1 Modularisation, and the first step, of understanding the customers’ needs, was achieved by a given list of demands, shown in Appendix 4. The demands were further discussed and since there were demands concerning standardised modules a table was made of these and another of the parts which should have standardised interfaces. The tables, shown in Table 6.1 and Table 6.2, were the basis for some of the demands and the wishes expressed in the product specification, shown in Appendix 7. The remaining steps in the modularisation process were taken later on in the thesis, see 6.3 Systematic Construction.

<table>
<thead>
<tr>
<th>Part/Detail</th>
<th>Seats the Modules Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foldable Passenger Seat</td>
</tr>
<tr>
<td>Seat squab</td>
<td>X</td>
</tr>
<tr>
<td>Backrest</td>
<td>X</td>
</tr>
<tr>
<td>Controls</td>
<td>X</td>
</tr>
<tr>
<td>Armrests</td>
<td>X</td>
</tr>
<tr>
<td>Floor attachment</td>
<td>X</td>
</tr>
<tr>
<td>Seat belt</td>
<td>X</td>
</tr>
<tr>
<td>Seat belt attachment</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 6.1 Standardised modules due to the functional demands

<table>
<thead>
<tr>
<th>Parts/Details between which the interface is</th>
<th>Seats the Interface Concern</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Foldable Passenger Seat</td>
</tr>
<tr>
<td>Seat squab – Seat base</td>
<td>X</td>
</tr>
<tr>
<td>Seat base – floor</td>
<td>X</td>
</tr>
<tr>
<td>Seat squab – Backrest</td>
<td>X</td>
</tr>
<tr>
<td>Backrest – Seat belt attachment</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 6.2 Standardised interfaces due to the functional demands

6.2.3 Aspects of Production

There are two mayor parts of the production of a truck seat: first the seat has to be manufactured and then it has to be assembled with the rest of the cabin. These two parts places different demands on the construction of the seat and all demands have to be considered to achieve a functional seat.

To better understand the demands from both the manufacturing and the assembly a fieldtrip was made to the seat manufacturer Be-Ge Industry AB, in Oskarshamn, and to Scania’s production plant, also in Oskarshamn, where they assemble all Scania cabins. At Be-Ge the manufacturing process of Scania’s current foldable passenger seat was shown and at Scania the cabin assembly line was followed, with special focus on the assembly of the seats. When talking with personnel and observing the two processes, some important aspects of manufacturing and assembly was seen. The aspects, stated in Appendix 6, were later translated into criteria expressed in a product specification, shown in Appendix 7.
6.2.4 Aspects of Reparability

The reparability of the seat is an important factor; a seat is a too expensive part of the cabin interior to be discarded due to wear and tear. To take the aspects of reparability into account when developing the seats, the matter was discussed with personnel at the seat manufacturer Be-Ge Industry. The knowledge gained from the field trip, stated in Appendix 6, made the basis for the criteria shown in the product specification in Appendix 7.

6.2.5 Functional Analysis

During the analysis of the main problems, the problem areas were divided into groups depending on the situation, for example stepping in and out of the cabin, adjusting the seat, and living in the cabin. The main groups are shown in Figure 6.1 and the rest of the functional structures are shown in Appendix 8.

6.3 Systematic Construction

The systematic construction phase was performed as described in 5.3 Systematic Construction. The separate steps: product specification, concept generating, concept evaluation, and detail construction; helped in finding the best solutions for the final result.

6.3.1 Product Specification

To create a product specification a compilation was made of the many criteria from the different parts of the elementary studies along with the given criteria from the functional demands (see Appendix 4). These criteria were then put together in a list and every criterion was deemed either as a demand, which had to be fully fulfilled, or as a wish, which only had to be fulfilled to some extent. The wishes were weighed against each other and given a specific weight factor, showing the importance of the wish in question to this thesis. This was realised through discussions both among the authors and with the supervisor at Scania.
6.3.2 Concept Generating

The steps written in 5.3.2 Concept Generating were followed, but for the wide and abstract description of the problem a functional analysis was used, which is described in 6.2.5 Functional Analysis. The next step in the search for a solution was to find part solutions, which was done with the help of brainstorming. The concept generating process continued with combining and evaluating the part solutions, which was done with the help of a morphological analysis.

Brainstorming

Since there were only two persons involved in the brainstorming, no leader was chosen. The brainstorming was divided into smaller areas based on the problems needed to be solved on the seats, for example the backrest, the folding function, the storage, and the armrests. A selection of the brainstorming sketches is shown in Appendix 9.

