More than just a Light Commercial Vehicle

Graduation Report

TU Delft
Delft University of Technology

Snoeks Automotive

Menno Rijsenbrij
4454049

Master Thesis

August, 2022
Delft, The Netherlands

Menno Rijsenbrij

MSc. Integrated Product Design
Faculty of Industrial Design Engineering
Delft University of Technology

Supervisory team

Chair: Ir. Ruud van Heur
Applied Ergonomics & Design
Faculty of Industrial Design Engineering Delft University of Technology

Mentor: Ir. Stefan van de Geer
Design Aesthetics
Faculty of Industrial Design Engineering Delft University of Technology

Company Mentor: Kenny Smit
Lead Engineer
Snoeks Automotive

Company Mentor: Maurice Rombout
Senior Engineer
Snoeks Automotive

Acknowledgements

For this Graduation Project I would like to thank my supervisory team for their guidance. I really appreciate the regular meetings and their willingness to visit the company several times to discuss my project.

My chair Ir. Ruud van Heur helped me from the very beginning with the creation of a project that suited me well. I was struggling to find a project in which I could really work on a physical product and push beyond the theoretical world that most projects end in. Thanks to his helped I managed to do just that. As a sparring partner at first, Ruud quickly offered to become my chair. Ruud, thank you for taking on this role and I am grateful for all your help and support before and during this project.

I met my mentor Ir. Stefan van de Geer before during the Honour Bachelor Program. His critical but creative view always amazed me. His inspirational anecdotes, motivated to let you consider certain alternatives, is something I can appreciate and I knew I wanted him as my mentor for this project. Stefan, thank you for your dedicated mentorship and the in-depth feedback on my report.

I would like to thank Maurice Rombout and Kenny Smit for their role as my mentor within the company. Maurice, I appreciate the weekly meetings we had and your involvement in my project. Your help and feedback on both my work and planning really helped me work through this Graduation Project.

Kenny, thank you for your advice and your believe in this project. I really appreciate the opportunity you offered me to actually build this prototype, even when the workspace capacity was limited. Thank you for your trust in this project and for offering the ability to prove myself.

I would like to thank the Snoeks Automotive for the opportunity to do my Graduation Project with them. I have had a great time at the company and in the R&D Department and appreciate the time and effort that several employees spend to help me bring this project to a successful end. I would also like to thank all the employees that would spend their lunchbreaks around the ping pong table. These daily 30 minutes really helped me to blow of some steam and get back to work with a clear mind.

Special thanks also to Dominique Snoeks. His amazing welding skills is what made the prototype work so well and he managed to do this in a very limited timeframe. I could not have hoped for a better execution.

I would like to thank my friends, family and fellow Yetianen for their support and all the fun times during the past few years that let to this moment. This is a huge milestone in my life and I could not have done it without you.

Finally, I would like to thank Huize Olympos for the great distraction after work. You all helped me to keep my mind of the project and to enjoy my evenings with my roommates and friends. Graduation Project or not: “Studeren is combineren”.

Executive Summary

This Graduation Project was made for Snoeks Automotive. Snoeks is currently most successful with their crew-cab products. These products allow users to use their LCV for both commercial and private usage. Their latest innovation is the Flex Cab, a double cabin that can fold forward to increase the usable cargo area. But why stop there? In 2021, Recreational Vehicle (RV's) shipments increased by 40% compared to 2020 (RVIA, 2021). The RV industry is growing rapidly, indicating an increasing demand for recreational activities. With the current RV trends and the expertise of Snoeks Automotive, an interesting opportunity can be found.

In this Graduation Project, an RV/LCV hybrid concept is created. A product that can be used for commercial, private and recreational activities. As customers mainly buy an LCV for commercial purposes, a large part of the challenge was to develop a hybrid concept that does not interfere with commercial usage.

For the recreational functionalities, the target group was first analysed. It was found that this target group is highly divided (Topsector Logistiek, 2017), and that the best solution for the company would be to develop a base product with some "must have" recreational functionalities, after which customers can choose to customize the vehicle themselves. Functionality research showed that the most important functionality to add is the ability to sleep.

Creating an innovative product was found to be difficult as the Automotive industry shows many signs of reluctance. Developing an innovative product within this industry often comes with large development costs and therefore it is a big risk to take. It was quickly understood that Snoeks Automotive would not develop a stand-alone recreational product as the expected development cost and the risks would not outweigh the potential profitablitity.

This is where the Flex Cab + comes in. A Flex Cab that is even more innovative than the current one as it offers the additional functionality of sleeping. This idea offers both an improved commercial and recreational usage compared to the regular crew cab. Developing a Flex Cab that is even more innovative might sound like a large risk, but this project aimed to prove that the additional functionality is achievable with minimal adaptations and complexity.

With the Flex Cab +, customers can use their LCV for commercial, private and recreational activities, as the product can be placed in three position: seating, sleeping and flexed forward, as can be see figure 1.

This Graduation Project proves the technical feasibility of the Flex Cab +, and shows that with relatively minimal engineering, the Flex Cab can be improved with large impact. By simultaneously developing the regular Flex Cab and the Flex Cab +, the additional developments costs can be kept at a minimum.

For this project, the K1 medium segment was chosen as this is the most sold LCV segment and the most popular category for Snoeks current double cabins. The concept might be applicable in other segments in a later stage as well.

The K0 was the chosen platform for proof of concept as this is the smallest and most popular K1 platform. Proving that this concept can be achieved within the confined space of the K0 also proves that it is also applicable on other K1 platforms as those internal dimensions are larger.

The concept was first validated on a theoretical level, by verifying the possible sleeping length, comfort and configuration. After the theoretical validation, a physical prototype has been made to verify the functional mechanism of this product and prove the technical feasibility within the vehicle.

The physical prototype successfully confirmed that the desired additional functionality is achievable with relatively minimal engineering. The prototype was able to achieve the seating, sleeping and flexed forward position within the K0 body, as can be see in figure 2.

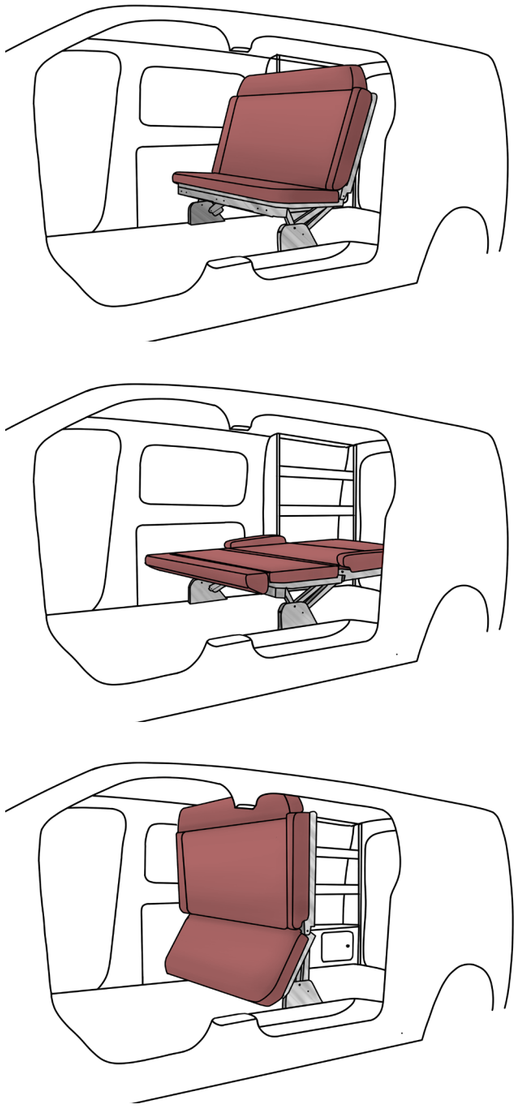

Figure 1. The three configurations in the K0 platform

Figure 2. The transitions of the mechanical framework into all three positions

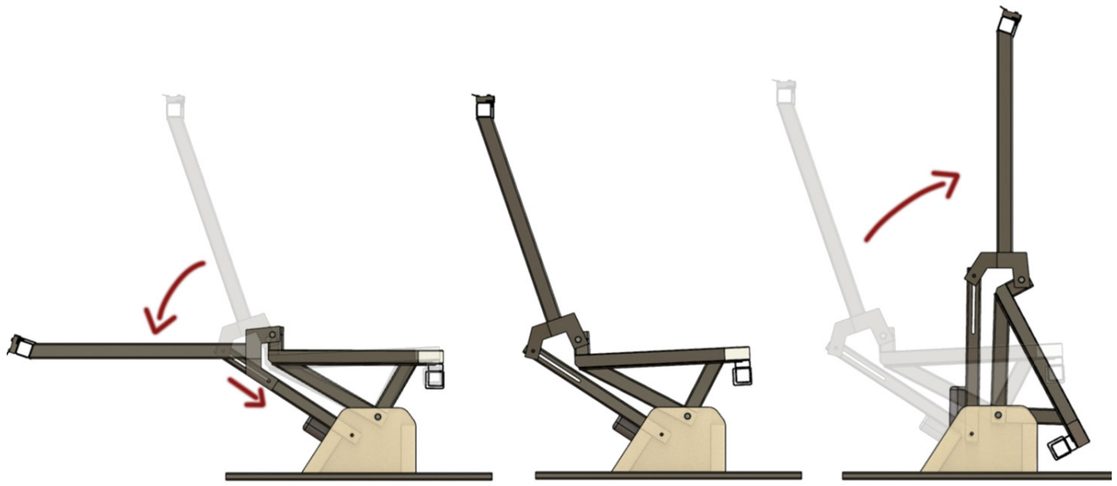

Figure 3. Achieving all three positions by shortening the back rod

The biggest difference between the Flex Cab and the Flex Cab + is that the rotation points of the Flex Cab + can be manipulated with the use of actuators. This enables the mechanism to be placed in three different positions (Seating, Sleeping and Flexed forward), as can be seen in figure 3.

For the development of the Flex Cab +, a double backrest and a modular headrest should be developed in order to create a full size double bed. The backrest is folded backwards onto a supportive frame, and the headrest is paced in front of the seat to create a comfortable bed length. This can be seen in figure 4.

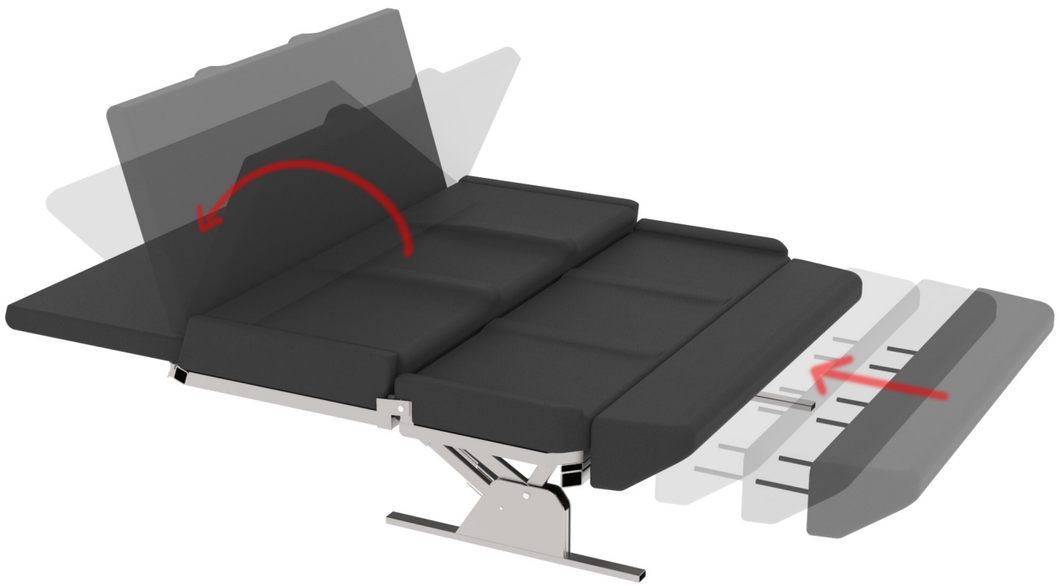

Figure 4. Folding of the backrest and placement of the modular headrest

The supportive frame in the back of the vehicle can be used to place shelves at the sides of the LCV. These shelves can be used for both commercial and recreational storage. This way the flex cab + offers optimal Commercial and Recreational usage, as can be seen in figure 5. As can be seen, the recreational functionalities do not interfere with the regular commercial usage. These shelves could potentially be added as a trim levels.

The Flex Cab + matches well with the fiscal regulations for France, Germany and the United Kingdom, which were found to be the largest players on the LCV market (ACEA, 2021). On top of that they showed the largest demand for recreational functionalities as these three countries have a combined RV market share of 72% in Europe. (Civd, 2021)

The biggest recommendation for Snoeks Automotive is to evaluate the market viability of this concept and to decide if this concept is worth further development. Even though the simultaneous development will keep the additional development costs at a minimum, the market viability and desirability in an uncertain factor. A cost and risk estimation should be made. It is advised to make a calculated estimation based on either the expected additional development costs or the expected achievable sales, and compare these results with the potential risk / reward.

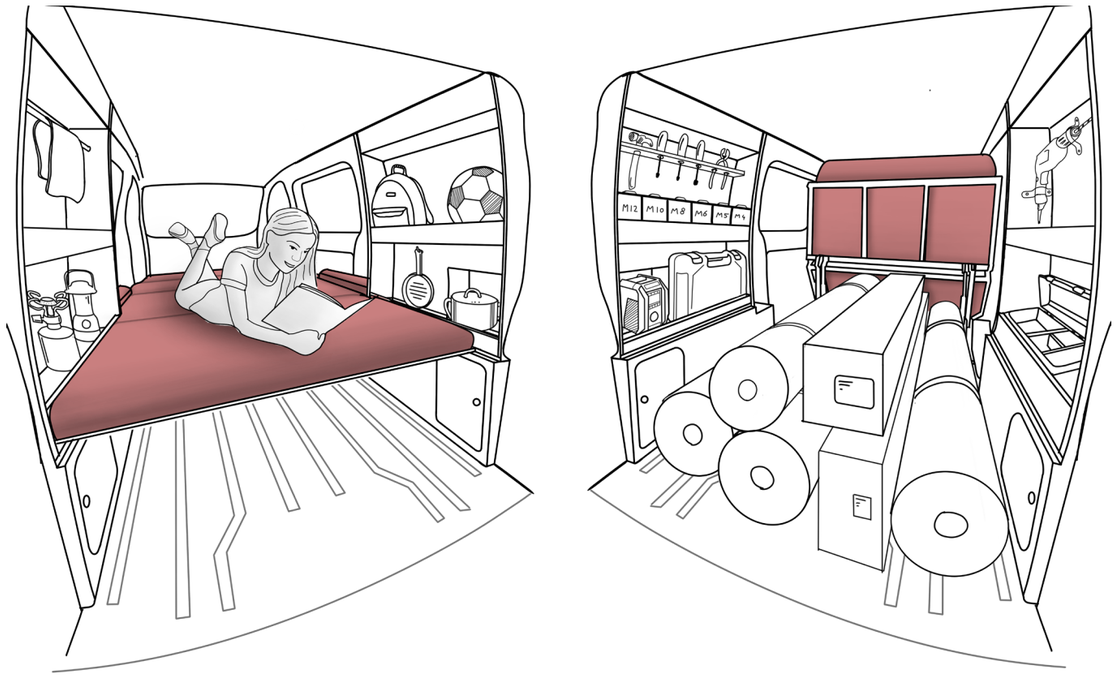

Figure 5. Recreational and commercial usage

Terms and Abbreviations

The Industry that this project focusses on is filled with many abbreviations, codes and regulations.
Most of these terms will be explained during the report, but here is a short summary of most terms with a short explanation for your convenience.

LCV = Light Commercial Vehicles. This is the commonly used term for commercially used vans.

LCV's consist out of 3 different classes. **F1** (compact van), **K1** (medium van) and **K2/3** (large van). The chosen segment for this project was the **K1 Medium van.**

LCV Platform / body. This is the name of the body / steel structure of the vehicle. The same platform or body can be used by multiple brands.
The platform that was used for this project was the **K0.**
The K0 body is used for the Citroen Jumpy, Fiat Scudo, Opel Vivaro, Vauxhall Vivaro, Peugeot Expert and Toyota Proace.

L1H1 = refers to the length and height of the platform. An L1H1 is the lowest and shortest version of a platform.
An L1H2 is a bit higher, and a L2H1 is a bit longer. For the chosen K0 platform, there is only one height and 3 different lengths; **L1** (compact), **L2** (regular) and **L3** (long). For this project, L2 and L3 are used.
RV = Recreational Vehicle

This term categorises all purpose-built vehicles for recreational usage. This technically includes both Motorhomes (campers) and Caravans. Note that the referral in this report is focussed specifically on the motorhomes segment.

OEM = Original Equipment Manufacturer
CAD = Computer Aided Design
VR = Virtual Reality
MVP = Minimum Viable Product
HR foam = High Resilience foam
Bolsters = Organic shapes within the seat for added comfort.
Crew cab = The double cabin of Snoeks Automotive, also refered to as **DC**
Flex cab = A flexible double cabin of Snoeks Automotive that folds forwards
C-Pillar = The tickened structure at the rear side of the passenger door. This pillar is used to strenghten the body and can be used to mount supportive fixtures.
Partition Wall = The wall that devides the passengers from the cargo area.

Abbreviations of important references:
ECF = European Caravan Federation
CIVD = Caravaning Industrie Verband
RVIA = RV Industry Association
ACEA = European Automobile Manufacturers' Association

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0 Introduction

Snoeks Automotive is the leading partner for car manufacturers to extend their product range in Light Commercial Vehicles (LCV's) by supplying them with innovative interior modification concepts. With over 80.000 converted vehicles a year, Snoeks Automotive is an expert in creating modular modifications for LCV's. They mainly focus on partition walls (figure 0.1), the crew-cab (figure 0.2 and the flex cab (figure 0.3).

The large majority of Dutch LCV users are sole traders or private limited companies (Topsector Logistiek, 2017). Figure 0.4 shows the desired activities of a small business owner. In order to perform the desired activities, the user now needs multiple vehicles.

This is where Snoeks Automotive steps in with their biggest success: The crew cab. The Crew cab is an additional backseat in the LCV with a separation wall behind the passengers. The main reason that was found to prove the success of this product is that the vehicle can be used privately and commercially while still having the financial benefits of a commercial vehicle. But why stop there?

The Recreational Vehicle (RV) industry has been growing for over 40 years now, but in the past 10 years this growth became enormous. In 2021, RV shipments increased by 40% compared to 2020 (RVIA, 2021). With the current RV trends and the expertise of Snoeks Automotive, an interesting opportunity can be found.