Morphological Analysis

After the brainstorming there were a great amount of part solutions, which were graded with one to three stars, where three stars was the best. With the help from this, total solution alternatives with good part solutions could be formed. Examples of total solutions are shown in Appendix 12.

6.3.3 Concept Evaluation

All concept solutions were evaluated in the Elimination Matrix by Pahl and Beitz (see 5.3.3 Concept evaluation) in order to eliminate the solutions that did not fulfil the demands, was not realisable or did not take care of the main problem. A separate elimination matrix was made for each area: the foldable passenger seat, the resting seat, and the bench. The matrixes for the foldable passenger seat and the bench are shown in Appendix 10.

The next step in the elimination process was made with the use of a Relative Decision Matrix by Pugh (see 5.3.3 Concept evaluation), but before this elimination step some of the concepts were shown for an expert group at Scania. This group works with the cabin interior and have thereby a lot of knowledge in the area that this thesis concerns. They gave relevant criticism but also new ideas on how different problems could be solved.

In the Relative Decision Matrix the concept solutions that made it through the Elimination Matrixes were evaluated and a final concept solution could be found. A selection of the matrixes for the different seats is shown in Appendix 11.
Realisation

6.3.4 Detail Construction

The method for detail construction suggested by Johannesson et al. (2004), explained in 5.3.4 Detail Construction, was followed as far as possible but with the modification, as Hubka (1982) suggested, to suite the specific task. Not all minor components were dealt with, like screws, fasteners, and so on. This also meant, only unique parts were dealt with and not standard components, even though they are a likely part of a finished product and its final product specification.

For every part of each seat; foldable passenger seat, resting seat, and bench; a decision of which way to go was made. If a part was considered uncomplicated and resembled a part from an earlier product, the decision was based on routine. This was for instance the case with the sliding system; the idea of today’s solution was used but with an increase in length. On the other hand, if a part was considered to be new and different, a special treatment of the part was preformed. This was certainly the case with some of the parts of the resting seat. If a part from an already existing product was used unmodified it was deemed a carry-over. This was the case with the seat belt and its attachment for the foldable passenger seat, the floor adapters, and the heating system of the foldable passenger seat and the resting seat.

The solutions for the parts in the different seats were realised through CAD-models, prototypes and final product specifications. The final product specification is shown in Appendix 13.

Prototypes of both the foldable passenger seat, see Figure 6.2, and the resting seat were made to evaluate the concepts. The prototypes were simplified in a number of ways since they were considered to be the first prototypes meant to only test the concepts’ functionality and principle ideas. The seat base of the foldable passenger seat was simplified, both according to the material and to the down-folding function which was chosen not to be tested. The storage of the seat under the bed was also chosen not to be tested with this prototype, since it required several adjustments of the interior of the cabin. The upholstery and the foam for the resting seat as well as the upholstery for the foldable passenger seat were made by Alfa Bil & Båt Sadelmakeri AB, situated in Stockholm.

![Figure 6.2 The prototype for the foldable passenger seat](image)
This chapter presents the major results which were achieved as described in chapter 6 Realisation. After the concept evaluation and the detail construction we had a solution for each of the three areas; foldable passenger seat, bench, and resting seat. The result for the resting seat can be seen in the internal report in Appendix 4.

### 7.1 Foldable Passenger Seat

The goal with the foldable passenger seat (see Figure 7.1 and Figure 7.2) was to make it possible to fold away in some way in order to free space in the cabin. This has been solved by making the seat base foldable all the way to the floor. If the backrest then is folded horizontally towards the seat squab it will be possible to push the seat into the space under the bed, as shown in Figure 7.3. The storage under the bed on the passenger side will only be possible to use when the foldable passenger seat is in an upright position.

![Figure 7.1 The foldable passenger seat](image1)

![Figure 7.2 The foldable passenger seat in an R-cabin](image2)

![Figure 7.3 The foldable passenger seat stored under the bed](image3)
In order to make the fold-away function work, but also to offer a comfortable seating position for all people, the seat base is changeable in height and has a tilt function. This is realised with the help of gas springs in the seat base; one for the tilt and one for the height adjustment (see Figure 7.4).

![Figure 7.4 The seat base of the foldable passenger seat](image)

The measurements of the seat are chosen to achieve a comfortable and ergonomic seating position according to ergonomic data for the European population (see Appendix 2). The measurements are given in the final product specification, as shown in Appendix 13.