Figure 0.1 Partition wall

Figure 0.2 Crew Cab

Figure 0.3 Flex Cab

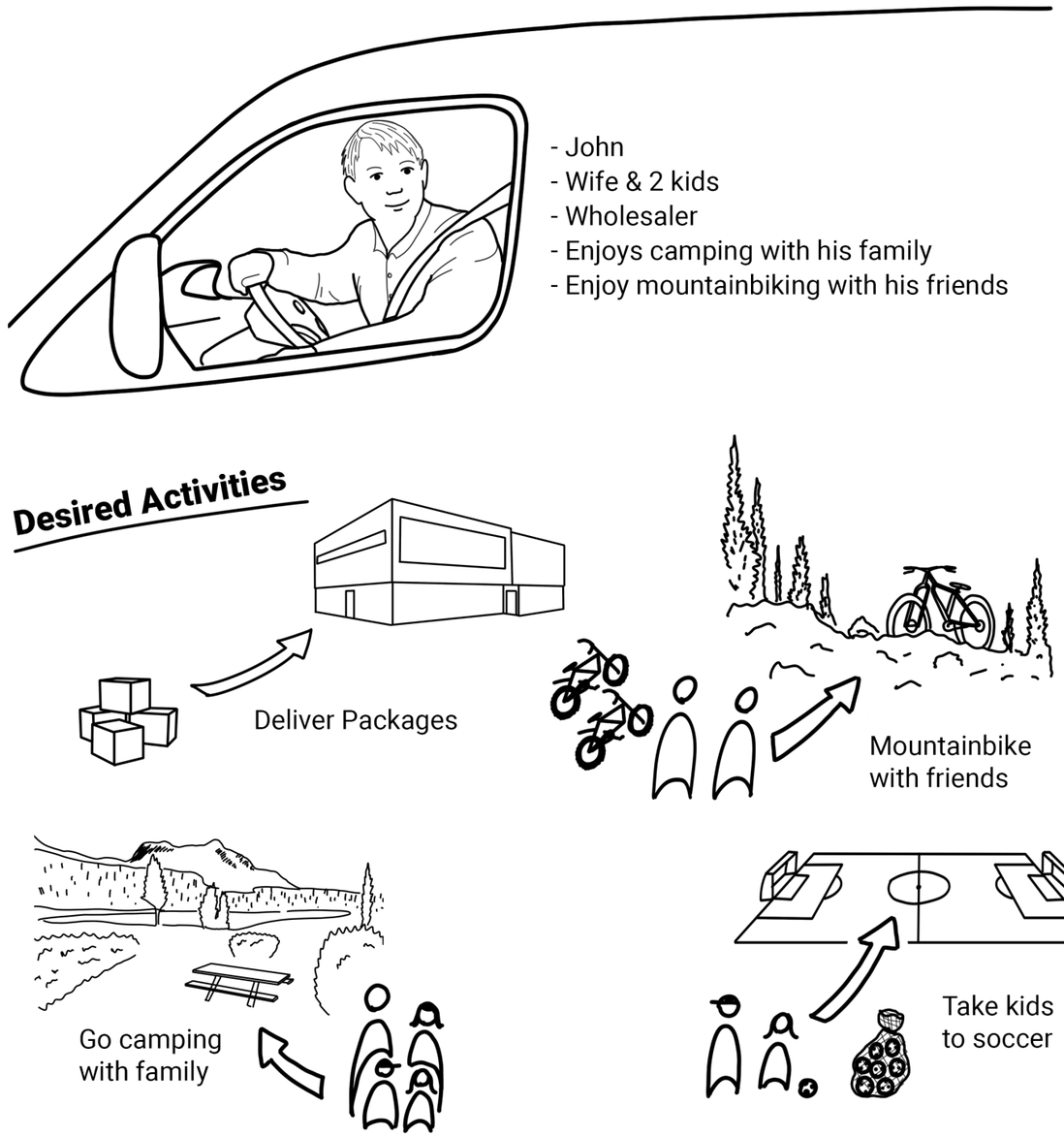


Figure 0.4 Desired activities of a small business owner

Currently, RVs are always separate, purpose-built vehicles used for leisure purposes only. Rather than customers having to buy a completely new vehicle for over 50.000 euro's, the opportunity that was found here is to combine work and leisure into one LCV.

In this Graduation Project, an RV / LCV hybrid concept is created. A modular concept that offers an upgrade on a user's commercial vehicle. This allows LCV users to use the same vehicle for commercial, private and recreational activities (figure 0.5).

Based on space and usability, a combination between an LCV and an RV does not seem like a logical combination. Both types are purpose-built vehicles. Rather than seeing this a threat, this could be used as the USP of this concept. A combination between the two could be a gamechanger in the market.

The original Project Brief that was used for this Graduation Project can be found in Appendix A .

Current Situation

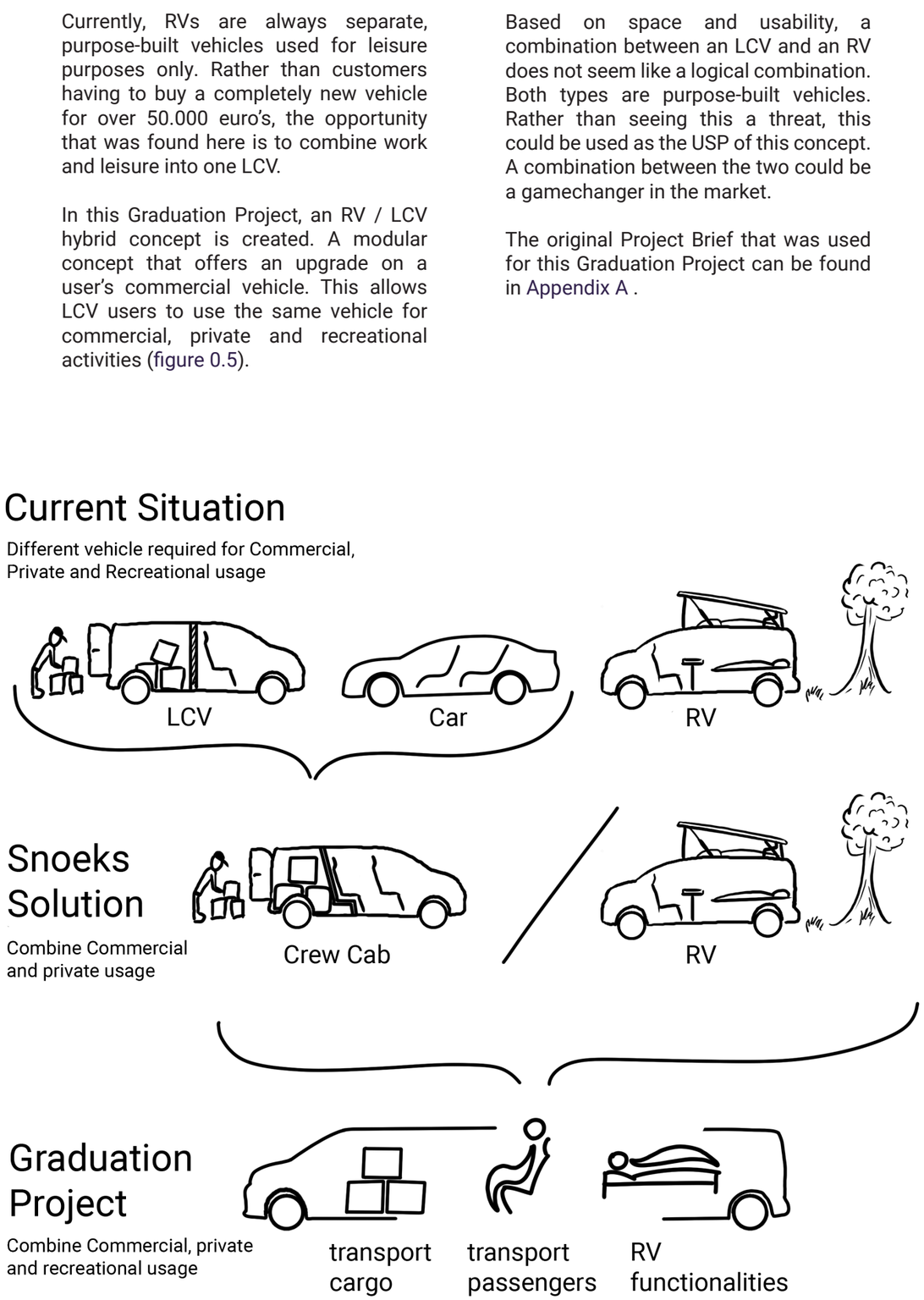


Figure 0.5 Current vehicle situation for target group

For this report, a schematic overview of the complete project can be found in figure 0.6. Each chapter will have its own overview for guidance through the report. The Appendixes that are used for each section can also be found within these overviews.

Structural Report Overview

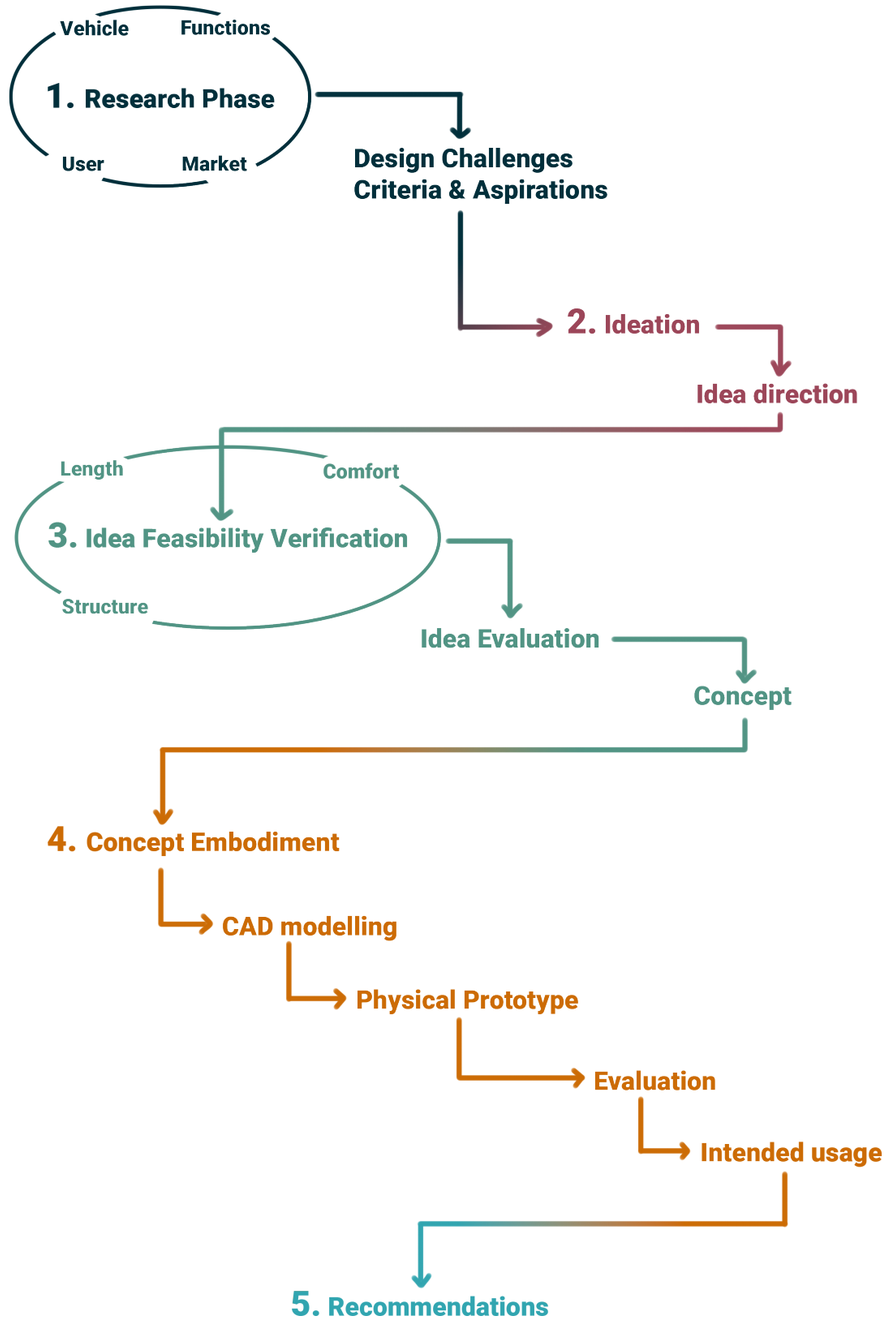


Figure 0.6 Schematic overview of the complete project

1 Research Phase

To design a feasible, viable and desirable RV/LCV combination (also referred to as hybrid), a certain amount of background knowledge is required. Several sub-research questions have been created and analysed in order to get a good grip on the project and to make well considered design choices.

There are many relations and dependencies that have an influence on certain parts of this project. Conclusions are often based upon findings within multiple categories. In figure 1.0.1 a dependency graph can be found. For your convenience, the report will mostly describe the conclusions and the key information that was used to base these conclusions upon.

Figure 1.0.1 Dependancy graph

In figure 1.0.2, a schematic overview can be found to indicate which steps are taken during this research process and which questions have been analysed. References in this visual indicate which analyses were involved to base the conclusions upon. The full research for each separate category can be found in the Appendix for more detailed information.

The most important analyses will be examined in the following subheadings. The results of these analyses were used to create a list of design challenges, criteria, and aspirations, which were taken into account during the following phases.

Research Phase Structural Overview

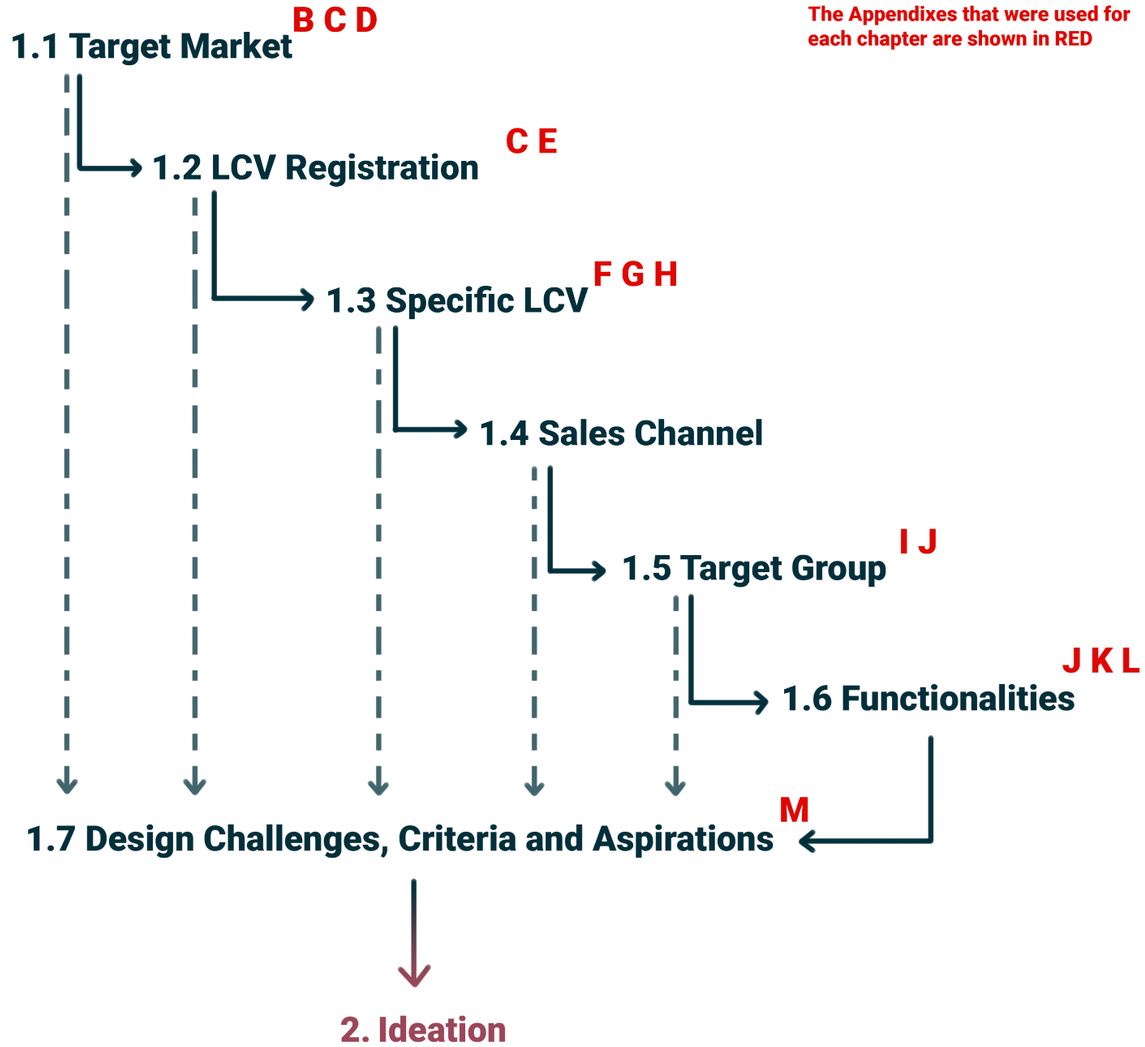


Figure 1.0.2 Schematic overview research phase

1.1 Target Market

To find out the right LCV to transform and the regulations that the vehicle should meet, it is desirable to get an idea of where this product could be most successful. To determine the right target group, it is important to look at the current market that Snoeks Automotive is operating in, as well as the most promising new markets. The three markets that are analysed are Snoeks current market, the RV market, and the LCV market (figure 1.1.1).
The elaborated research towards these markets can be found in Appendix B.

Snoeks Automotive is currently mainly based in Europe and make most of their sales in France, followed by Belgium, the Netherlands, Germany, and the UK (Snoeks, 2020). Targeting their existent market could increase the feasibility as they already established a position within that market.

A potential market for an LCV with recreational features could be found in countries with high RV sales, as this indicates an urge for recreational usage of a vehicle. Germany is the European RV market leader, followed by France and the UK (figure 1.1.2).

These three countries have a combined market share of 72% (Civd, 2021). The introduction of an LCV/RV hybrid in these countries could potentially reach a new target market of LCV owner that would also like to use their vehicle for recreational activities.

When looking at the LCV market, France can be found in the number one position with 450k newly registered vehicles in 2019. Followed by the UK at 367k, and Germany with 328k. (ACEA, 2021)

Placing these rankings in figure 1.1.3, it can be seen that France, Germany and the UK are doing well within every market. Note that The Netherlands and Belgium are ranked high at Snoeks Current market. Where this could potentially be an interesting market, the fiscal regulations for these countries are very strict (see Appendix C). As the Netherlands and Belgium only cover a small part of the RV & LCV market, it was decided to neglect these countries.

Figure 1.1.1 Analysed markets (1. Snoeks current market. 2. RV market 3. LCV market)

The US market was also considered as the recreational industry seemed to be growing and Snoeks is currently expanding its market in the US as well. It was however decided that this market will not directly be considered, as motorhomes are far less popular there and Snoeks Automotive is not established in this market yet. More details can be found in Appendix D.

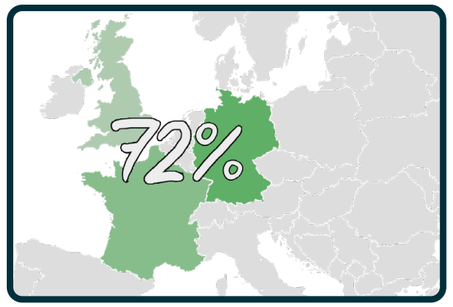


Figure 1.1.2 Combined RV market share

Rank	*Snoeks Current market*	*RV Market in Europe*	*LCV market in Europe*
1	France	Germany	France
2	Belgium	France	UK
3	The Netherlands	UK	Germany
4	Germany	Switzerland	Spain
5	UK	Italy	Italy

Figure 1.1.3 Rankings overview for analysed markets

Main Takeaways

It is recommended to focus mainly on the French, German and the UK market as they account for 72% of the European RV market and are the bestsellers in the European LCV market.

As the Dutch LCV regulations are way more complicated than the rest of Europe and their sales are only 1.5% of the European market, it is decided to neglect this market completely.

1.2 LCV Registration

The registration type of the vehicle plays an important role in its success. How will this vehicle be placed on the market? The vehicle can be registered as either an RV or an LCV. The registration for one of these types comes with several regulations and benefits that need to be compared. A comparison between these regulations and benefits for the desired target market can be found in Appendix E. The tax regulations are often quite elaborated and complex, but the complete details can be found in the annual Tax Guide by ACEA (European Automobile Manufacturers Association).

For this concept, the LCV registration would be most ideal. This registration allows customers to use the vehicle for commercial purposes and to get certain tax benefits like VAT deduction (ACEA, 2021). It also matches well with Snoeks current market strategy and knowledge which could make it easier for them to implement this product in their repertoire. It is important to note that the fiscal regulations that should be met to apply for these tax benefits is different for each county (Appendix C). These regulations should be seen as criteria or aspirations depending on the impact.

Conclusions

The product should be placed on the market with an LCV license plate, combining the fiscal benefits and current strengths of Snoeks Automotive.

This means that the product should match the Fiscal and Safety regulations of LCVs within the chosen target markets: France, Germany, and the UK.

1.3 Specific LCV

Due to the complexity of this project, the scope for this concept will be limited to the interior of one specific vehicle. To determine which vehicle is most viable to start with, the categories and platforms were analysed. The choice was mainly based on market potential, customer usage, Snoeks current market & ergonomics. First the category was determined, after which a specific model was chosen to work with. The complete research that was done to determine the specific LCV can be found in Appendix F.

LCV Category

LCV's can be categorized in three types: F1 (compact van), K1 (medium van) and K2/3 (large van). These can be seen in figure 1.3.1.

Each category has certain pros and cons when it comes to daily usage, storage space and comfort. Apart from that, market statistics and Snoeks current developments have also been used to determine which category could have the largest viability. Based on the previous conclusions and sub research, as list of important factors has been created. These factors have been analysed and listed as requirements and aspirations (Appendix G). A Harris Profile has been created to determine the right LCV category to focus on. The results can be seen in figure 1.3.2. This shows that the K1 medium class scores significantly higher in the determined factors and therefore shows the largest viability.