To make the fold-away function work, a choice was made to place the upper belt attachment on the B-pillar.

The backside of the backrest can be either soft or hard. When the foldable passenger seat is combined with the resting seat the backside is soft, but if there is no resting seat, the backside can be hard and then also function as a side table for the bed.

### 7.2 Bench

The main purpose with the bench was to accommodate two passengers on the passenger side of the cabin. Focus was also placed on storage possibilities and assembly difficulties. To ease the assembly of the bench into the cabin the bench is divided into two units, an inner and an outer seat, which are assembled into the cabin one at a time.

The use of the bench in all cabin types is realised with different seat bases. The outer seat base is always used, for the G-cabin only an adapter for the fastening on the engine tunnel is needed, but for the P- and R-cabins additional parts are also needed. For the R-cabin an inner seat base is added and for the P-cabin, because of the high engine tunnel, an increased height of the outer seat base is required for the seats to be at the same level. The bench for the R-cabin is shown in Figure 7.5-Figure 7.7.

Storage is placed under the outer seat, in the seat base, and is accessible from the front of the outer seat. In the R-cabin, storage is also made possible in the seat base of the inner seat and is then accessible from the driver’s side (see Figure 7.6).
Both the seats have 3-point seat belts, which are laterally reversed in order not to interfere with each other. In difference to the foldable passenger seat’s seat belt these are placed on the bench’s seats.

The bench and the foldable passenger seat have several parts in common and the bench has, like the foldable passenger seat, backrests which are possible to fold down giving more space in the cabin and eventually the option of having a hard backside on the backrest which then could function as a table. The bench in its folded position is shown in Figure 7.7.
7.3 Upholstery
The same material varieties of upholsteries have been chosen for all seats (see Table 7.1) but with one exception; velour will not be available for the foldable passenger seat. This because velour is sensitive to heat and has, during earlier tests at Scania, showed evidential changes on a folded seat after a period of time in high temperature. Since the foldable passenger seat can be folded away under the bed and stored there for a long time, it is not suitable to use velour on this seat.

<table>
<thead>
<tr>
<th>Surface material</th>
<th>Bench</th>
<th>Foldable Passenger Seat</th>
<th>Resting Seat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leather</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Velour</td>
<td>o</td>
<td>-</td>
<td>o</td>
</tr>
<tr>
<td>Knitted</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Vinyl + Knitted</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>Vinyl</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
</tbody>
</table>

Table 7.1 Options for upholstery materials (o = optional, - = not available)

7.4 Slide Rails
For the horizontal adjustment of the foldable passenger seat, today’s solution with slide rails will be used but with an increase in length since the foldable passenger seat shall be able to be stored underneath the bed. The slide rails will be covered by rubber covers which will allow the occupant to step on the slide rails without experiencing pain or discomfort. The rubber covers will be attached to the floor adapter and be pushed aside by the seat base when the seat is adjusted horizontally, as shown in Figure 7.8.

Figure 7.8 Rubber covered slide rails on the foldable passenger seat
7.5 Changes in the Cabin
In order to realise the three seats in today’s cabin some changes of the interior of the cabin are needed. For the foldable passenger seat to be stored under the bed there must be an opening in the bed support large enough to for the seat when it is completely folded.

Additional fastening points are needed on several places in the cabin, for example on the engine tunnel for the inner seat of the bench.

7.6 Modularisation
The three seats are modularised to the extent that they have common parts when possible and common interfaces. The interfaces of the seats are standardised to accommodate variations, for instance the interface between the seat squab and the seat base is the same for the bench and the foldable passenger seat. Another interface, common for these seats, is the interface between the seat base and the slide rails. The bench and the foldable passenger seat have several parts in common, for example the seat squab, the backrest, and the headrest.
8 Discussion

This chapter is a self-critical discussion of how this master’s thesis has been carried out, why some of the choices have been made, and how the final result turned out.

The purpose with the thesis has been to develop three different passenger seat concepts with focus on modularisation, functionality and production. The different concepts are: a foldable passenger seat, which is possible to fold away completely, a bench for two passengers, and a resting seat for resting during breaks.