Figure 1.3.1 LCV categories

Figure 1.3.2 Harris Profile for LCV categories

Conclusions

For this project the K1 medium class is the most ideal category. This category has the biggest market value, highest viability based on the potential customers and fits well with Snoeks current market.

The biggest weak point for this segment is ergonomic comfort. This should be optimised as well as possible in the ideation and design phase.

LCV Platform

After the Medium category was chosen, a specific model was selected to place this product on the market and for prove of concept.

It is important to note that many LCVs are built on the same platform. As an example, the K0 platform is used for the Citroen Jumpy, Opel/Vauxhall Vivaro, Peugeot Expert, Toyota Proace and soon the Fiat Scudo. An overview of this can be found in Appendix F. As a certain design for a specific platform can be used for several types/brands that are built upon that platform, this paper will mostly refer to platform codes rather than specific brands or vehicles.

The most successful LCVs for the crew cabs from Snoeks Automotive (Snoeks, 2022) and the most popular medium LCVs in Europe (Parkers, 2022), have been analysed and compared to determine the specific vehicle. This analysis can be found in Appendix F.

The biggest current development in the K1 medium van segment is a collaboration between Ford and Volkswagen (Volkswagen, 2020). They currently own the best and second best-selling medium LCV and their new combined platform is expected to make an enormous impact on the current market. Creating a solution for the future VW/Ford platform has the largest viability. However, as this concept is still in early development and there are large confidentiality issues, it has been decided to use an existing platform for proof of concept.

The K0 is the best-selling current platform on the European market and within Snoeks Automotive.

This platform can also be used for physical prototyping and testing, which makes it ideal for this research. In a later stage, a roadworthy vehicle will also be made available for the creation of a final proof of concept model. An example of a vehicle built on the K0 platform is the Fiat Scudo (figure 1.3.3)

Figure 1.3.3 The Fiat Scudo, a K0 platform

The K0 is slightly smaller in every dimension than the new Ford/VW platform. If the proof of concept is successful for this platform, it is likely that the solution could also be applied for the new platform as the size restrictions are less extreme. The ability to apply this concept in different vehicles within the same segment (K1 medium LCV's) is high on the aspirations list.

LCV's can come in different heights and lengths. This was analysed in Appendix H. For the K0, the medium platform usually comes in two dimensions, regular (L2) and long (L3) as can be seen figure 1.3.4.

It is desirable to create a solution that is both applicable in the L2 and L3 version of the vehicle. This way customers can choose their type of vehicle based on the functionalities that they require, and do not have the weight in the factor of recreational functionalities until after the specific LCV has been chosen. Making the product available for both lengths could potentially increase the viability as customers can choose a vehicle based on their needs and preferences. The product could be a trim level (Optional version of a vehicle) on top of the currently existing variations.

Important Insights

The K0 is the best-selling current platform within the K1 segment and would be a logical choice to use for the development of the first crew camper.

The new Ford/VW platform is expected to the have the largest impact on the market in the near future. This should be the future focus for this concept.

The K0 platform is physically available for this research and will be used for proof of concept. As the dimensions are slightly smaller in every direction, the solution is likely to be applicable on the new Ford/VW platform and other platforms in a later stage as well.

It is desirable to create a solution that is applicable in both the regular (L2) and long (L3) version of the K0 platform.

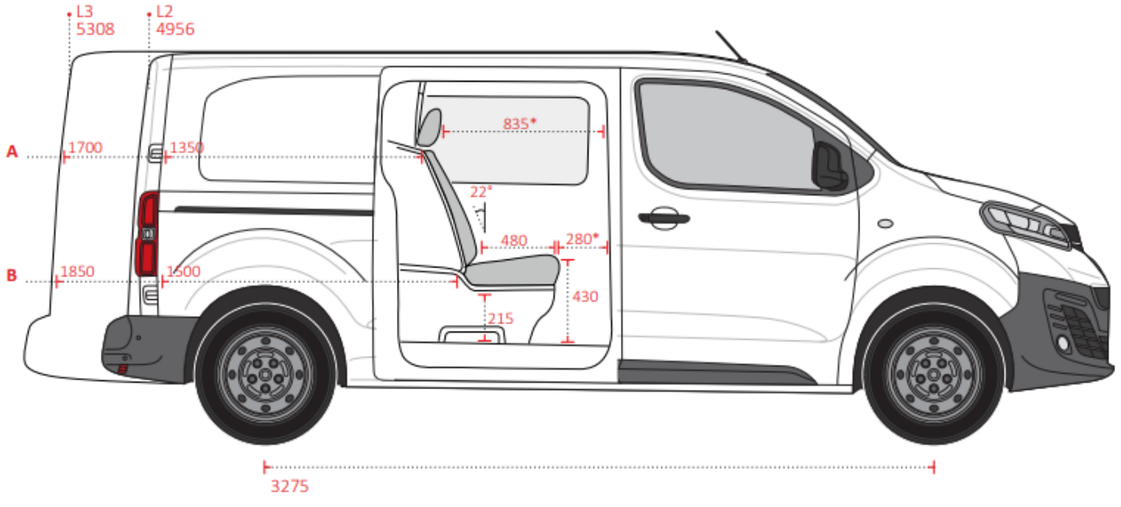


Figure 1.3.4 The two different length variations of the K0 platform

1.4 Sales Channel

Snoeks sell their modifications via three different sales channels: OEM (Original Equipment Manufacturer), Dealer network & After fit.

It seems beneficial to focus on the OEM channel as this covers almost [redacted] % of their sales, but this could prove some difficulties when it comes to the development of an LCV/RV hybrid. This is because most campervans are currently created by second parties. Volkswagen is the first and only OEM to produce their own RV version of the VW Transporter (the VW California) within their factory.

The reason to use second parties often has to do with safety regulations. When creating a pop-top roof (an extendable rooftop that creates two extra sleeping places) at OEM level, this feature should be assessed thoroughly and could result in large safety testing and development costs according to the Sales department at Snoeks. It should be noted that as Volkswagen already produces their own RV version within their factory, the new Ford/VW platform could be a way to still place the RV/LCV hybrid directly on the market via OEM.

It is expected that this product does not intervene with the sales of a potential own RV version of their new platform.

This is mostly because of the way that this product will be placed on the market; As an LCV with some potential recreational features. The RV will still be a purpose-built vehicle and the market for this LCV/RV Hybrid is not expected to buy an RV and vice versa. It should therefore still be clear that the main purpose of this concept is being a commercial van, only with some additions so it could be used for leisure activities.

This concept could also be implemented as an After-fit product. This is likely to reach less sales, but profit margins could be larger in this sales channel. OEM channels are often used for large quantities with smaller margins, so for this introduction of a new concept like this, the After-fit market might have some advantages.

The product could also be integrated in collaboration with an OEM, where they produce the base vehicle and have a partner convert the vehicle into a crew-camper. This is how Ford now sells their Ford-nugget campers by collaborating with Westfalia (Ford, 2022) and Renault sells their SpaceNomad in collaboration with Pilote (Renault, 2021). This sales channel is technically considered After fit as well.

Conclusions

The product can be sold via OEM or After-fit sales channel. Both channels could make this vehicle viable.

The After-fit market is generally less strict and could make the implementation of this concept easier.

1.5 Target Group

In order to design a vehicle with recreational possibilities, it is important to take the end-user into account. Snoeks automotive mainly delivers to manufactures (car companies). Therefore, they are not in direct contact with the end-user. Due to confidentiality regulations, direct research with the target group is currently not possible. Instead, Snoeks current knowledge and a research paper by Topsector Logistiek (2017) were used to get a better understanding of the end-user. This paper analyses the users and deployments of delivery vans in The Netherlands. It is now assumed that this distribution of vans in The Netherlands is comparable within other European countries.

The research paper proved that the target group is extremely diverse, as can be seen in Appendix I. There are many different categories and professions in which people use LCV's. As the target group is highly divided, it was decided to analyse the similarities rather than the differences. What do these groups have in common and how can the interior of the LCV be designed in such a way that it is suitable for the majority of LCV users.

35% of all vans is owned by sole traders (CBS, 2015). As most of the customers for the K1 crew cab chooses for the comfort edition rather than the eco version, it can be assumed that this vehicle is also used for private usage, especially for the sole traders. Customers can use their vehicle on their own for commercial usage and use the crew cab to seat their friends or family during private usage.

What most trade sectors have in common is the main purpose of the LCV: transporting cargo or tools from one place to another. For some trades, the cargo will be fully loaded in and out of the vehicle, where other trade sectors might keep their tools secured in the cargo space of the LCV. It is important that this main purpose is not obstructed by any recreational functionalities. To prevent this, a space optimization analysis has also been done, as seen in Appendix J.

The target group is not directly related to the RV target group. LCV users like painters, electricians, plumbers, or carpenters might have different preferences when it comes to recreational activities. To make the vehicle as usable as possible for each sector, only the most important functionalities will be installed within the base product.

With these main features, several other functionalities could be added in the form of modular upgrades to personalize the vehicle. This is likely to increase the desirability of the concept for LCV users as they can personalize the vehicle for the recreational purposes that they desire.

Main Takeaways

As the target group is divided, it is advisable to create a product with only "must have" functionalities, while offering the possibility to add additional modules to personalise the product and increase its desirability.

The main target group to focus on are sole traders and private limited companies

The recreational possibilities should not intervene with any regular commercial usage.

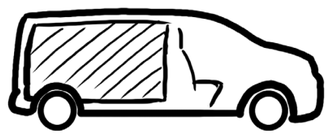
1.6 Functionalities

What kind of functionalities are the most important to implement within the product? To answer this question, the functionalities have first been divided into two categories: Commercial functionalities and Recreational functionalities. As mentioned before, the commercial usage is the main reason why people will buy the LCV. Therefore, the commercial functionalities will have priority over optioRecreational functionalities. At the same time, there should be significant added value of recreative functionalities for this concept to become a viable product as it focusses on the combination of these two types of usage.

Commercial Functionalities

Commercial functionalities are based on regulations and must haves in order to be able to sell the product (according to Snoeks). These functionalities are critical for the success of the product and must all be integrated in order for this product to be feasible, viable and desirable.

Must have (to be able to sell this product on the market)

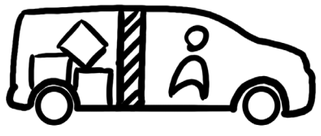


Cargo space

Without a doubt the most critical element of an LCV. This vehicle is bought with the purpose of selling or moving goods that are shipped in the cargo space. Here it is mandatory to meet the regulations for the desired target market. The cargo space must be 51% of the length of the interior, and at least 0.5*the original cargo space + 0.3m. The space must be blinded, and the vehicle must be able to carry a payload of at least 1000kg. It is desirable to keep the cargo space as large as possible to allow customers to comfortably transport any type of cargo.

Seating for at least five people

This vehicle needs to be usable for the transportation of people during both commercial and private usage. As the main idea of this concept is that the user does not require an additional vehicle, it should fit at least the same amount of people as a regular car. Therefore, the vehicle should have at least enough seats to transport five people during commercial usage.
As the LCV is mostly used for commercial usage, the ergonomic comfort of these seats is of large importance. The seats should offer a comfortable travel experience for its passengers.



Partition wall

Having a partition wall installed is an absolute must have. The regulations should be taken into account here and the wall must meet the safety standards of DIN 75410-3 / ISO27956. It should also always be installed during commercial usage. Rather than creating a very complex system that makes it physically impossible to drive without a partition wall, an alarm could be installed as well.

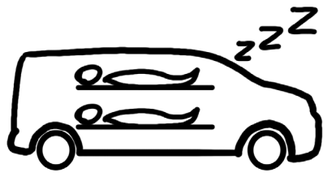
Seatbelts

Seatbelts are part of the European safety requirements. According to Snoeks, all seats must be equipped with 3-point safety belts and since September 2021 all newly registered LCV's must be equipped with a seatbelt detection system.

Recreational Functionalities

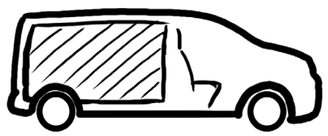
To determine which recreational functionalities are the most essential, The Camper Expo Houten was visited to analyse RV functionalities. In Appendix K a large overview can be seen of functional elements and the different forms in which they come. These functionalities, the analysed spaces like truck cabins, boats, and tiny houses (Appendix J) as well as previous research have been used to create an Must have, nice to have, and could have list of functionalities for this concept. These are assumed to be the most important for this specific target group for now. The final concept will be used after this project to validate this and assess the desirability and viability for LCV users.

Must have (to be able to sell this product on the market)



Sleeping places for two people

The main feature of any RV is the ability to sleep inside the vehicle. To put this product on the market as a vehicle that can be used for recreative activities, the sleeping functionality will be seen as the most important additional feature. The vehicle must at least offer two sleeping places for people inside the vehicle.



Storage space

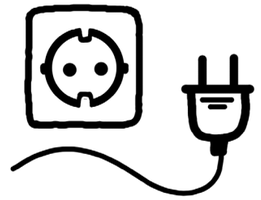
As was seen during the expo, storage space is a key factor to the success of a campervan. Especially in a LCV/RV hybrid, this functionallity is of large importance. Large size suitcases of around 115 litres are the number one in popularity (bestcheckedluggage, 2020), good for a two-week trip with comfort in packing. As it is expected that the recreational functionalities will mostly be used for short trips, this should be more than enough luggage at any time. As the vehicle should offer sleeping space for two (or four) people, it is expected that 500L of storage space is more than sufficient. Lockable storage space and easily accessible storage space should also be considered.

Seating for at least four people

This vehicle needs to be usable for the transportation of people during recreational usage. It is found that the group size of short-term campers in Germany consists 53.8% of the time out of one or two people and 43,5% out of three or four people (Westtoer, 2011). It is decided to make it a must have to transport at least four people during recreational usage to serve the large majority of potential customers.

Additionally, there are several nice to have and could have functionalities that could increase the desirability. These functionalities are further elaborated in Appendix L.

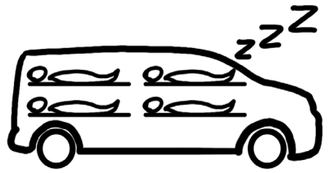
Nice to have (to increase desirability)



Power outlets

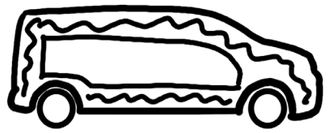
"livingroom" area

Ability to stand

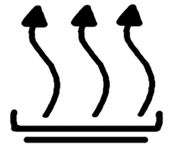


Sleeping space for 3-4 people

Could have (ability to personalize the vehicle)



Insulation



Heating

Cooking facilities

Water supply

Main Takeaways

The most important commercial features that must be considered are the cargo space, seating for at least five people, the partition wall, and seatbelts.

The most important recreative features that the vehicle must have, is a sleeping space for two people, seating for at least four people and enough storage space (>500L).

The ability to stand, power outlets, a "Livingroom" area and additional sleeping spaces are recommended 'nice to have' features that could improve the recreational user experience.

1.7 Design Challenges, Criteria and Aspirations

With the previous research and conclusions, a list of design challenges, criteria and aspirations was created. These design challenges, criteria and aspirations have been considered during the Ideation & Design phase. The concepts have been evaluated with these criteria to determine which concept should be further developed and assessed in a physical vehicle.

Design Challenges

The biggest design challenge is the creation of a vehicle that combines commercial and recreational purposes. Because of the limited space the combination does not seem logical, but if it can be done, the product could attract a whole new market.

Regulations are often very strict. A commercial vehicle should function like a commercial vehicle and not like something else. It will be an important design challenge to offer recreational features without displaying the vehicle as an RV. All features should somehow be relatable to commercial usage in order to get the LCV licence with the fiscal benefits.

The commercial usage of the vehicle is seen as the main reason for customers to buy the product. It will be a large design challenge to create a concept that does not intervene with this regular commercial usage. Ideally everything is always located inside the vehicle, but modular options that require some storage space will be accepted if that increases the commercial usability or ergonomic comfort.

To allow the transport of both passengers and goods, the concept will be based on the already existing crew-cab. This allows the customer to still receive fiscal benefits and have an ideal combination of commercial and private usage. The challenge here is to transform the system in such way that it can be used for recreational activities as well while still matching fiscal and safety regulations.

When the vehicle is being used for recreative purposes (Camp-mode), the vehicle may not be used for commercial usage as unsafe situations could occur. The partition wall must always be in place during commercial usage.

The K1 (medium) LCV is the most promising LCV for this concept. The largest design challenge here is to make a somewhat comfortable concept as the dimensions of this vehicle are limited. It is not possible to stand in the vehicle and a transition between the seating area and the cargo area should be created. It should be noted that as the main purpose is still commercial usage, the ergonomics will be made as optimal as possible for this commercial usage. It is considered acceptable if this results in a less comfortable transition for recreational activities, but the challenge is to make both types of usage as comfortable as possible.

The cost price should remain relatively low. The idea remains to offer the customers to experience some recreational RV features without having to invest in a very expensive vehicle. If this price becomes too high, the USP of LCV/RV loses its value. Production and cost should also be considered here. When developing a concept for OEM level, the safety regulations could be a lot stricter, and testing might be more expensive. Therefore RVs are now often created by a different party. On the other hand, creating an after-fit concept could result in less sales, which could mean that the modification needs cheaper development costs.

Criteria

The concept should be usable for both Commercial and Recreative usage.

The vehicle needs to be registered as an LCV. As the Target market is focussed on France, Germany and the United Kingdom, their fiscal regulations should be met to provide a financially attractive product, making the concept more desirable. The criteria for these regulations will be:

- The cargo space should be 51% of the length of the interior. (It is allowed to measure under the seats). If this requirement is not met, the Payload should be larger than the passenger weight.
- The cargo space should be 0,5 * the original cargo space + 0,3 meters.
- Cargo space should be blinded.
- Payload should at least be 1000kg. As these vans can often handle 1400kg, the weight of the entire interior modification should be less than 400 kg. (This regulation does not apply to electric LCVs, as the fiscal benefits do not outweigh the now existing electric LCV benefits.)
- The partition wall should meet the safety standards of DIN 75410-3 / ISO2956

The partition wall must always be in place during commercial use.

As the product will be developed for the K0 body, the concept is required to fit and function within the dimensions of this platform.

The concept must contain the “must have” functionalities for both commercial and recreational usage.

Aspirations

As Snoeks often delivers their concepts in complete packages that are ready to install (Appendix M, Snoeks Capabilities), the concept should be produced as a ready to install package.
The concept should offer a smooth transition between commercial and recreational usage.

The initial K0 platform that will be used for proof of concept is a Diesel version of the vehicle. There is a strong intention by the designer to make this product applicable to electric versions of this vehicle as well.

The K0 platform is chosen for the first development and prove of concept of this product. The concept should be developed in such way that could also be applied to different K1 platforms.

The concept should fit in both the L2 (regular) and L3 (long) version of this K0 platform, as well as for other platforms within the K1 segment.

The concept should allow sleeping possibilities for at three - four people.

The concept should have as little as possible modular components that require storage outside of the vehicle. It is undesirable for users to store many components at home.

The concept should align with the current market and production capabilities of Snoeks Automotive for faster integration.

The concept should offer a comfortable experience to the user in both commercial and recreative usage. The commercial usage comfort will have priority over the recreational comfort.

The concept should offer the ability to install additional features like the “nice to have” and "could have" features (that can be found in chapter 1.6 functionalities) in the vehicle to personalize the product and increase the viability and desirability.

2 Ideation Phase

During the ideation phase, several different design tools have been used. Apart from the general sketching, Virtual Reality has been applied to try out certain ideas within the confined LCV interior space (figure 2.0.1). A CAD boundary box was created and imported into VR to create a good three-dimensional understanding of the workable space and its possibilities. Other possibilities have been tested using cardboard mock-ups in a so called “body in white”, the metal frame of he vehicle. For the sketching phase, pictures and realistic renderings of the K0 LCV’s have been used to serve as a template in which initial ideas have been drawn. It should be noted that this method is not an accurate representation of reality. It serves the ideation purposes, but the generated ideas would have to be verified on their feasibility before they can be seen as potential concepts or concept directions.

A Morphological chart (figure 2.0.2) was created to combine certain sub functions into possible solutions. These outcomes have been analysed and judged by the design challenges and criteria. The following sub functions were derived from the criteria and must have functionalities; support five passengers, support sleeping, support storage, opening partition wall, transition to recreative usage, support additional elements.

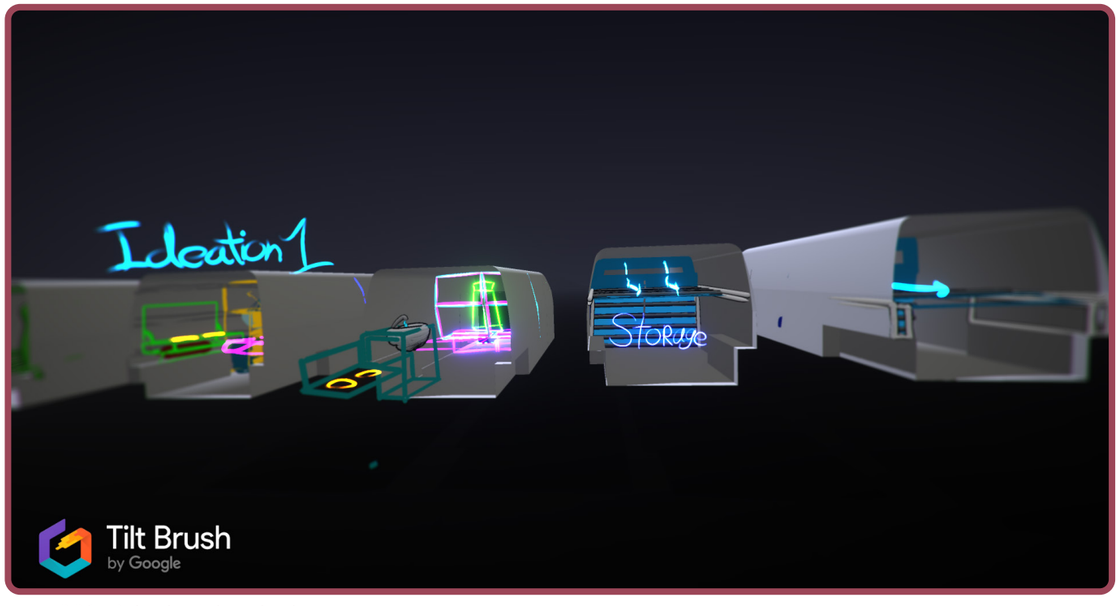


Figure 2.0.1 VR sketches in boundary boxes

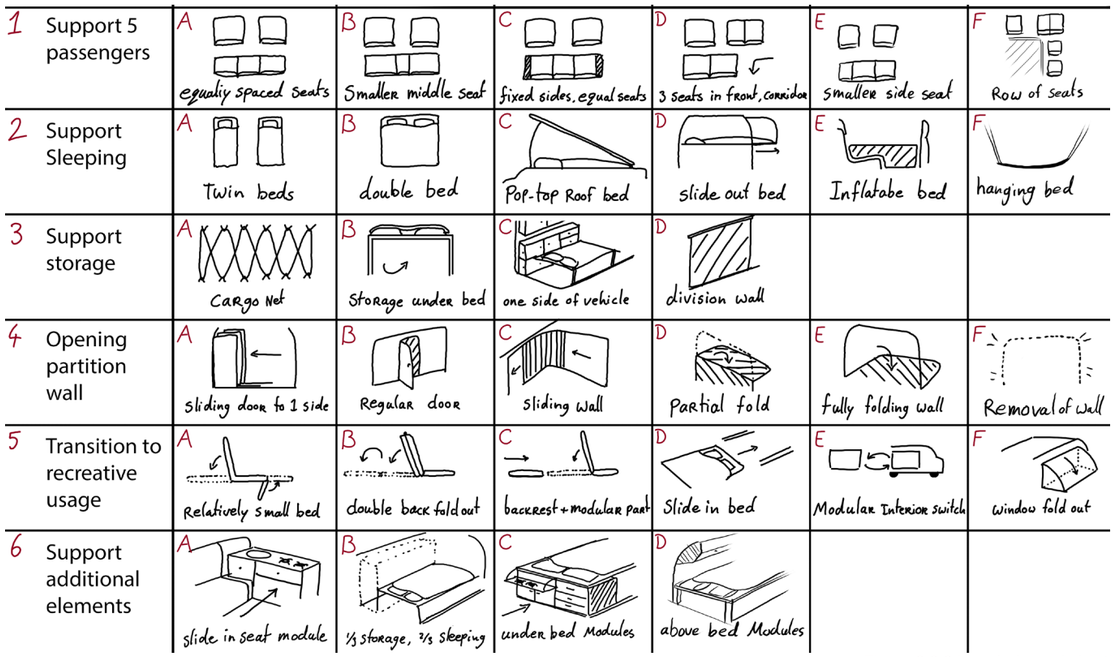


Figure 2.0.2 Morphological chart

2.1 Idea Directions

With the usage of the Morphological Chart, multiple ideas have been created. Some of these ideas have been used as a basis for a new idea with an additional feature or functionality. The combinations that were used can be seen in Appendix N.

The generated ideas have been clustered into 11 different idea directions, as can be seen by the names in figure 2.1.1. Each direction has their own pros and cons. A complete list with a small explanation for each idea direction and their expected pros and cons can be found in Appendix N.

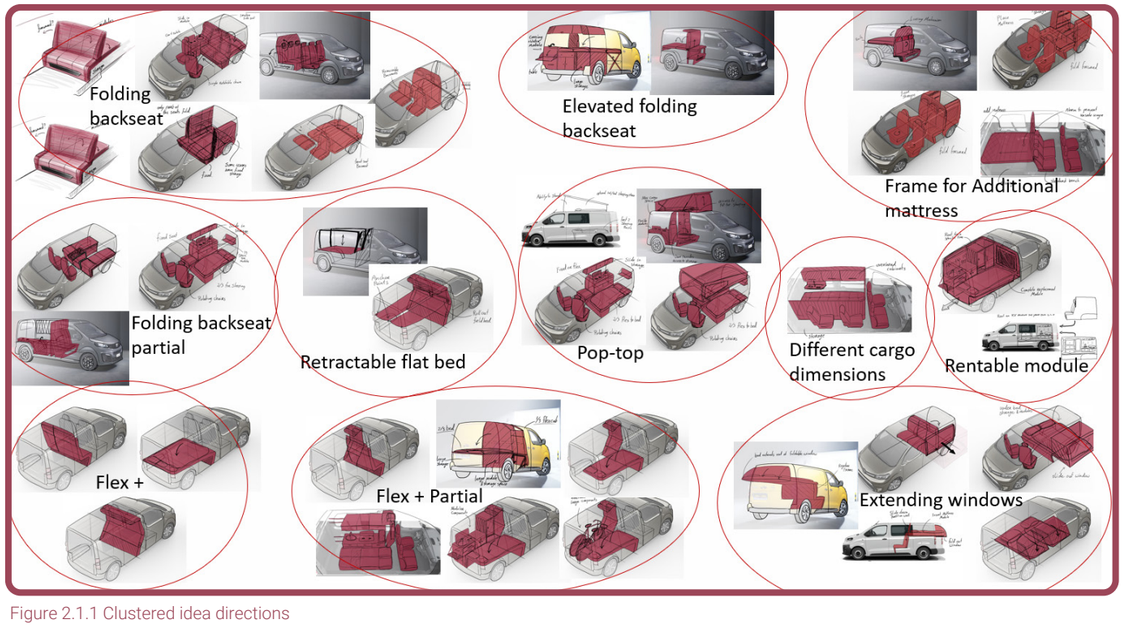


Figure 2.1.1 Clustered idea directions

The idea directions have been analysed with the usage of a Harris Profile based on their expected outcome compared to the criteria and aspirations. By placing the profiles side by side, it was clearly visible which ideas have the biggest potential. The complete Harris profiles and the used criteria can be found in Appendix O. The aspirations are ranked in order of importance based on previous research and internal conversations within the R&D department. In this ranking the company, customers, production, conversion stations, dealers and OEMs were considered as stakeholders.

The six idea directions that came out best have been compared to each other using another Harris Profile (Figure 2.1.2). It should be noted that the Harris Profile has been applied according to the Delft Design Guide. This is a bit different than the original method. Rather than giving exact criteria to determine the point system, an estimation has been made for each idea. This analysis is not very accurate but creates enough information to determine which idea directions have the highest potential. Within these six remaining concepts, four directions clearly show a better score.

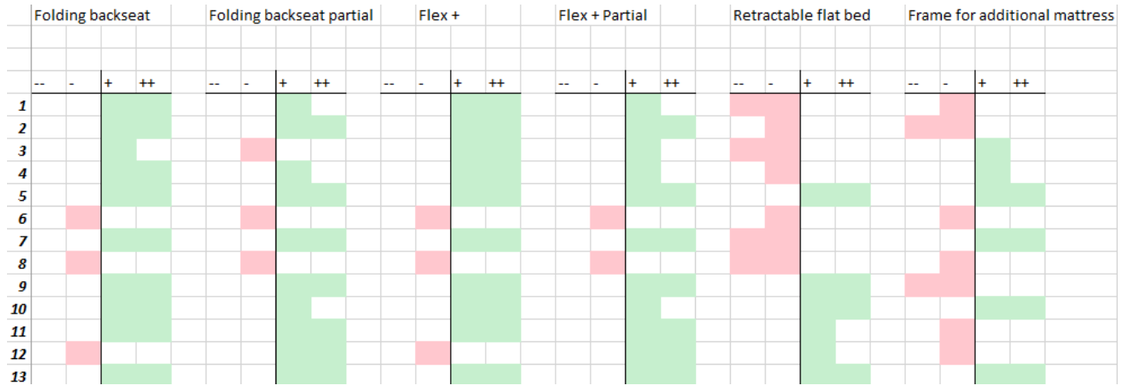


Figure 2.1.2 Harris profiles of the six best idea directions

Main Takeaways

Several design tools, a morphological chart and Harris-Profile evaluations were used to derive a selection of potential idea directions.

the best scoring idea directions were the Folding backseat, the Flex cab +, the Folding backseat partial and the Flex cab + partial.

2.2 Most Viable Idea Directions

After analysing the idea directions, the most promising directions that came out were the Folding backseat (figure 2.2.1), Flex cab + (figure 2.2.2), Folding backseat partial & Flex cab + partial. (Figure 2.2.3)

It was found that these idea directions can be seen as intensifications of each other. Each direction adds possible functionalities but comes with a more complex and possibly expensive system that requires additional development.

Making a choice in which direction to pursue here was difficult, as customer desirability is still an unsure factor. Therefore, it is difficult to predict the viability of these directions as it is uncertain if extra functionalities are worth the additional testing and development costs. Will the more complex systems reach a larger target market that makes it worth the additional investment?

Due to the uncertain customer desirability, using the MVP (Minimum Viable Product) method is a recommend choice for Snoeks. Bring a product on the market that still has the high standards that Snoeks Automotive strives for but has the minimal amount of added complexity. This can then be used to measure market interest and customer desirability, which could potentially lead to Snoeks expanding within this market direction. This can be done in forms of trim levels, different platforms, larger LCV segments or even an OEM market focus.

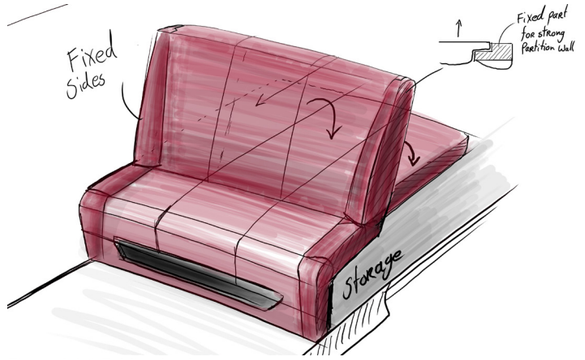


Figure 2.2.1 Folding backseat

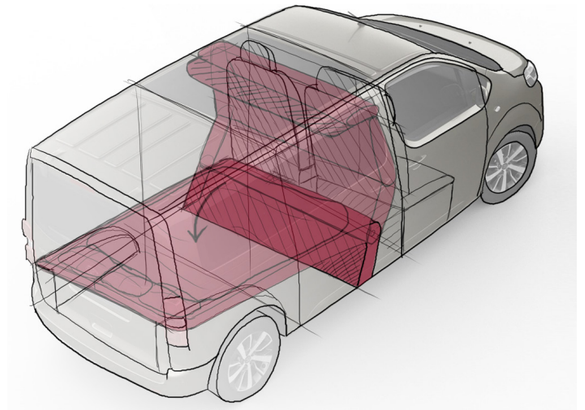


Figure 2.2.2 Flex cab +

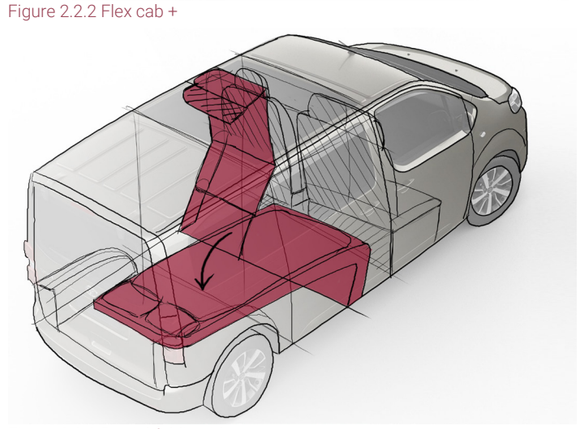


Figure 2.2.3 Partial folding ideas

Important insights

The best scoring ideas directions can be seen as intensifications of each other.

A consideration had to be made between added complexity and added functionality

2.3 Chosen Idea Direction

The Flex cab + is seen as the MVP for Snoeks to place a new product on the market with added value, without taking too much of a risk. The choice for the Flex cab + is mainly based on its functionalities. This idea has the basic functionality of additional passenger seats, like Snoeks most successful product; the crew cab. On top of that it uses the additional functionality of the Snoeks flex cab, the ability to flex the seat forwards, increasing the usable cargo space. The idea then builds on by adding recreational functionalities to the product as well. For the recreation part the product offers the ability to sleep in the vehicle. The three possible positions can be seen in figure 2.3.1.

This idea is an extension of Snoeks current Flex cab. By using the same principle but adding the ability to sleep, the product matches with their current market capabilities while also attracting a potential new market for people that are interested in an LCV/RV hybrid.

Snoeks has its roots in the after-fit market. They started out as a conversion company and later started focussing on OEM's as well. Even though most sales go through OEM's, the After-fit market is an important market for Snoeks to evaluate their customer desire and validate their concepts. The success that they make within the After-fit market plays a significant role in the persuasion of deals with their OEM clients.

Snoeks currently doesn't have a Flex cab on the After-fit market yet. At the same time there are already several competitors that do offer flex modifications for this market. For Snoeks to enter this market, a clear USP could strengthen their chances of becoming successful in this market as well. With the Flex +, a whole new product can be launched in this market with both commercial and recreational benefits, therefore increasing the viability and desirability.

This product can be used to prove the desirability of a concept with these features/functions. If the product turns out to be a success, they can apply multiple trim levels for optimal user experience and use those results to eventually reach out to OEMs for direct implementation. If that turns out successful, they can consider developing a partial version of the flex cab and reach out to different target markets like customers that have multi-day jobs or those who need to take a break during or after a long workday.

Main Takeaway

The Flex cab + is the chosen concept direction as it offers both an improved commercial and recreational features compared to the crewcab. This creates a unique product to introduce in the After-fit market. If the product becomes a success, the product can be expanded with different trim levels and possibly be implemented directly by OEM's.

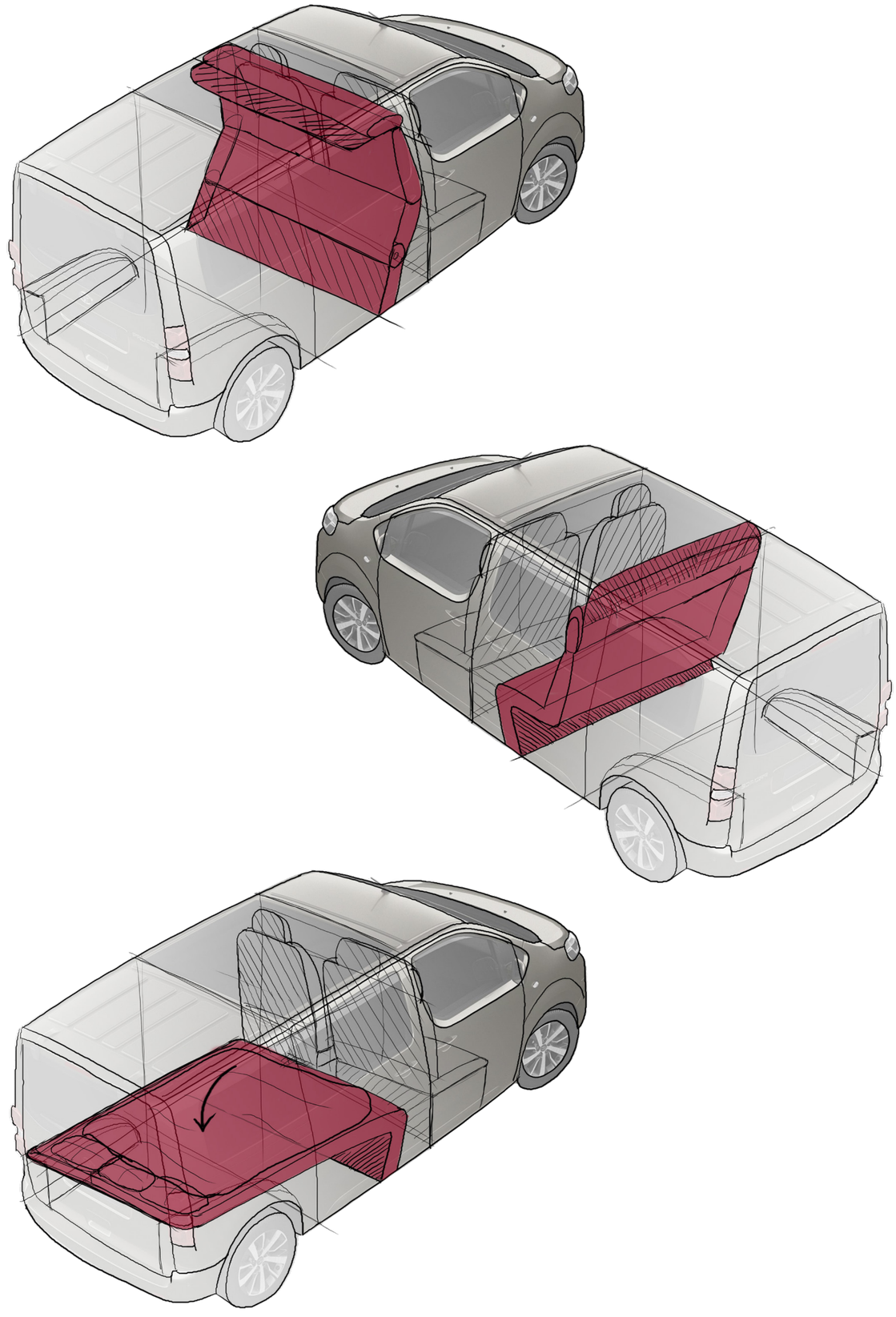


Figure 2.3.1 Three positions of the Flex cab +

3 Verifying Idea Feasibility

To verify if this idea direction can be a concept direction, cardboard mock-ups were used in a physical K0 body to evaluate if this idea could actually be created and how it would fit in the vehicle (figure 3.0.1). An existing K0 fixed double cabin, K0 flex cab and an older flex prototype were used in combination with the cardboard to evaluate the positioning and folding and to make the dimensions as accurate as possible.

As was found in the earlier research phases, due to the complexity of the target group, the most important task to make this potential concept viable is to offer a few basic recreative functionalities. The seating and storage functionalities are mostly covered for with the commercial functionalities, so the most critical aspect that needs to be proven is the ability to sleep in the vehicle. Sleeping is seen as an absolute must have to offer an LCV/RV hybrid product. Some of the most critical elements that therefore needed to be verified to turn this idea direction into a potential concept direction were the achievable length and comfort of the bed and the mechanical functioning of the system.
In the following chapters, these elements will be analysed, and the creative process will be explained. In figure 3.0.2, a schematic overview indicates how this process was executed. The following chapters will have marked indicators to make it clear which elements are being accessed.