8.1 Working Method

The title of the thesis is Modularised Passenger Seats which indicates the focus on modularisation, but this was only one of the focus points along with functionality and production. Standardised interfaces have been used both for the whole seats and for different parts of the seats as modules. The seats can be further modularised both with respect to the complete seats in relation to the rest of the cabin and with respect to different parts of the seats in relation to each other. This should be a consideration for future work.

We have used the structure and ideas of systematic construction, described in 3.3.4 Systematic Construction. One of the advantages with using this method was that there are defined stages with deadlines which helped us move forward with our work. Systematic construction increases the chance of finding good ideas and creates a foundation for decisions.

There are several methods to choose from in systematic construction. In retrospect we might have given to much attention to brainstorming and different evaluation matrixes. They are good tools if used correctly but can also be carried to far. We could also have done more prototypes earlier in the project to aid the development process visually.

According to Suh (1990), a good designer knows which functional requirements to fulfil and does not fulfil more than necessary. In view of this, we could have formed less and more compact demands and wishes. The demands and wishes we used are in some extent often connected to each other and the number of requirements could have been minimized and by that the evaluation work might have been easier and not as time consuming.

8.2 The Results

This thesis had a wide focus as well as three separate seats to develop, which left little time for deeper investigation into areas which could have benefited from further studies. As an effect our result does not go into details in many areas but rather gives three concept solutions which fulfil the demands placed on the passenger side of the cabin.

It was given in the project assignment that we should use anthropometric data for the European population, but that is something that can be questioned since Europe is not Scania’s only market. On the other hand, one can not make a seat suitable for every person in this world, but one should focus on the main target groups.
Another problem with anthropometric data is the shortage of accessible and accurate data. People change and the average European does not look the same today as thirty years ago. People within the population groups are also different and one should consider to use anthropometric data for a more detailed and specific group; for example in our case, truck drivers.

The comfort of a passenger seat is important. Our seats has been developed based on anthropometric data as well as theories about seating position and comfort, cited in 3.1.6 Comfort and Discomfort Regarding Sitting. Adjustability and room for movement is key factors for comfort. Many features of the seat are adjustable and although the space in the cabin is limited there is always enough room for movement in the seats. Nevertheless, due to the different demands on the separate seats adjustability have in some cases been pushed down on the priority list.

An important issue during this master’s thesis has been the safety of the seats. Can our concepts handle a crash with a complete truck against a trailer back? Even though we have not tested our concepts, one can presume that both the foldable passenger seat and the bench are likely to handle a crash in a good way. This because some of the most crucial parts of the seats are carry-overs from earlier seats, like the floor adapters and the seat belts, and by that already proven to be safe.

Another important issue during development work is economy; are the concepts economically realistic meaning are they possible and profitable to manufacture? We consider the foldable passenger seat to be economically realistic. The biggest change is the seat base but we use a technology which is already known and tested at Scania; gas springs.

When choosing which final concept solutions we should continue with, the demands and wishes were considered and the goal was to fulfil them all. Unfortunately this could not be done for all demands and wishes. Most of them have been fully fulfilled, some have been fulfilled to some extent and a few have either not been fulfilled at all or need further information to determine if they are fulfilled.

In order to realise our concepts some changes need to be done of the cabin interior and these can be more or less realistic. Changes similar to existing solutions are easier to make, for example the fastening points for the bench on the engine tunnel, while other changes are larger and by that might interfere with other areas of interest, for example the change of the area under the bed. To fold away the foldable passenger seat completely there must be a total change of the storage area under the bed, which includes many different working groups. A change is possible, but one need to be sure that it is for the best for all parties and that the need for more space in the cabin is more important than, for example, storage space.
8.2.1 The Foldable Passenger Seat

The foldable passenger seat is a multifunctional seat. It can be used as a normal passenger seat, it can “disappear” under the bed and it can be used as a part of the resting seat. A multifunctional seat attracts a wider spectrum of customers and by doing that it may also be easier to sell. We believe that we have succeeded in achieving a seat which is ergonomic and comfortable for 95 per cent of the European population and we have achieved that through the measurements of the seat but also by making it adjustable to a high extent. Because of the time limitation, we have not put that much effort into how the adjustment controls should be designed in order to make them easier to understand for the occupant.

We chose to offer armrests for neither the foldable passenger seat nor the bench. Armrests do relieve the back of pressure but in our case there was not enough space for them.

Since the foldable passenger seat should be able to be placed and stored under the bed, we decided that the best and safest alternative was to place the upper seat belt attachment on the B-pillar. A disadvantage with this decision is that it is more difficult to adjust the seat belt in height to make it comfortable for as many occupants as possible. As with the armrests, functionality did in this case go ahead of comfort.