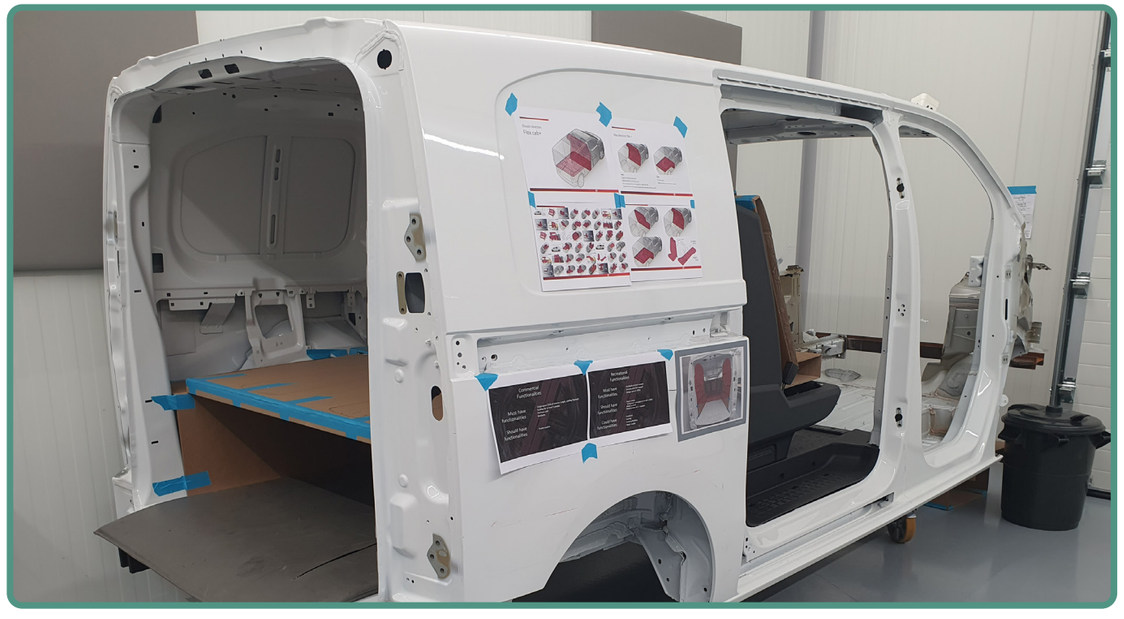


Figure 3.0.1 The K0 body that was used for verification

Idea Verification Structural Overview

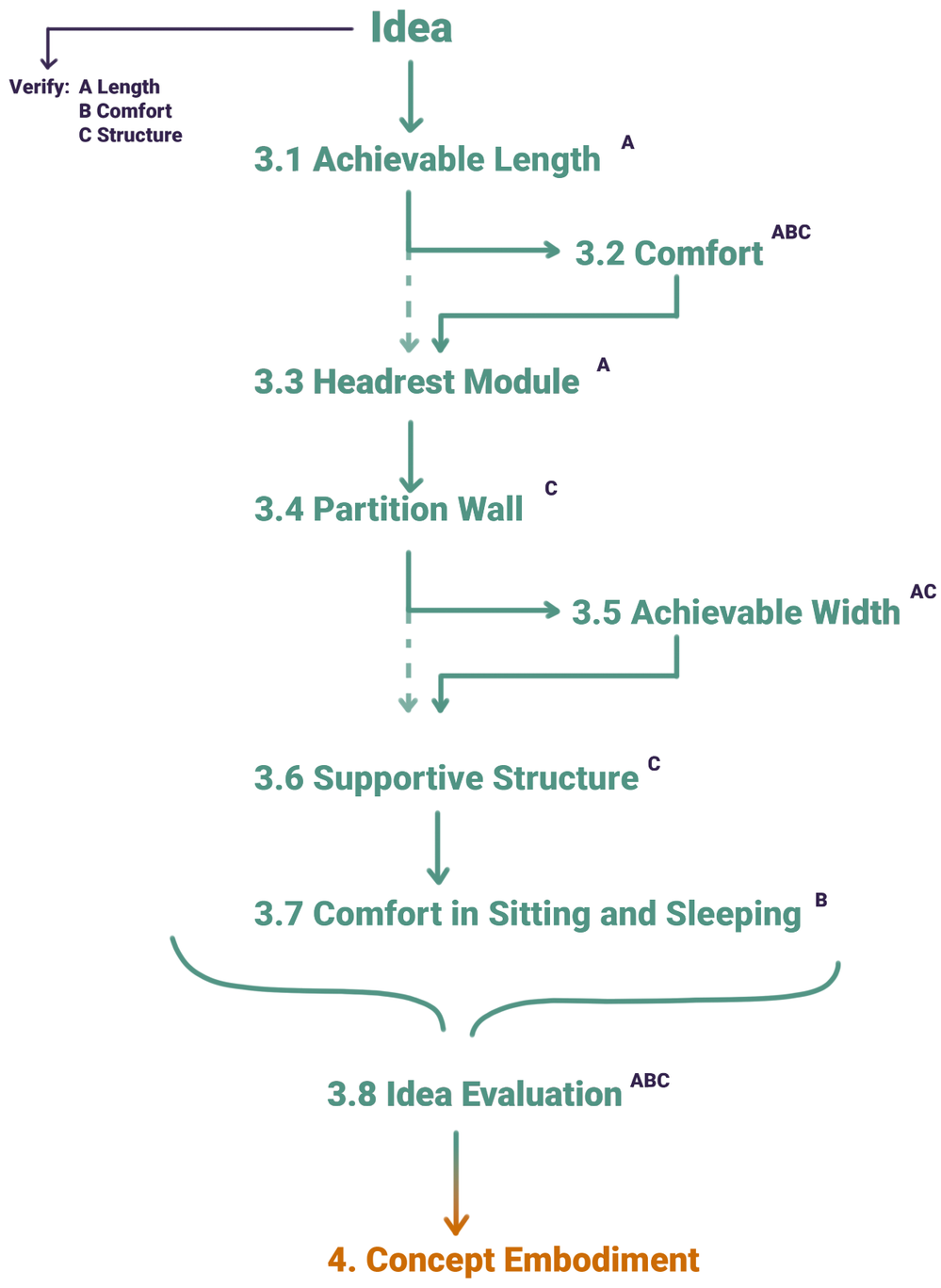


Figure 3.0.2 Schematic overview of the idea verificiation

3.1 Achievable Length

The achievable length is an important element that was found during the ideation phase. The length of the sleeping space is a critical factor when it comes to offering the sleeping functionality. As the length in the back of the vehicle is limited, sleeping solutions had to include the space where the backseats are located. Other attempts to achieve this length did not prove to be successful when analysed with the criteria and aspirations.

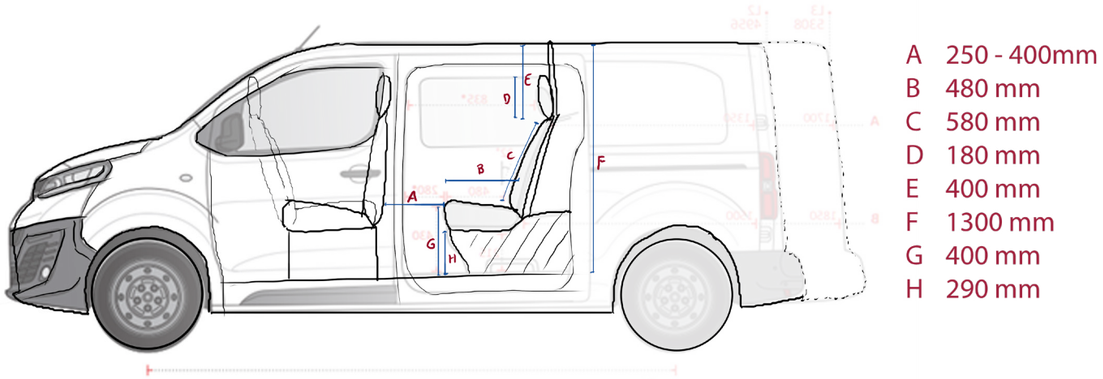
Generally, in Europe, the average double bed size is 135 x 200 cm. In the UK, the average length is around 191 cm, in Germany 200 cm and in France 190cm, with the 200 cm becoming increasingly popular (Sizechart, N.D). As many RV's mattresses are also around 190 cm (Sleepfoundation, 2022), this will be seen as an acceptable minimal dimension.

After measuring internal dimensions as can be seen in figure 3.1.1, it was found that a certain complexity within the system is required to achieve a comfortable length to sleep.
The length cannot be achieved by only folding the backseat down. In most RV's the folding bench contained either a thick double back or an additional fixed cushion installed at the back of the van.

Rather than adding an extra module or an externally kept mattress, it is desired to develop an integrated system so a place to sleep can always be created without the need to sacrifice cargo space or to store large modules at home. the only integrated solution to achieve a comfortable mattress length is to implement a double component. This can be done using either the backrest or the seating.

Using cardboard mock-ups, possible configurations have been evaluated within the vehicle to see if they can fit properly. Several configurations that were considered can be found in Appendix P.

To pick the best configuration for this idea, the comfort first had to be considered.



A 250 - 400mm
B 480 mm
C 580 mm
D 180 mm
E 400 mm
F 1300 mm
G 400 mm
H 290 mm

Figure 3.1.1 Internal dimensions of the K0

Main Takeaway

A certain complexity within the configuration is required to create a fully integrated product that can reach a comfortable bed length of at least 190 cm long.

3.2 Comfort

The comfort for sitting and sleeping is another critical element. Often a concession is made between these two as seating and laying down both require a different type of comfort and support. For sleeping, the surface should be flat and quite soft, whereas a car seat is often sturdier and has some organic shapes to increase the seating ergonomics. These shapes are also referred to as bolsters (see figure 3.2.1). It is desirable to include these bolsters in the concept, as they offer great comfort and support when driving through curves.

Figure 3.2.1 Bolsters in the backseat

Most folding beds in RV's have almost no bolsters in the seats, as can be seen in Appendix Q. This results in a flat sleeping surface, but the seating experience is less comfortable. As commercial usage is the main reason for customer to buy the vehicle, the comfort of the seats is considered more important.
The seating functionality is also expected to be used more often than the sleeping functionality. The seats should have some kind of bolsters or different padding to create a comfortable travel experience. Ideally these bolsters should not be felt when the user tries to sleep on the bed as this could results in an uncomfortable sleeping experience. Several possible bolster configurations have been evaluated and can be found in Appendix Q.

It was found that comfortable sitting and sleeping could be achieved if the backrest could be flipped. As the earlier configuration options showed the need of a double component, the double backrest became the chosen configuration. By folding down the backrest and then folding the double back cushion, the bolsters will be on the bottom side of the cushion and a flat sleeping surface is created, as can be seen in figure 3.2.2.

For the seat, the same surface will be used for both sitting and sleeping. By placing the seat in a declining angle, passengers are still being held in their seat and the bolsters in the backrest can offer them their seating comfort.
A different type of stitching or fabric pattern can be applied to create an optical illusion. This is often done in RV's and helps to create a feeling of comfort, even if the surface is in fact flat.

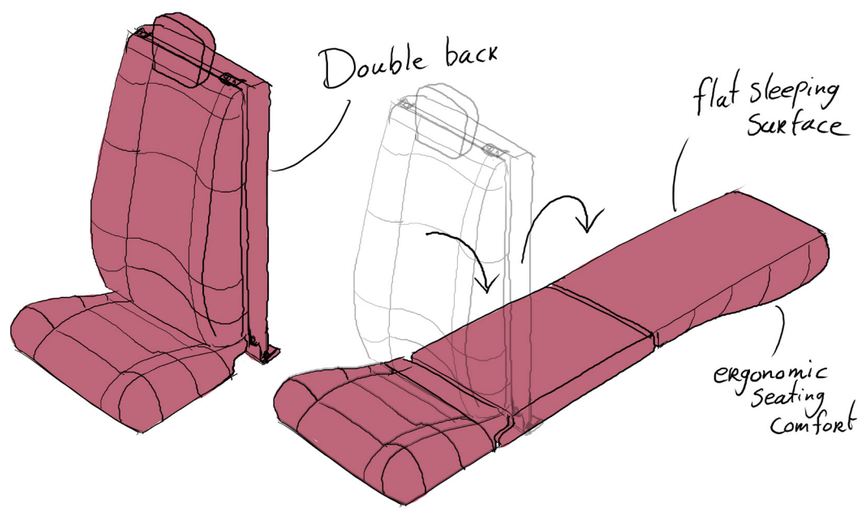


Figure 3.2.2 Double back folding

Comfort in configuration

By creating a negative bolster shape in the supportive frame, the bolsters could fall into place and will not interfere with the flat surface of the rest of the cushion. This creates a flat surface with equal supports, increasing the sleeping comfort. (Figure 3.2.3 and 3.2.4)

As the fixed backrest needs to align with the seat after folding, the foldable cushion should be placed in front of the current backrest. This means that the sitting depth is reduced by the thickness of the folding backrest (as seen in figure 3.2.5). The seat should be extended by this same thickness to provide a comfortable seating dept.

This results in a longer seat length when the bed is folded out, which is beneficial in order to achieve the desired bed length. It should be considered when calculating the rotation points.

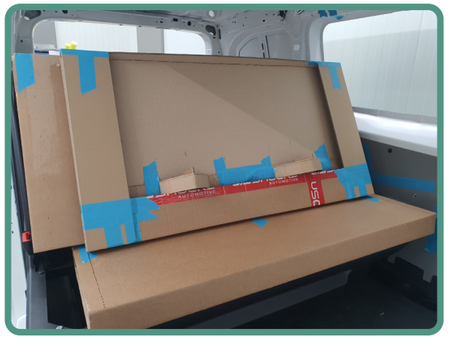


Figure 3.2.3 the backrest with bolsters

Figure 3.2.4 folded out backrest

Figure 3.2.5 Increased backrest thickness due to double back

Main Takeaways

The combination of comfort for both seating and sleeping is difficult and often comes with concessions. For this project, the bolsters will be integrated in a double backrest. When folded backwards into a support frame, the surface becomes flat. The seat will not contain large bolsters in the middle, but an optical pattern will be implemented to indicate comfort.

The seat will also be positioned under an angle, so the support is provided by the bolsters of the backseat.

3.3 Headrest Module

To create an optimal configuration, an additional part of around 20 cm should be added to the current seat and double backrest configuration. It was observed that a large part of the available space above the backrest of an LCV is not used for either commercial or recreational purposes. Classic headrests are now always separate small headrests, but these may be replaced with one long cushion (as is confirmed by the homologation department).

By replacing the individual headrests for one modular block that could also be positioned in front of the backseat, the additional required length of the bed could be created.

Using an old flex prototype with a slightly different mechanism than the K0 flex, it was found that that the product could be flexed forward while remaining enough space above the backrest to fit the headrests in a straight up position. (As can be seen in figure 3.3.1.) This proves the feasibility of a modular headrest

The modular headrest will be optimised to the dimensions of the available space. This will be done after the functional mechanism and rotation points are determined. The module will still match the headrest safety regulations. The configuration of the rotation points will be discussed in chapter 4.4, working principle.

Conclusion

By creating a continous, modular headrest, a final extension of the bed can be made.
The modular headrest will be used in the configuration of the bed and makes it possible to achieve a bed length of >190 cm.

Figure 3.3.1 Flexed forward position with headrest

3.4 Partition Wall

If the partition wall is connected to the rooftop, the motion freedom is limited and there is practically no available space left above the backrest as the headrest module will most likely have to fold. An attachment to the roof would also be inconvenient in case the user wants to install a pop-top roof on the vehicle.

The chosen length configuration uses a double back in order to achieve a comfortable bed length. The initial thought was that an internal frame could be used to support both parts. This proved to be difficult because the required construction would need to be much thicker as the backrest for seating and the folded backrest for sleeping could not share the same foam (see figure 3.4.1). This would create an undesirably thick backrest that is both aesthetically unpleasing and takes up a significant amount of cargo space.

This configuration could however work if the front cushion of the backrest did not contain a frame but is only stitched to the back cushion of the backrest. It would need to be supported by an additional frame at the back of the LCV.

For this product it is recommended to attach the partition wall to the back of the bench frame using sliders and an actuator, as can be seen in figure 3.4.2. This allows the partition wall to slide in a straight line, parallel to the bench frame.

With this sliding ability the partition wall can provide safety in the seating and flexed position, as can be seen in figure 3.4.3.

For the sleeping position, the partition wall can function as the structural frame that supports the folded backrest cushion, as seen in figure 3.4.4.

The partition wall must be tested to confirm that all safety regulations are met. As the wall is only connected to the bench frame and the entire module is only connected to the floor, this is a crucial element to investigate. If required, a locking mechanism could be added at the top of the partition wall for a structural connection to the roof or sides of the vehicle. This connection can be disabled when the bench is transformed into a bed.

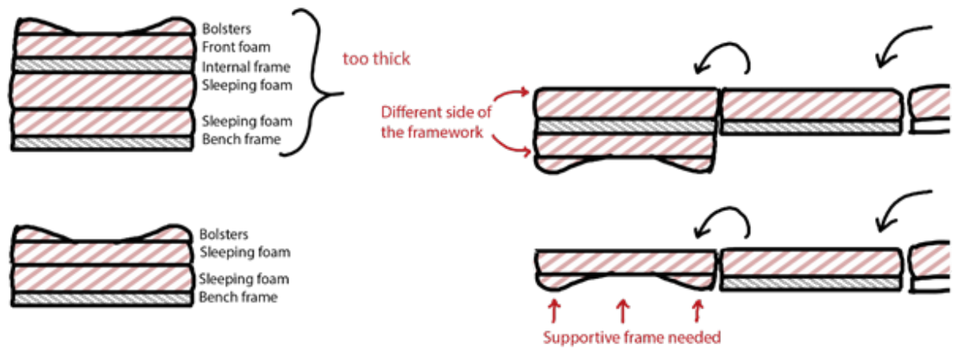


Figure 3.4.1 Foam configuration with and without internal frame

Main Takeaways

The partition wall will be attached directly to the back of the frame and move simultaneously with the rest of the system.

The partition wall can be used to support the double cushion in the back of the vehicle.

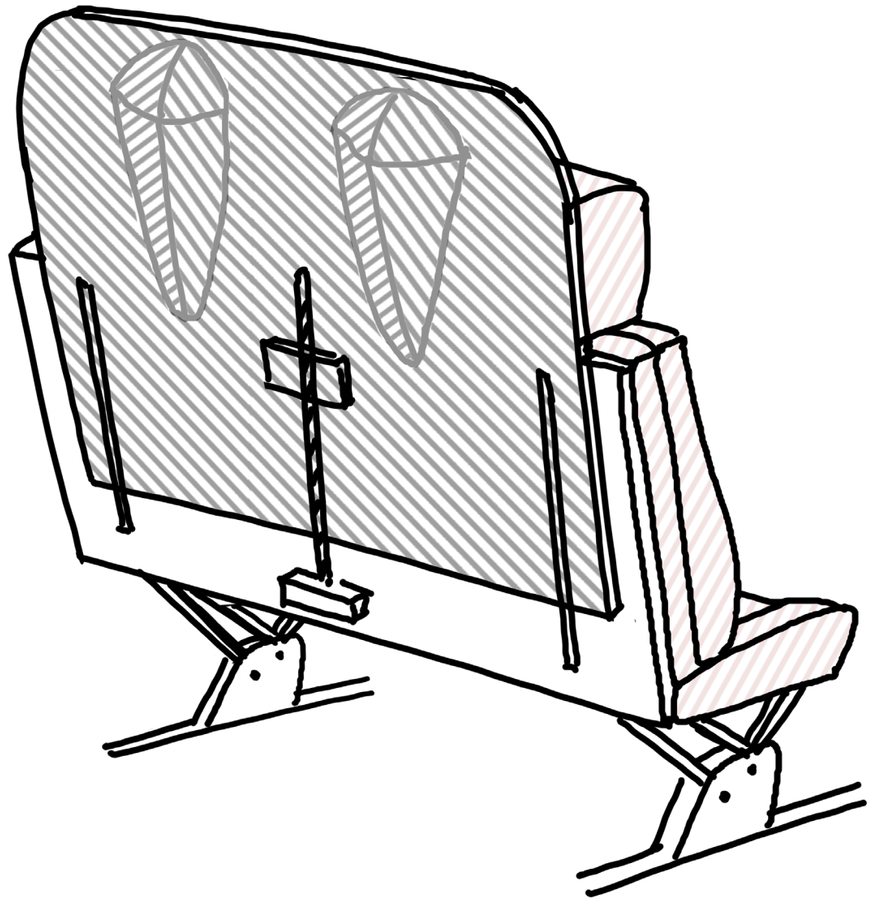


Figure 3.4.2 Partition wall attached to the back of the backrest

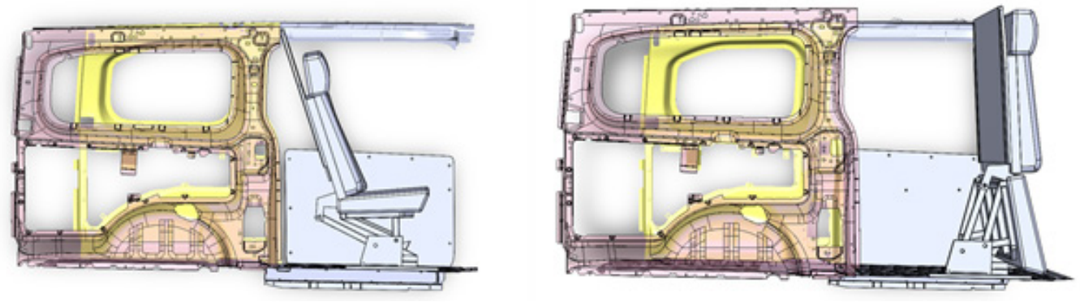


Figure 3.4.3 Safe partition of cargo and passengers in seating and flexed forward position

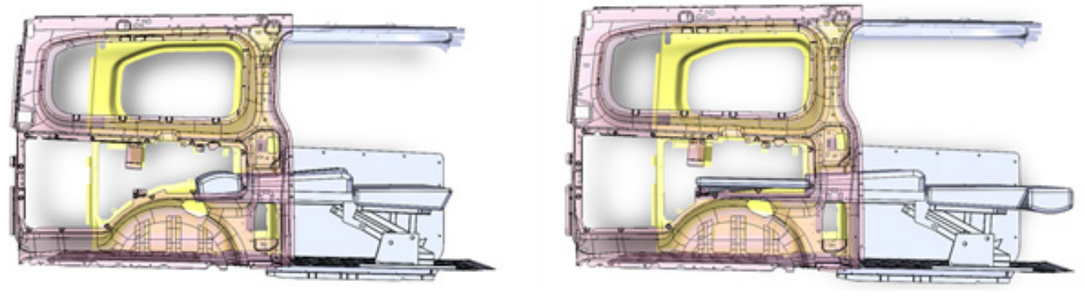


Figure 3.4.4 Partition wall as supportive frame

3.5 Achievable Width

Now that the length configuration has been determined, it is time to specify which width could be achieved using this configuration. There are several factors that play a role when it comes to the achievable width of the bench and bed. These factors can be seen in figure 3.5.1.