8.2.2 The Bench

The bench fulfils the demands on: accommodating two passengers, storage, and possibility of a table. The comfort and space for the users of the bench is not as good as for other passenger seats since the space in the cabin is limited. The backrests of the bench can be folded which gives more space in the cabin but it does not effect the comfort of the passengers. For the user of the inner seat of the bench, there is a clear limitation in space due to the engine tunnel and the storage on the centre console. The bench can be used in all cabin types and all lengths, but the comfort and space varies due to differences in engine tunnel height and cabin length.

Since the bench is made up of two separate units the assembly of the seat is aided because the current lifting device can be used and it is easier to handle. But it also results in two completely separate seat squabs and backrests which, along with the desire to have as many parts as possible in common with the foldable passenger seat, makes it impossible to use the theories described in 3.1.5 Seats for More Than One Person. This means that the bench is wider than the recommended value and consequently takes up more space. In this issue the desire to ease the assembly of the bench has been prioritised.

We chose to not make a prototype of the bench; mainly due to the limitations in time but also since the bench has several parts in common with the foldable passenger seat. Nevertheless, the evaluation of the bench would have benefited from a prototype and this should be a priority for further work.
9 Conclusion

This final chapter will present the conclusions of our work and answer the research questions from the beginning of the thesis.

To design a functional and ergonomic seat for a truck one must first define the purpose for the specific seat, which results in demands and wishes on the seat. Based on relevant ergonomic measurements and theories the shape of the seat is defined, but to make it suitable for a large number of people the seat should be adjustable to a high extent.

The passenger seats should, in order to support the passenger’s need for relaxation, give good support for the entire body. There should be enough space in and around the seat in order to ease movements as well as getting in and out of the seat.

In order to easy the manufacturing and assembly of the seats and also make it more effective, the construction of the seats should strive to eliminate the possibility to do anything wrong. It should also limit the number of separate parts and, if possible, the same part should be used on several places in the same product. By limiting the size and weight of the seats the assembly into the cabin is made easier.

To aid the modularisation of the seat, the interfaces between the parts of the seats should be standardised. The seats should also have several parts in common.

Scania’s Product Identity can be realised both through the seats construction and in the way they are perceived. A seat is a part of a truck and as such it should help to fulfil the product identity.

To conclude, product development takes time and it should be allowed to take time in order to ensure a good result. The development process benefits from structure and iterations.

9.1 Counsels for Future Work

This thesis ended with prototypes meant to test the concept for the foldable passenger seat and the resting seat. Some suggestions for future work are that a final prototype of each of the seats should be made along with a complete final product specification. Test and calculations to dimension the seat should also be made.

Another suggestion for further work is that the assembly and production of the seats should be investigated in detail. A future test assembly on Scania’s development line should be carefully studied and the opinions of the personnel should be taken into consideration.
10 References


References


**Internal sources**


**Personal Communications**

Lindquist, K. (June 21, 2007). Object leader seats, RCCT Scania CV AB.

Rabenius, B. (October 2, 2007). Road Safety Manager, RTC Scania CV AB.
Appendix

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## Appendix 1 – Scania’s Cabins

<table>
<thead>
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<tbody>
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<td>Normal</td>
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<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Day cabs</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Short cabs</strong></td>
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<tr>
<td>P</td>
<td>G</td>
<td>R</td>
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## Appendix 2 – Anthropometric Table

Table A2.1 Anthropometric estimations for British adults aged 19-65 years with all dimensions in millimetres. (Pheasant, 1996)

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th>Women</th>
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<tbody>
<tr>
<td></td>
<td>5th %ile</td>
<td>95th %ile</td>
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<tr>
<td>1</td>
<td>Stature</td>
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<td>2</td>
<td>Sitting height</td>
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<td>3</td>
<td>Sitting eye height</td>
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<td>4</td>
<td>Sitting shoulder height</td>
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<tr>
<td>5</td>
<td>Sitting elbow height</td>
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</tr>
<tr>
<td>6</td>
<td>Thigh thickness</td>
<td>135</td>
</tr>
<tr>
<td>7</td>
<td>Buttock-knee length</td>
<td>540</td>
</tr>
<tr>
<td>8</td>
<td>Buttock-popliteal length</td>
<td>440</td>
</tr>
<tr>
<td>9</td>
<td>Knee height</td>
<td>490</td>
</tr>
<tr>
<td>10</td>
<td>Popliteal height</td>
<td>395</td>
</tr>
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<td>11</td>
<td>Shoulder breadth</td>
<td>420</td>
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<tr>
<td>12</td>
<td>Hip breadth</td>
<td>310</td>
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<tr>
<td>13</td>
<td>Shoulder-elbow length</td>
<td>330</td>
</tr>
<tr>
<td>14</td>
<td>Elbow-fingertip length</td>
<td>440</td>
</tr>
<tr>
<td>15</td>
<td>Foot length</td>
<td>240</td>
</tr>
<tr>
<td>16</td>
<td>Hand breadth</td>
<td>80</td>
</tr>
</tbody>
</table>

![Illustrations of anthropometric data](image)

Figure A2.1 Illustrations of anthropometric data
Appendix 3 – Scania’s Product Identity

Confidential information only available in the internal report.
Appendix 4 – The Resting Seat
Confidential information only available in the internal report.
Appendix 5 – Demand List

Confidential information only available in the internal report.
Appendix 6 – Aspects of Production and Reparability

A6.1 Production

A6.1.1 Manufacturing
- When manufacturing a seat it is good to have as few and as simple parts as possible, this in order to make the production simpler and faster.
- After every step of the manufacturing process the quality of the product should be verifiable in order to avoid unnecessary discards in the end of the manufacturing due to faults made in the beginning of the process.
- The construction of the different parts of the seat should try to eliminate the possibility to do anything wrong. Meaning that it should not be possible to use the wrong screw or do things in some other order then the desired.

A6.1.2 Assembly
- When a seat is assembled in the cabin a lifting device is used to make it easier for the assembly personnel. There is only one type of lifting device for the seats and this is considered as an advantage both since it does not complicates the assembly step by having to choose between several devices and also because it does not crowd the assembly line.
- The lifting device uses the gap between the seat squab and the backrest to lift the seat. This is only possible if the backrest can be folded to a certain extent. Since today’s bench does not have a gap and also since it is large and difficult to handle it must be lifted by hand and carried by at least two people into the cabin.
- Anything heavier than 10 kilos must be lifted with the use of a lifting device.
- The seats should at the assembly line consist of as few separate parts as possible to make the assembly quick and easy.
- Every aspect of the assembly should be verifiable with regards to quality in order to avoid faults which may be hard to correct later on.
- The assembly of the seat in the cabin should be easy with as few steps, and as little fine adjustments, as possible.
- When assembling the cabin, the seats have to be taken in through the doors of the cabin which means that the seats have to be constructed with this in mind. The seats should be able to go straight through the door without having to be tilted in any direction.
- The construction of the seats should eliminate the possibility to assemble them wrong.

A6.2 Reparability
- The seat is constantly subjected to wear and tear as well as accidents. The most crucial parts in this sense are the upholstery and the foam of the seat since they are highly affected by the environment of the cabin and the occupant.
- The material for the upholstery and the foam should be chosen with regards to the ability to endure wear and tear and how easy the seat upholstery is to clean.
- The foam is also likely to age with time and become more brittle, which will make the seat uncomfortable.
- Instead of completely changing the seat one can prolong the seat’s lifetime if it is possible to change the upholstery and the foam. This process should preferably be made quick and easy.
- The adjustment controls are subject to wear and tear mainly by the occupant. If the occupants are unaware of how to use the controls and what their respective effects are, they are for example likely to pull too hard which results in non-functioning controls.
Appendix 7 – Product Specification

Confidential information only available in the internal report.
Appendix 8 – Functional Structure

Passenger seat

- Step in/out of the cabin
- Dampen movements from person, while entering
- Positioning person
- Offer crash safety
- Dampen movements of the cabin, while driving
- Offer wellbeing
- Living in the cabin
Appendix 8 – Functional Structure

Step in/out of the cabin

- Space
  - Easy to access the door from inside
  - Floor space

- Adjustment of the seat
  - Lowering the seat
  - Special adjustments depending on the type of seat

Dampen movements from person

- Movements in X direction
  - Backrest
  - Seat squab
  - Seat base

- Movements in Z direction
  - Seat squab
  - Seat base

Easy to access the door from inside

Floor space
Appendix 8 – Functional Structure

Dampen movements of the cabin

- X direction
  - Backrest
  - Seat squab
  - Seat base

- Y direction
  - Backrest
  - Seat squab
  - Seat base
  - Lateral support
  - Side support