Apart from the general safety regulations, the dimensions play an important part. The wheelbase has a certain radius and the height at which the bed is located is dependent on the mechanism and rotation points. The main dimensions that must be considered can be seen in figure 3.5.2.

The chosen dimension for the frame width is 1440mm as it covers the largest amount of usable space while still being able to fold backwards as a whole. The double back and the headrest will be made 1340mm in width, due to the tapering shape of the vehicle and some difficulties with the seatbelts, as they could interfere with the folding ability of the double backrest cushion.

The seatbelts will be attached to the side of the bench frame, and the middle seatbelt will contain a double buckle at the top of the bench frame, as can be seen in figure 3.5.3. The detailed reasoning for this seatbelt decision can be found in Appendix R.

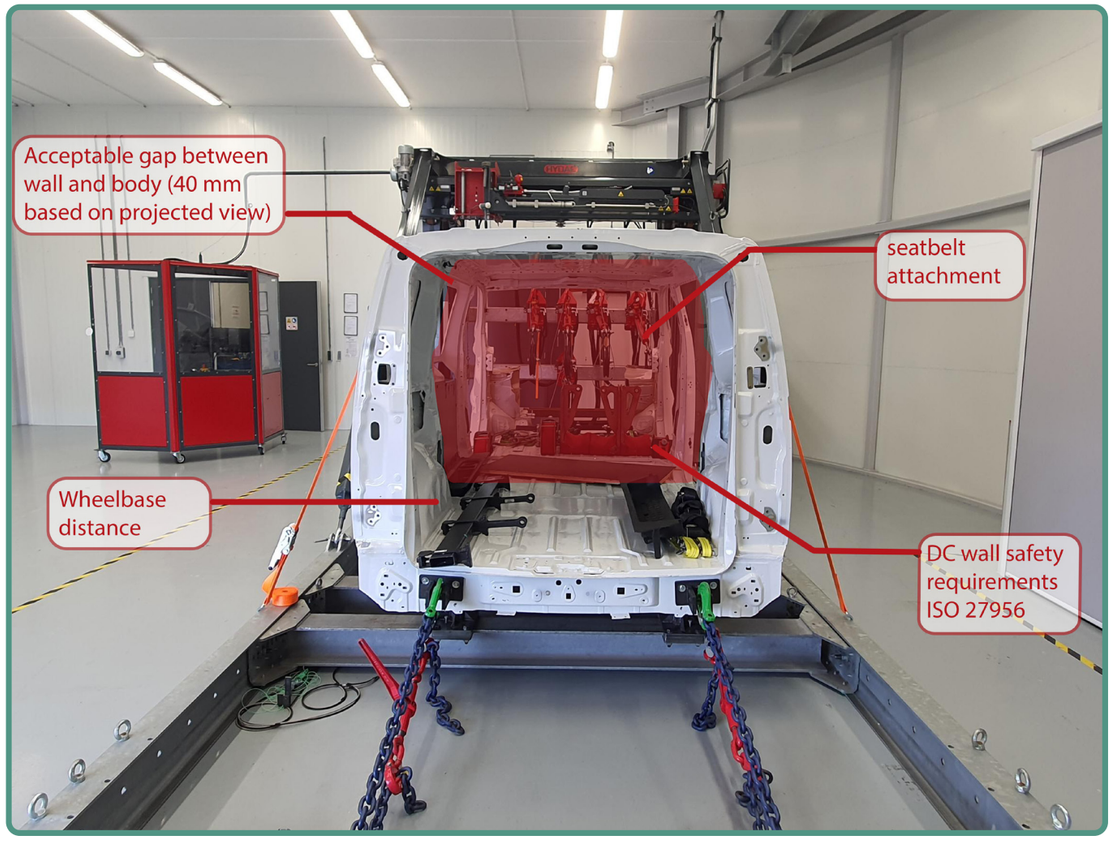


Figure 3.5.1 Factors that influence the achievable width

Figure 3.5.2 Width dimensions in the K0 body

Figure 3.5.3 Seatbelt configuration solution

3.6 Supportive Structure

If the bench folds out into the cargo area of the vehicle, a large force occurs at the back of the structure and some additional support is required to deal with the forces (see figure 3.6.1). In normal conditions it is not unlikely that the users sit at the very back of the bedframe. The structure must be tenable against these kinds of forces.

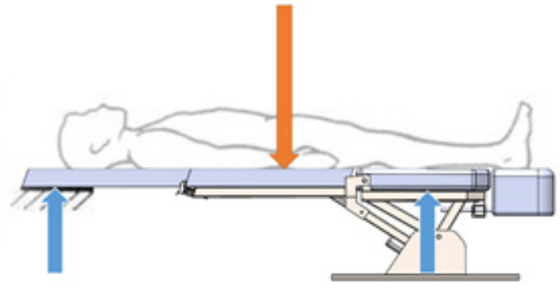


Figure 3.6.1 Forces on the benchframe

A construction can be created around the wheelbase to create a supportive frame that can carry the weight of the folded down backrest, as can be seen in figure 3.6.2. This is done in a way that the frame is supported over the entire length.

The amount of usable cargo space that is reduced by doing this is very limited, as there is only a small amount of relatively unpractical space behind the wheelbase. A small lid could even be created to use that space between the wheelbase and the back of the LCV for smaller storage like tools or toiletries.

The benefit of this construction is that the space above the frame could be used for additional storage for both commercial and recreative storage of smaller items. (As was learned from the space optimization research.) A possible layout can be seen in figure 3.6.3 & 3.6.4.

The configuration of the selves/usable storage space will not be considered during this project, but it is recommended to do some further investigation in the type of shelve space that is currently used in commercial vehicles and which configurations could be desirable for the customers. This could also be offered in the form of an optional trim level.

Main Takeaway

Some support is required to deal with the forces that are put on the product. The best way to do this is to create a framework around the wheelbase. This can be used for possible storage space as well as cabinets can be installed on the sides of the vehicle.

Figure 3.6.2 Structural support over the wheelbase

Figure 3.6.3 Possible commercial layout with the supportive structure and shelves

Figure 3.6.4 Possible recreational layout with the supportive structure and shelves

3.7 Comfort in Sitting and Sleeping

When it comes to the comfort of sitting and sleeping, several factors need to be considered. Some of the most important factors are user weight, usage percentage, progressive pressure bottoming out and foam type/structure.

The weight of the user is a critical factor when it comes to comfort experience. If a user weighs less than 65kg for example, they could experience a seat as very hard, whereas a person above 100kg could experience this same seat as medium-soft.

The usage percentage plays an important factor when it comes to decision making. Especially in an LCV, the seating functionality is likely to be used significantly more than the sleeping functionality. It should be noted that the duration of usage should be considered here as well.

Progressive pressure will play one of the most important factors when seating and sleeping are combined. In sitting position, the user needs significantly more support than when they are laying down. With the basic P = F / A formula, one can determine that the pressure on the sitting area could easily be five times higher as the same force is applied on a much smaller area.

Using progressive pressure, the top layer can support a lower pressure and offer a relatively soft feeling, while the bottom layer could offer enough support to support the sitting pressure without bottoming out. (Bottoming out is what occurs when the foam does not support the pressure and the user practically sits on the floor/supporting surface. It is better to use a foam type that is firmer, then to use soft foam that is uncapable of supporting the pressure).

The density of the foam does not need to be the exact same at every position. This is often done with mattresses as they are supposed to be reversible, but this is not the case for this product. A users back requires more support than its legs. Ergonomically, it is even better for a user to have their feet a bit higher than their back for optimal blood flow. (C. Nederhorst, 2022) For this product, that means that the foam of the seating area could be slightly thicker or firmer. Doing so could prevent the foam from bottoming out when the user sits on the chair with the much higher pressure, while still allowing a comfortable sleeping position as the legs require less support.

Comfort versus space consideration

Rather than working with additional modules, it was found that a fully integrated system is desirable so that it would always be possible to transform the seat into a bed. A large consideration to make for an integrated system is comfort versus space. The more compact the system would be the less comfort can be achieved. It was decided that the integrated bed should provide enough comfort to sleep on for one night. If users want to sleep on the bed for several nights in a row, a topper would be advisable for extra comfort (figure 3.7.1). With this decision customers can sleep in their LCV at any time if required, without having their cargo area permanently significantly reduced.

With this configuration in mind and after careful consideration it was found that a 70mm thick HR 65-70 foam layer should be sufficient to offer a decent sleeping experience. Depending on personal preferences and body posture, customers can buy a topper with a thickness that they prefer.

Slightly thinner foam or foam with a softer HR could be assessed during the development stage to see if this would be acceptable, as it could decrease the thickness of and cost of the backrest.
Using cut-ins in the foam, progressive pressure can be increased. This means that the sleeping comfort could feel slightly softer, without the risk of bottoming out in the seating position.

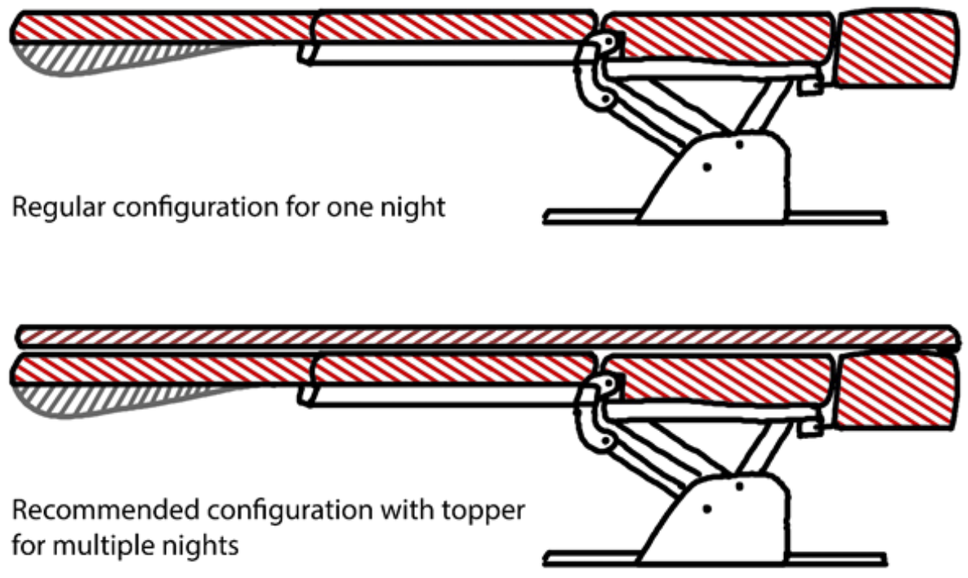


Figure 3.7.1 Configuration with and without topper mattress

Important Insights

The best way to combine seating and sleeping is to use progressive pressure.

As every user has different preferences and the product should be as compact as possible, a base version of 70mm thick foam will be used to offer one night of decent sleep. A topper mattress is recommended for longer trips or to adapt the bed to a customer's personal preference.

3.8 Idea Evaluation

Before the verification of this idea it was determined that the sleeping functionality was the most critical aspect that had to be verified in order to turn this idea into an actual concept. Now that the configuration has been determined and the general comfort and dimensions have been worked out, it was time to re-evaluate the idea using the refined criteria and aspirations.

Overall, the idea was expected to successfully meet all these criteria and most of the aspirations, as can be seen in the evaluation in figure 3.8.1.

The green coloured cells are expected to be achievable in theory. The two yellow cells are uncertain factors that need to be verified. For the safety standards it is expected that there are possible solutions to make the concept strong enough in case the initial idea does not match this criteria. The 51% cargo space regulation for the German fiscal regulation might not be achievable, but according to the Homologation department, it is also acceptable to match the regulation where the possible cargo payload is higher than the possible passengers weight total. Matching this requirement still allows the vehicle to be used for commercial purposes, but gives a slightly less beneficial fiscal benefit. As it was found that this is the case in every K1 medium LCV and the fiscal benefits for this specific regulation in Germany are not that large, this is seen as acceptable.

Some aspirations are only achievable with certain additions like the optional pop-top roof. These aspirations can be achieved with certain trim levels. It will be up to the customer to decide if the additional cost is worth the additional comfort.

After a successful evaluation, the theoretical feasibility of this idea is confirmed. The idea matches the criteria, and the comfort, configuration and structure are theoretically possible. and the idea will now be referred to as concept. On concept level however, there are certain aspects that need to be proven before it is possible to claim the feasibility of the product itself.

For the ability to sleep it is now proven that a theoretical length and width can be achieved. The next step is to create a mechanism (that meets al safety requirements) that is capable to transform a seat into a flat sleeping surface. The aspiration of the smooth transition between the seating and sleeping functionality should also still be assessed.

In the next stage of this project several aspects will be evaluated on concept level. As the product is too complex to verify all aspects within the timeframe of this project, a list will be created to determined which parts will be verified during the project and which parts will be suggested as recommendation for future research and development.

	Criteria (are the ideas expected to meet the criteria?)	Criteria elaboration	Can this be achieved (in theory)
1	**Usable for commercial and Recreative**		
2	**LCV registration**	**EU fiscal regulations**	
3		**EU safety regulations**	
4	Cargo space fiscal regulations	Cargo space 51% of length	
5		cargo space 0.5 * original length + 0.3m	
6		Blinded cargo space	
7		must weight less than 400 kg	
8	partition wall safety standards	max gap size of 40mm in projected view	
9		ISO27956	
10	Benchframe safety standards	Ability to hold forces safety test (30kN)	
11		Seatbelt safety configuration	
12	Partition wall in place during commercial usage		
13	fit within K0 dimensions		
14	seating for at least 5 people		
15	sleeping possibility for at least 2 persons	Achievable length > 190cm	
16		Achievable width > 120cm	
17		Achievable comfort	
	Aspirations (Are the ideas expected to fulfill the aspirations?)		
1	Deliverable in ready to install package		
2	Smooth transition between commercial and recreational usage		
3	Comfortable experience in recreational and commercial usage	Seating comfort	
4		Sleeping comfort	
5	Align with current market capabilities of Snoeks		
6	Applicable on different K1 platforms		
7	Ability to stand in the vehicle		
8	"livingroom" area	Rotating chairs	
9		table	
10	Allow sleeping for 3-4 people	Pop-top installation	
11	Small amount of modular components that require external storage		
12	Applicable on electric vehicles		
13	Applicable in both the L2 and L3 version of the K0		
14	Power outlets		
15	Ability to install "could have" modules / features	Insulation	
16		Heating	
17		Cooking facilities	
18		Water supply	
19	Align with current production capabilities of Snoeks		

Figure 3.8.1 Idea evaluation using refined criteria and aspirations

Main Takeaways

After evaluating the idea with the refined criteria and aspirations, the theoretical feasibility of this idea is now confirmed.

Integrating all functionalities within this project is impossible due to the complexity of the concept and the limited timeframe. Choices must be made for the most essential elements that should be confirmed.

The rest of this research will focus on these essential aspects, and recommendations will be given for the development of other functionalities.

4 Concept Embodiment

In this stage of the project, the concept is worked out into a new level of detail. The complete concept is quite complex and there are many technical difficulties that should be solved before this product can be successfully launched in the market. Some of these issues could make or break the concept or its future development. Due to the limited time of this project, it is not possible to come up with solutions for all these issues. It is important to make choices in which aspects to focus on.

In this chapter, choices have been made for the most essential elements that should be confirmed. These elements have been worked out with a physical prototype (figure 4.0.1) and a final prototype evaluation was used to provide the company with well-considered recommendations. The schematic overview of this chapter can be seen in figure 4.0.2.

Figure 4.0.1 The building of the physical prototype

Concept Embodiment Structural Overview

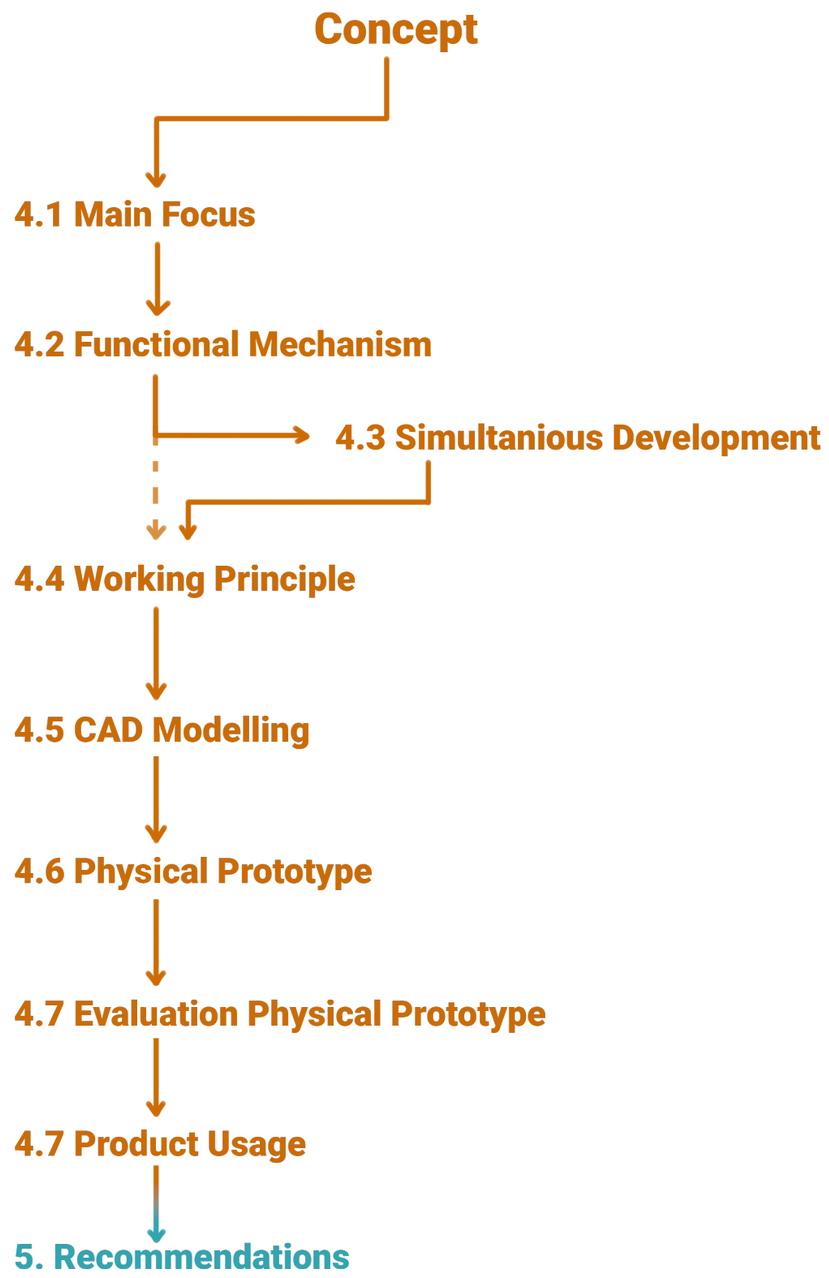


Figure 4.0.2 Schematic overview of the concept embodiment phase

4.1 Main Focus

After meeting with several departments of Snoeks and learning the procedures of the company, it was found that in order to present a convincing project proposal, two key aspects stand out: Visuals and a prototype.