- Z direction
  - Seat squab
  - Seat base

Offer wellbeing

- Change the temperature
  - Cool
  - Warm
  - Ventilation

- Pleasing/Attractive

- Variations in seating position
  - Seat adjustments
  - Back position
  - Leg position
  - Arm position

- Ease communication

- Ease job assignments

- Easy cleaning of the chair

Freedom of movement
Appendix 8 – Functional Structure

Living in the cabin
- Resting
  - Seating position
    - Space for the legs
      - Flexibility
      - Proper pressure distribution
    - Lying down
      - High body exoneration
      - Flexibility
    - Amusement/Relaxation
      - TV/DVD/Computer
      - Telephone
      - Music
      - Reading

Intermingle
- Verbal contact
  - Active occupation
    - Seat = Unloading
    - Easy access to other ways of unloading
  - Unloading/Relief
    - Seat = Storage
    - Easy access to other storage
  - Storage
    - Coffee break
    - Mealtime
  - Seating
    - Space for the legs
    - Flexibility
    - Proper pressure distribution

Eat
- Office
  - Storage
    - Seat = Storage
    - Access to other storage
    - Writing support
      - Minor work
      - Mayor work
    - Seating
      - Adjustable
      - Shifting position
      - Standing

Movement
- Space
## Appendix 9 – Brainstorming Sketches

<table>
<thead>
<tr>
<th><strong>Function</strong></th>
<th><strong>Solution</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Backrest</strong></td>
<td>![Sketch 1] ![Sketch 2] ![Sketch 3]</td>
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<tr>
<td>One-piece</td>
<td>![Sketch 4] ![Sketch 5] ![Sketch 6]</td>
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<tr>
<td>Two-piece</td>
<td>![Sketch 7] ![Sketch 8] ![Sketch 9]</td>
</tr>
<tr>
<td><strong>Bench</strong></td>
<td>![Sketch 10] ![Sketch 11] ![Sketch 12]</td>
</tr>
<tr>
<td><strong>Table</strong></td>
<td>![Sketch 13] ![Sketch 14] ![Sketch 15]</td>
</tr>
<tr>
<td>Folded out from the door panel</td>
<td>The seat acts as a table</td>
</tr>
<tr>
<td>Jalousie</td>
<td>![Sketch 16] ![Sketch 17]</td>
</tr>
<tr>
<td>Removable table</td>
<td>![Sketch 18]</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>![Sketch 19] ![Sketch 20] ![Sketch 21]</td>
</tr>
<tr>
<td>Below seat squab</td>
<td>In the backrest</td>
</tr>
<tr>
<td>Cup holder, on armrest</td>
<td>Locked compartment on armrest</td>
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</table>
## Appendix 9 – Brainstorming Sketches

<table>
<thead>
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<table>
<thead>
<tr>
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<td><img src="image13" alt="Headrest Sketch" /></td>
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<th>Sitting</th>
<th>Resting</th>
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<td>Audio system</td>
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<td>Exercise</td>
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<td>Massage</td>
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<td>Clothes-rack</td>
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<tr>
<td>Ladder</td>
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## Appendix 10 – Elimination Matrixes

### Elimination Matrix for: The Foldable Seat

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Solves the main problem</th>
<th>Fulfils all demands</th>
<th>Realisable</th>
<th>Within the frame of costs</th>
<th>Safe and ergonomic</th>
<th>Fits the company</th>
<th>Enough info</th>
<th>Comment</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>*</td>
<td>-</td>
<td></td>
<td></td>
<td>* No room to rotate</td>
<td>-</td>
</tr>
<tr>
<td>F2</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>*</td>
<td>+</td>
<td>* New technology, possibly more expensive. Telescope armrest expensive? ** Change headrest</td>
<td>+</td>
</tr>
<tr>
<td>F3</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>*</td>
<td>-</td>
<td>* Changes in the bed is required</td>
<td>+</td>
</tr>
<tr>
<td>F4</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>F5</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>*</td>
<td>-</td>
<td>* Changes in the bed and the back wall is required</td>
<td>+</td>
</tr>
<tr>
<td>F6</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>*</td>
<td>-</td>
<td>* Advanced backrest, possibly expensive.</td>
<td>+</td>
</tr>
<tr>
<td>F7</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>F8</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>*</td>
<td>-</td>
<td>* Advanced seat base</td>
<td>+</td>
</tr>
<tr>
<td>F9</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>*</td>
<td>-</td>
<td>* Advanced seat base</td>
<td>+</td>
</tr>
<tr>
<td>F10</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>F11</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>+</td>
<td>*</td>
<td>-</td>
<td>* Advanced backrest, possibly expensive.</td>
<td>+</td>
</tr>
<tr>
<td>F12</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>Does not have any function when folded</td>
<td>-</td>
</tr>
<tr>
<td>F13</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>Does not have any function when folded</td>
<td>-</td>
</tr>
<tr>
<td>F14</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>*</td>
<td>-</td>
<td>**</td>
<td>-</td>
<td>* Advanced seat squab and backrest ** Not ergonomic</td>
<td>-</td>
</tr>
<tr>
<td>F15</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>Does not have any function when folded</td>
<td>-</td>
</tr>
<tr>
<td>F16</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>Blocks the door</td>
<td>-</td>
</tr>
<tr>
<td>F17</td>
<td>+</td>
<td>+</td>
<td>?</td>
<td>*</td>
<td>**</td>
<td>+</td>
<td>+</td>
<td>* Are there enough room to rotate? ** Advanced backrest, changes in the bed required</td>
<td>+</td>
</tr>
</tbody>
</table>
### Appendix 10 – Elimination Matrixes

#### Elimination matrix for: The Bench

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Solves the main problem</th>
<th>Fulfils all demands</th>
<th>Realisable</th>
<th>Within the frame of costs</th>
<th>Safe and ergonomic</th>
<th>Fits the company</th>
<th>Enough info</th>
<th>Comment</th>
<th>Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>*</td>
<td>The inner seat is not safe in a crash and disturbs the driver</td>
<td>-</td>
</tr>
<tr>
<td>B2</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>B3</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>B4</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>*</td>
<td>Crash safety: How much can the inner seat be angled?</td>
<td>+</td>
</tr>
<tr>
<td>B5</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>B6</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>B7</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>*</td>
<td>Not enough room in cabins with bed</td>
<td>+</td>
</tr>
<tr>
<td>B8</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>*</td>
<td>To have room for storage a large angle of the seat is required and this will lower the crash safety in the cabin.</td>
<td>-</td>
</tr>
<tr>
<td>B9</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td>*</td>
<td></td>
<td></td>
<td>Not possible to have the same backrest on the foldable and the bench</td>
<td>-</td>
</tr>
<tr>
<td>B10</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Not possible to have the same seat squab on the foldable and the bench</td>
<td>-</td>
</tr>
<tr>
<td>B11</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Does not work in day cabins</td>
<td>-</td>
</tr>
<tr>
<td>B12</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Not possible to have the same backrest and seat squab on the foldable and the bench</td>
<td>-</td>
</tr>
<tr>
<td>B13</td>
<td>+</td>
<td>-</td>
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<td>Not possible to have the same backrest and seat squab on the foldable and the bench</td>
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</tr>
<tr>
<td>B14</td>
<td>+</td>
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<td>Does not work in day cabins</td>
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<tr>
<td>B15</td>
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<td>B16</td>
<td>+</td>
<td>-</td>
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<td>Does not work in day cabinets</td>
<td>-</td>
</tr>
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<td>B17</td>
<td>+</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Does not work in day cabinets</td>
<td>-</td>
</tr>
</tbody>
</table>

#### Elimination criteria:

- (+) Yes
- (-) No
- (?) More info is needed
- (!) Check product spec.

#### Decision:

- (+) Fulfil solution
- (-) Eliminate solution
- (?) Search for more info
- (!) Check product spec.

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Appendix 11 – Relative Decision Matrixes

Confidential information only available in the internal report.
Appendix 12 – Concept Solutions

**Concept F2**
+ Gives more space in the cabin
- New technology, possibly more expensive
- Complicated to rotate and fold

---

**Concept F3**
+ Gives more space in the cabin
+ Easy to fold away
- Changes in the bed will be required

---

**Concept F1**
+ More floor space
- No room to rotate forward
Appendix 12 – Concept Solutions

**Concept B4**
+ More room for the legs
+ Storage possibilities
Crash safety?

**Concept B2**
- Seat squabs on different levels
+ Storage possibilities
+ Two separate units

**Concept B3**
+ Storage possibilities
+ Two separate units
- Room for the legs