A prototype should prove the concept of the mechanism. Before deciding to invest in a concept direction, it should be clear that the concept is actually feasible.

The focus in this project will be on proving that the benchframe could potentially both flex forward and fold backwards into a full-size bed, without interfering too much with potential commercial usage. If a working prototype for this could be created, the proof of concept is expected to play an important role in convincing the company.

The second most important thing will be good-looking visuals. Whether it is about convincing the company or an OEM, it often starts with a beautiful looking drawing or render of the product to indicate its potential.

This convinces clients of the idea and then the development process is started, after which the modelling will begin. For this project it will be important to make some good-looking visuals that clearly indicate the expected result, its functionalities and potential usage.

These two aspects combined with a clear story of why these functionalities are so important and why this could be a potential success on the market will be the main focus of this project.

This will be followed with a recommendations list of key elements that should be further developed when pursuing the direction, both in terms of technical development and market research. The visuals and prototype could potentially be used to already evaluate the customer desirability with dealers or at conversion stations.

Main Takeaways

In first instance, this project aims to convince the company to pursuit this concept / concept direction and to invest in the further development.

The main focus in this project will be on the mechanical proof of concept, as well as strong visualizations that illustrate the functionalities and the potential usage of the product.

4.2 Functional Mechanism

How exactly should the mechanism work to achieve the three desirable positions; seating, sleeping and flexed forward? How should the framework be built? How should every part be attached and how should each part move exactly?

To determine the answers to these questions, first an old prototype (figure 4.2.1 was used to analyse how exactly the current flex mechanism functions and what could be done to use a similar mechanism to achieve a sleeping position as well.

The main working principle of a flex cab is based on the four rods mechanism. This mechanism connects the seat to the back in a way that the flexed forward position pulls the backrest into an almost vertical line. This configuration allows for the biggest possible cargo space as the backseat is folded into the most optimal achievable position. (See figure 4.2.2).

Figure 4.2.1 The old prototype that was used for first insights

Figure 4.2.2 The additional cargo space that the flex cab enables

Insights current flex prototype

By disassembling the attachment of the back frame to the back rod, the prototype could be placed in an almost flat position. To better understand what happens here, CAD models have been used to analyse the motion.

What was found is that the backrest can be folded backwards by altering the length of the back rod. Figure 4.2.4 shows how shortening the back rod could move the backseat backwards and to a potentially flat position.

Using this knowledge, and opportunity can be found to create the desired positions without altering the basic flex concept too much.

As there are four rotation points and two rods that could be fixed in place, a test was done with a CAD model to see which rod should be fixated in order to create best transition to a flat bed. The transition from backrest to flat surface within motion with one fixed rod can be seen in figure 4.2.5.

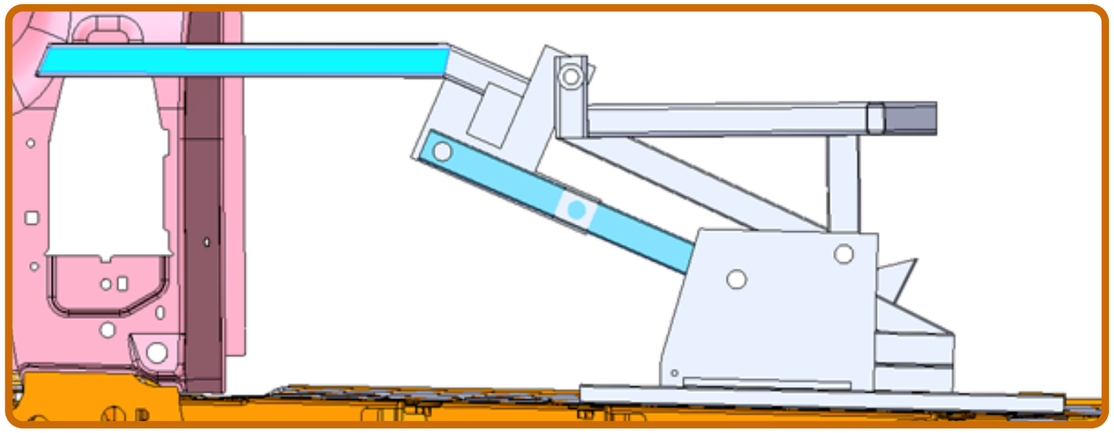


Figure 4.2.4 The backrest folds into a flat position if the backrod becomes shorter

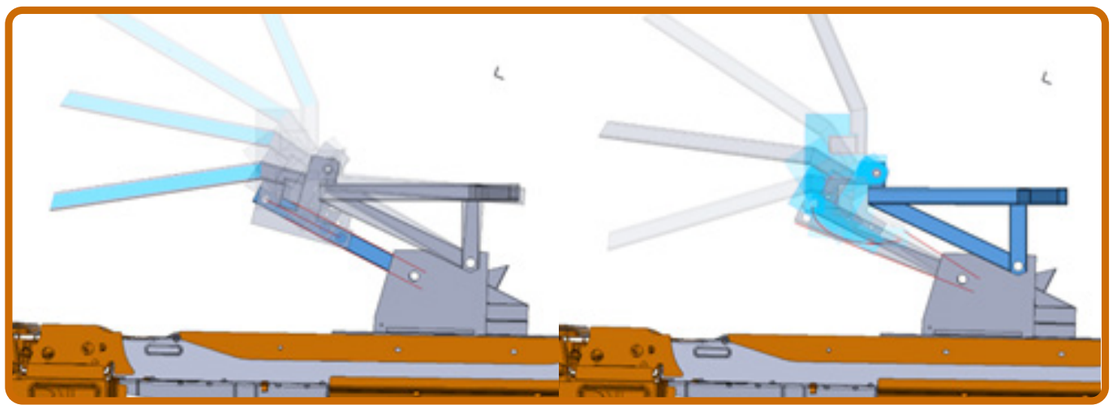


Figure 4.2.5 The most ideal motition can be created by fixing the back rod in place

Keeping the back rod fixed in place moves the seat slightly up and down. In resting position, the seat is still fully supported, and the forces on the actuator can be better contained if the actuator can be locked in place. Simply shortening the back rod in a straight line can result in a flat surface.

An opportunity was found here to plot the rotation points in such a way that the movement of the seat is used to create a flat surface in sleeping position and an inclined surface for the seating position. This way most parts of the regular Flex Cab can remain the same.

Main Takeaway

By fixating the back rod and moving the rotation point in a linear direction, the backrest and seat can be placed in a flat position for sleeping and an inclined position for optimal seating comfort.

4.3 Simultanious Development

During this project it was found that one of the largest issues with this concept remains the cost. The viability and desirability are still unclear as this concept idea reaches for a completely new market. Little is known about the willingness to pay for the ability to sleep in a commercial vehicle. Several comparable ideas can be analysed, but these often do not directly apply for the specific target group.

The focus on a new market could be a great market opportunity, but it also comes with high risks as there are many uncertainties about the demands and aspirations of this new target market. One way to minimize these risks is to create a way in which the development costs of the concept could be reduced as much as possible. It is given that the development costs of the current flex concepts have been well over 1.5 million euros.

As this concept is an even more complex system, it is not unlikely that the development costs could rise to a similar amount if this concept is developed on its own. If this remains the case, it is unlikely that Snoeks will invest in this direction as the risk is simply too high.

Rather than developing this concept on its own, it could be integrated simultaneously with the regular flex concept. By matching the components and taking both functionalities into account, the development costs of the product could be significantly reduced.

During the development of this concept, as much overlap as possible is created between a new flex system and this flex + system that transforms into a sleeping place. The physical prototype will be used to proof that this product could be achieved with relatively small adaptations compared to the regular flex cab, therefore increasing its potential viability.

Important Insight

The development of a Flex cab and this concept can be done simultaneously in order to reduce the development cost, therefore increasing the concept viability.

4.4 Working Principle

Figure 4.4.1 shows the three possible positions that can be achieved within this concept. Where the current flex cab only offers the seating and flexed forward position, this concept can achieve the same positions and also fold backwards into the sleeping position. It was found that the required position for the sleeping functionality could be achieved by shortening the length of the back rod in the current flex mechanism. To do this in a smooth way, a linear actuator is used. The actuator will move the rotation point over a straight line and allows the backrest to fold backwards while slightly lifting the seat to a flat surface. These positions can be seen in figure 4.4.2.

For the mechanism to work properly, the rotation points had to be repositioned. The way these rotation points were determined to achieve the desired positions can be found in Appendix S.

All three positions can be achieved by using the same kind of system that is used for a regular flex product but with an additional actuator and sliding slot in the back rod. This back rod is still required as the actuator cannot fully replace the back rod. The forces that would be applied on the actuator during usage or during a potential crash would be too large for the actuator to be safe. Therefore, a rectangular tube should still be applied.

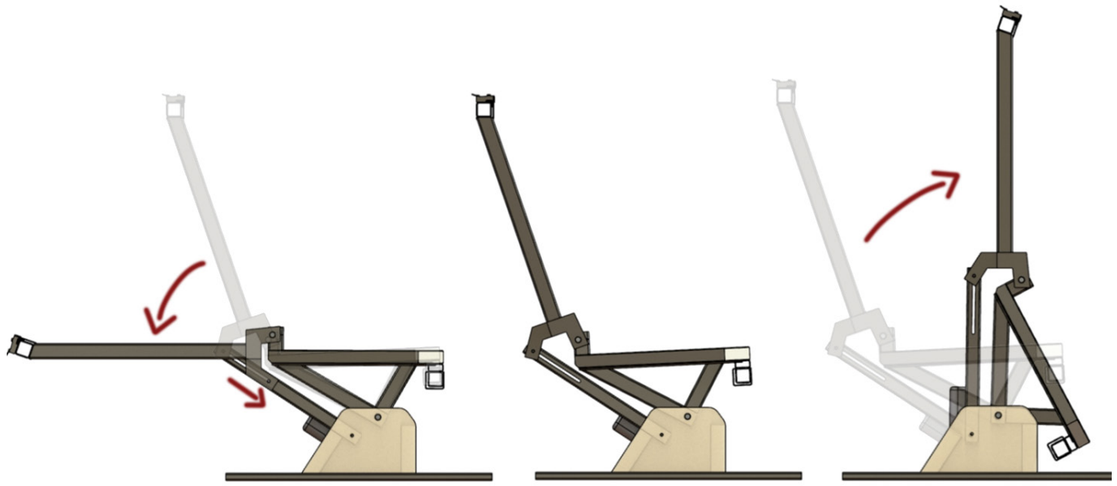


Figure 4.4.1 The three positions; sleeping, sitting and flexed forward

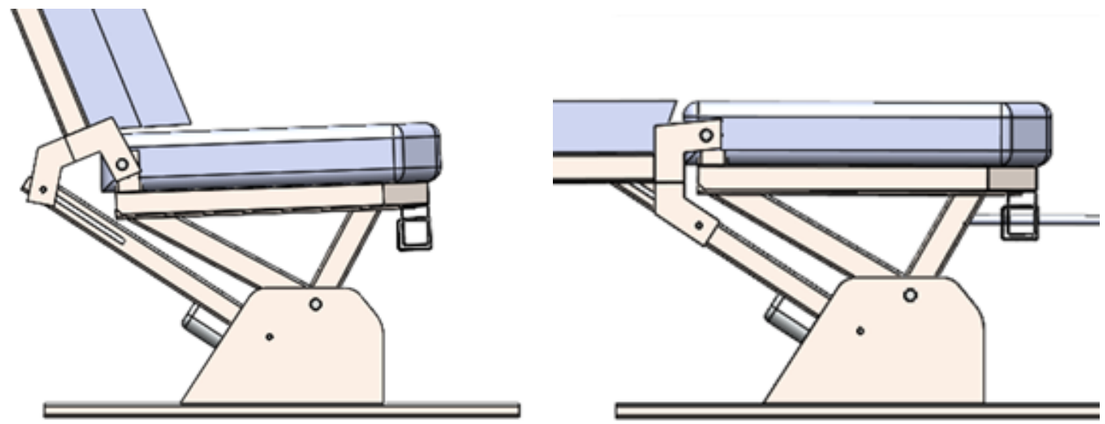


Figure 4.4.2. Folding the backrest down slightly lifts the seat to a flat surface

A slot will be created inside the rectangular tube, and the actuator will be mounted next to this slot, as seen in figure 4.4.3.

The actuator will slide the rotation point within the slot from the seating to sleeping position and vice versa.

By using an actuator on both sides of the model, the actuators will create a controlled transition between the desired positions. The actuators can be programmed to stop at the desired moment or in case of an emergency.

One of the benefits of this configuration is that the rectangular tube can also be blocked quite easily at the desired angle. In figure 4.4.4 can be seen that two rectangular profiles can be welded in the bottom construction to block the rotation in seating, sleeping and flexed position.

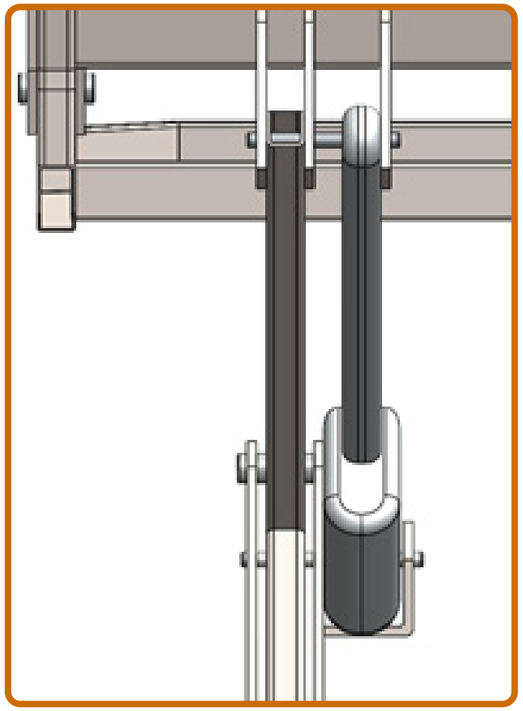


Figure 4.4.3 The actuator is mounted next to the backrod

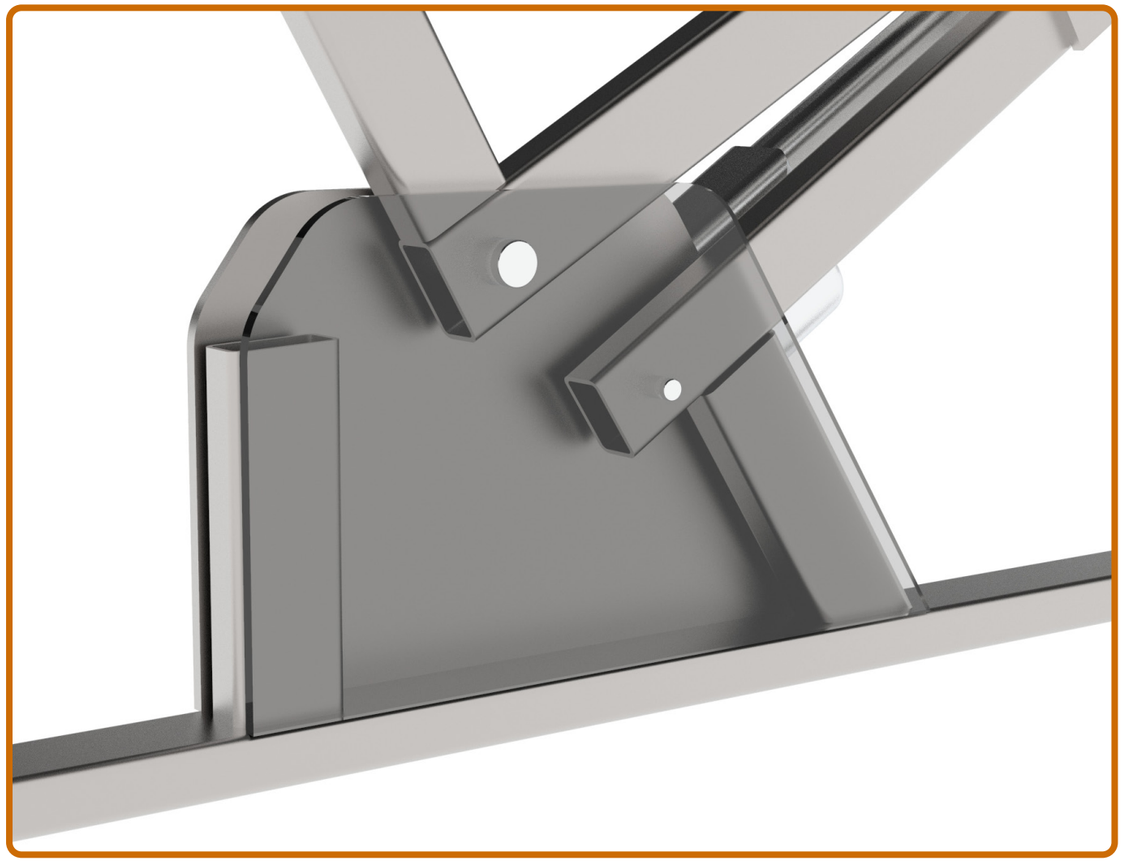


Figure 4.4.4 Profiles can be used to block the rotation in the desired position

To reach the maximum bed length, the headrest module is taken out of the backrest and installed in front of the backseat, as can be seen in figure 4.4.5.

If preferred, the headrest could even be pulled out a bit to extend the bed length, or it could be rotated a little for a slight elevation of users head.

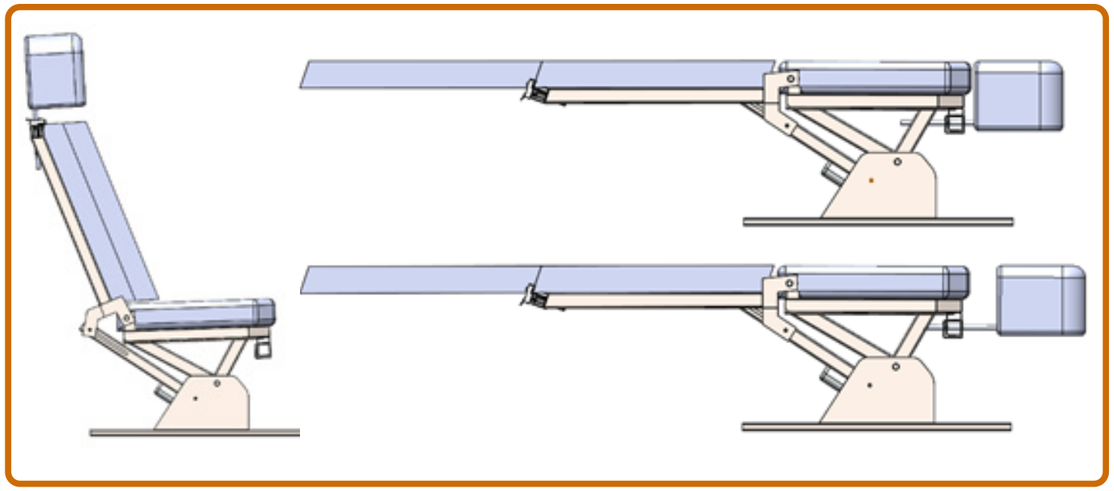


Figure 4.4.5 The headrest module is place in front of the seat to create a comfortable bed length

Main Takeaway

The mechanical structure with its rotation points have been successfully plotted in a way that all three positions (sleeping position, seating position and flexed forward position) can be achieved in their optimal positioning within the CAD environment.

4.5 CAD Modelling

Before a full-scale physical prototype could be created, several aspects of the mechanism had to be proved first. Using the plotted rotation points, a 2D prototype (figure 4.5.1) was created on a scale of 1:2 using a 3D printer. This mock-up was used to verity if the rotation would work and if the stiffness was still acceptable, as the rotation points are located relatively close to each other. After the 3D printed showed promising results, the mechanism had been optimized in order to perfectly fit the actuators and the next steps for this project were discussed.

After analysing other bench frames and Flex cabs, the CAD model was further developed into an actual metal framework that could be produced with the same production techniques that Snoeks currently uses.

The CAD product was developed within the K0 body to get as close as possible to the real dimensions.
The developed framework can be seen in the seating, sleeping and flexed position in figure 4.5.2.

Figure 4.5.1 3D printed mockup to evaluate the rotation points

Figure 4.5.2 The CAD framework in seating, sleeping and flexed position

Due to the limited available capacity within the workplace as other important deadlines had priority, several possibilities were discussed to finalise this project: A full focus on the report with recommendation and a CAD model, a scaled 3D printed model or a full-sized welded mechanical prototype.

After optimizing the CAD model and debating the benefits of an actual prototype It was decided to create an actual 1:1 steel prototype that could be built into the actual vehicle.

After several evaluation sessions with a few internal mechanical engineers and production, the CAD model was finalized and ready to use for the physical prototype.

Technical drawings of the assembly and parts have been created and can be found in Appendix T. An exploded view with all the structural parts that were used in the prototype can be found in figure 4.5.3.

It should be noted that the CAD model has been created in a way to make it as easy as possible for the workplace to create a functional prototype, using the form follows function principle. The functional CAD model with the headrest and cushions can be seen in figure 4.5.4.

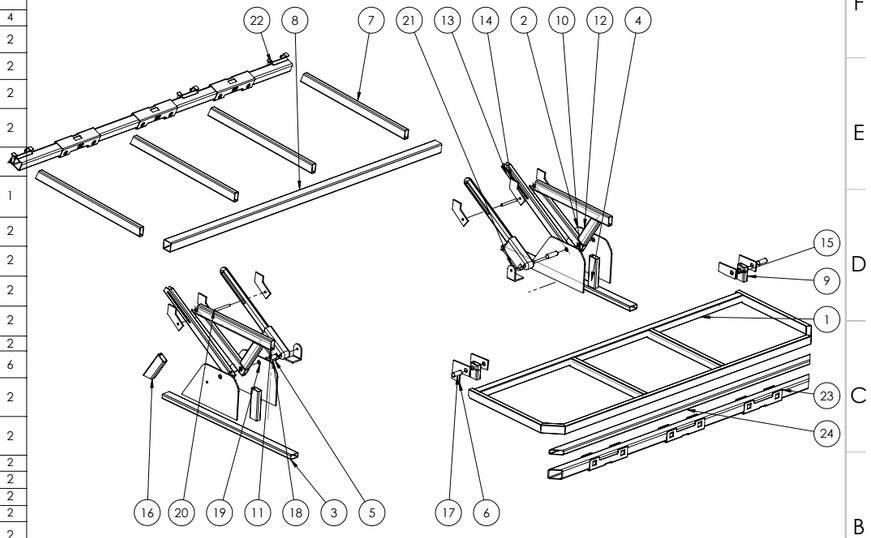
The actual product can be much more aesthetically pleasing, but for this project the current model is sufficient for the mechanical prove of concept.

Main Takeaway

A CAD model has been created for the development of a 1:1 scaled steel prototype. This model has been built in a way that the mechanical mechanism can be proved.

The dimensions are specifically created for proof of concept in the K0 body.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Subassembly Benchframe		1
2	base sideplate		4
3	base floor beam		2
4	Flex forward block		2
5	Actuator placeholder		2
6	outer side bracket seat to back		2
7	backrest frameheight		
8	Backrest lower support beam		1
9	benchframe rotation point		2
10	triangle frame back piece		2
11	triangle frame upper piece		2
12	triangle frame front piece		2
13	Backrod		2
14	bracket back to backrod		6
15	inner side bracket seat to back		2
16	flex backward block		2
17	16x40mm pin		2
18	16x50mm pin		2
19	8x95mm pin		2
20	8x80mm pin		2
21	bracket actuator		2
22	backrest upper beam with brackets		1
23	headrest brackets under benchframe		1
24	offset for headrest brackets		1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL:
WEIGHT:
TITLE: Flex plus Assembly
DWG NO.
A3
SCALE:1:20
SHEET 1 OF 1

Figure 4.5.3 Exploded view of all mechanical prototype components

Figure 4.5.4 Framework with cushions and headrest

4.6 Physical Prototype

A physical prototype has been developed and was built in a way that certain important criteria could be verified. It was kept as simple as possible to validate the working mechanism and indicate the potential usage, while minimizing the complexity for the building process (see figure 4.6.1).

The main criteria that had to be validated with this prototype are based on previous research and consultation with the R&D department. In the next chapter the evaluation will be further discussed.

Apart from validating certain criteria, the prototype also plays an important role in convincing the company of the potential of the product and to possibly pursue this direction. The physical product makes it significantly easier to communicate the intended usage towards the rest of the company.

Figure 4.6.1 The building process of the prototype

Insights prototype

The prototype successfully transitions into all three positions, as can be seen in figure 4.6.2. The system easily moves from seating to flex forward position. This can be explained as the headrest brackets under the bench frame increases the weight, and the relatively large lever towards the rotation point makes it easy to push the frame upwards.

The actuator manages to successfully drop the frame towards a flat position. It also causes the inclined seat to move towards a horizontal plane. The two actuators were found to be strong enough to move the backrest up and down. Specifications of the used actuators can be found in Appendix U.

Figure 4.6.2 The transitions of the mechanical framework into all three positions

The actuator range matches with the desired positions. The maximum range (as seen in figure 4.6.3) enables the seating and flexed forward position. The minimal range transforms the framework into the sleeping position.

The complete mechanical framework can be seen in figure 4.6.4. The stance is as wide as possible to increase the stability of the frame.

The attachment to the body is now done with existing connection holes in the floor of the body om order to keep the prototype fixed in place.

The prototype can fold into the flat sleeping position with around 1cm to spare between the back frame and the C-Pilar. This covers the largest possible surface area between the cargo space and passenger area.

Figure 4.6.3 Actuator in Flexed forward position

Figure 4.6.4 Mechanical framework in K0 body

After the framework was successfully created, placeholder foam was added to showcase the potential working principle of the double back folding (figure 4.6.5). The foam that was used for the prototype is softer mattress foam. This was done purely to indicate the working principle and to intended dimensions. The foam cannot be used to validate seating or sleeping comfort.

A wooden wheelbase was created to support the double backrest, as can be seen in figure 4.6.6. For the prototype it was decided to use a separate frame to support the folding cushion. The frame is now attached to the roof of the vehicle. The intention is that the partition wall will be used as supportive frame in the final product, so no additional elements are required.

Figure 4.6.5 Placeholder foam for folding principle

Figure 4.6.6 Supportive structure around the wheelbase

For the modular headrest, two existing headrest frames have been connected to each other and are slightly adapted to indicate the intended usage. The headrest can be place on top of the back frame or in front of the seat, as can be seen in figure 4.6.7.

The dimensions of the headrest are based on the interior dimensions of the K0 body. In figure 4.6.8 can be seen that the headrest reaches all the way to the rooftop in the flexed position and fully separates the cargo area from the passenger area.

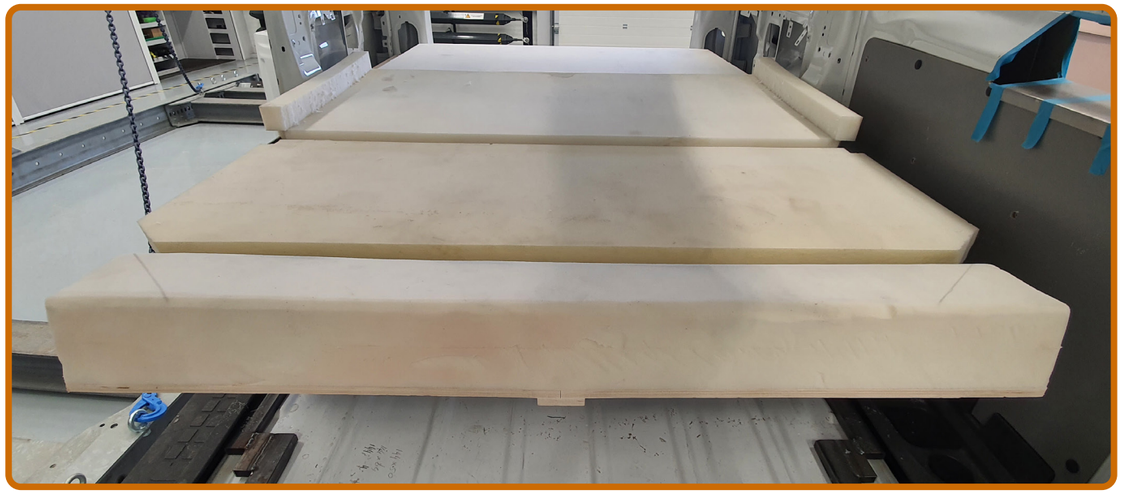


Figure 4.6.7 Modular Headrest in front of the seat

Figure 4.6.8 Flexed forward position with full separtion

Important Insights

The mechanism of the prototype manages to achieve all three desired positions within the K0 body and proofs the technical feasibility of this concept.

The modular headrest can be used within the configuration to achieve the desired bed length, but the transitioning must be optimised.

4.7 Evaluation Physical Prototype

The prototype was evaluated using the list of criteria and aspirations. In figure 4.7.1, a checklist can be seen of which aspects have been verified during this project. A short argumentation is added for all criteria. The validations that were made using the prototype will shortly be described in this chapter.

The colored rows have been analysed using the prototype. The criteria and recommendations that have not yet been verified are shown in white and will be implemented in the recommendation chapter with clear instructions, indicating the required process in order to verify the concept.

	Criteria (Does the concept meet the criteria?)	Criteria elaboration	Confirmed Yes/No/Partial	Short argumentation
1	**Usable for commercial and Recreative**		Yes	The mechanism proves possible usage for both commercial and recreational purposes
2	**LCV registration**	**EU fiscal regulations**	Partial	Apart from a specific german regulation, the fiscal regulation can all be achieved
3		**EU safety regulations**	No	Not all safety regulations have been verified yet
4	Cargo space fiscal regulations	Cargo space 51% of length	No	Not achievable, alternative regulation: Payload > passenger load is still achievable
5		cargo space 0.5 * original length + 0.3m	Yes	The meassured cargo area is larger than minimal requirement
6		Blinded cargo space	Yes	Can be achieved as seen in current prototype
7		must weight less than 400 kg	Yes	The structure now weights FIXME kg, even with additions this will stay below 400kg.
8	partition wall safety standards	max gap size of 40mm in projected view	Yes	The gap size is less than 40mm except for one spot in the corrugation of the C-pillar, which is permissible
9		ISO27956	No	This safety regulation should be evaluated with the developed partition wall
10	Benchframe safety standards	Ability to hold forces safety test (30kN)	No	This safety regulation should be tested with the developed benchframe
11		Seatbelt safety configuration	No	This ability to install three safe seatbelt configurations must be verified
12	Partition wall in place during commercial usage		No	The partition wall should be developed and requires programming to fulfill this criteria
13	fit within K0 dimensions		Yes	The prototype fits well within the dimensions of the K0 body
14	seating for at least 5 people		Yes	The prototype offers sufficient seating space to support 5 people (3 passengers on the backseat.)
15	sleeping possibility for at least 2 persons	Achievable length > 190cm	Yes	The achieved length is > 197cm
16		Achievable width > 120cm	Yes	The achieved width is 134cm
17		Achievable comfort	Partial	Flat position can be achieved. Foam cannot be validated yet.
	Aspirations (Does the concept fulfill the aspirations?)			
1	Deliverable in ready to install package		No	The developed product should be transportable within standard Euro pallet dimensions (1800x1200x1350mm)
2	Smooth transition between commercial and recreational usage		Partial	Overall transition is good, headrest module is currently inconvenient.
3	Comfortable experience in recreational and commercial usage	Seating comfort	Partial	Seat is currently too hard, as expected as the foam is just the placeholder. Ergonomic dimensions are good.
4		Sleeping comfort	Partial	Flat position can be achieved. Foam cannot be validated yet.
5	Align with current market capabilities of Snoeks		Yes	The product can be placed within the same Afterfit or OEM sales channels
6	Applicable on different K1 platforms		Partial	Not applied, but applicability on K0 is proven, other vehicles have larger dimensions so should be achievable.
7	Ability to stand in the vehicle		No	This can be achieved with a Pop-top roof trimlevel. If this is desired the safety regulations should be verified
8	"livingroom" area	Rotating chairs	No	This is proven to be possible in current K0 RV builds, but might require a sliding rail to function correctly
9		table	No	This is proven to be possible in current K0 RV builds, but might require a sliding rail to function correctly
10	Allow sleeping for 3-4 people	Pop-top installation	No	As the product does not use the roof or sides of the vehicel, this is likely to be possible but it should be verified
11	Small amount of modular components that require external storage		Yes	No additional components are required. A topper mattress is an optional addition of extra comfort
12	Applicable on electric vehicles		No	The basic dimensions will be similar, but the attachement to the body of the electric version should be verified
13	Applicable in both the L2 and L3 version of the K0		Yes	The product fits well in the L2 body. The L3 body is identical except for a rear extensions, thus applicable.
14	Power outlets		No	This functionality could be added, but Snoeks should consider if they want to implement this in the basic vehicle
15	Ability to install "could have" modules / features	Insulation	No	It is likely that this functionality can be installed, but it is not recommended for Snoeks to do this themselves.
16		Heating	No	It is likely that this functionality can be installed, but it is not recommended for Snoeks to do this themselves.
17		Cooking facilities	No	It is likely that this functionality can be installed, but it is not recommended for Snoeks to do this themselves.
18		Water supply	No	It is likely that this functionality can be installed, but it is not recommended for Snoeks to do this themselves.
19	Align with current production capabilities of Snoeks		Yes	The exact same production techniques can be used for the production of this product.

Figure 4.7.1 Evaluation of the Mechanical Prototype using the Criteria and Aspirations

Evaluated Criteria and Aspirations

The cargo space regulations
The cargo space regulations are partly confirmed. The French tax regulation can be achieved, as can be seen in Appendix V. The German requirement that the loading area should be 51% of the length and the vehicle is physically impossible. After discussing this issue with the Homologation department, it was found that this is the case for all K1 crew cabs. The fiscal benefits in Germany for this specific regulation is however less significant, as it only applies for a small road tax benefit. An alternative regulation: cargo load > passenger load is met, which still allows most benefits. (See Appendix C, fiscal regualtions)

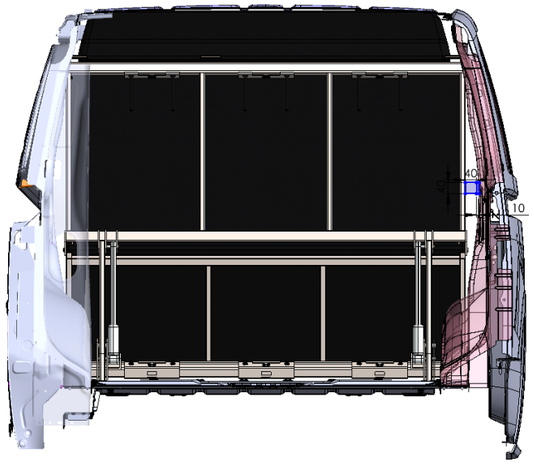
Weight
The current weight of the prototype is less than 70 kg. For the final product this is expected to be a bit higher as a locking mechanism should be installed, the foam will be slightly heavier and some additional struts might be required to meet the safety regulations. Even in the worst-case scenario these adaptions are not expected to weight more than 30kg. The weight limit of 400kg is certainly achievable.

Bed length
The criteria is to create a minimum bed length of 1.90m. The current length with the folding double back and headrest is 1.97m. (The headrest could potentially be extended a little to increase the bed length if preferred.)This means that the requirement of length > 1.90m is met.

Bed width
The criteria for the minimum width of the bed is 1.20m. The current bed width is 1.34m over the entire length except for the headrest. As this part only supports a user's head or feet, this small tapering can be neglected. This means that the requirement of width > 1.20m is met.

Achievable comfort.
The ability to create a flat surface with the intended foam dimensions is confirmed. The prototype is not perfectly flat due to the foam that was used and the attachment to the bench frame, but clearly shows that it is physically possible. The comfort of the foam still requires validation as the foam that was used for the prototype is less dense than the intended HR60 foam.

Gap size < 40mm.
In this prototype the gap size between the bench frame and the C-pillar is smaller than 40mm except for one point where the gap is slightly larger than the 40mm, as can be seen in figure 4.7.2. According to the regulation (ISO 27956, section 3.2), a larger value is permissible in case of corrugations in the side walls. As this is the case, the criteria is found to be successfully met within the prototype.



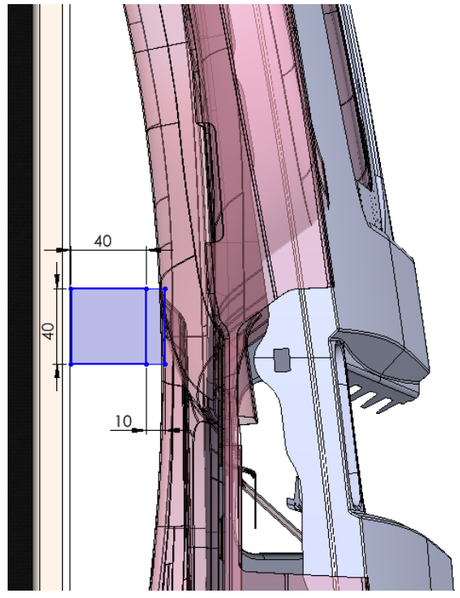


Figure 4.7.2 Gap size between the benchframe and C-Pillar

Smooth transition between commercial and recreational usage
In the current prototype, the mechanic transition from seating to sleeping position takes around 25 seconds. This is done because the actuator needs to move a heavy load in a controlled way, and to keep the transition as safe as possible. From a designer's perspective, this control and safety is seen as more important than the time it takes to make the transition happen. As this transition is likely to only occur a few times a year, a 25 second transition is seen as acceptable. This should however be verified with the target audience.

The transition for the headrest is currently not ideal. This mainly has to do with the attachment. Currently the transition is done by removing the headrest using four pins. These need to be unlocked on both sides and as the headrest is one large module, the slightest disparity in the removal of the headrest causes it to jam.

Seating for at least five people
The prototype can seat three people and the width is comparable to most three sit bench frames. With the two or three front seats, seating for at least five people is achievable.

Align with current market capabilities of Snoeks.
The product matches with the current product line of Snoeks and can be developed as a trim level. The same sales channels (OEM or After fit) can be used to sell the product.

Align with current production capabilities of Snoeks.
The prototype successfully proved that only a few small additions are required to transform the current Snoeks flex cab into the intended product.

Applicable on different K1 vehicles
It was found that the product fits within the K0 body and comfortable positions can be achieved within this framework. As the alternative K1 medium LCV's all have larger dimensions, it was found that this concept must be applicable on these vehicles as well.

Small amount of additional components that require external storage.
In the current prototype there is only one additional component, which is the supportive frame for the folding part of the double back. In the final product, it is recommended to use the partition wall as the supportive frame, therefore eliminating any additional components.
The only elements that require external storage are your basic bedding a topper mattress if preferred.

Fit within K0 dimensions & Applicable in both the L2 and L3 version of the K0.
The applicability of the concept in both the L2 and L3 versions are confirmed. The prototype was successfully installed within the L2 K0 body and all functionalities and desired positions have been achieved. As the L3 version of this vehicle is exactly the same as the L2 version except for a 0.35m extension at very back of the vehicle, this automatically means that the product also fits within the L3 version of the vehicle. This was also confirmed using the CAD files of both vehicles.

Additional Insights

Safety locking mechanism
The transition between the seating and flexed forward position happens easily. This is beneficial for a smooth transition, but does prove that some kind of locking mechanism is required in order to keep the product locked in a certain position.

Actuator safety
The actuators can place the backrest in any angle between the seating and flat sleeping position. This could create a comfortable relaxing position to read a book or watch something, but the user's safety cannot be guaranteed in these positions as the partition wall would not separate the passengers from the cargo area.

There is also potential danger during the transition between seating and sleeping. As the mechanism is now open, a user could potentially get their hands stuck between the rods or the structural support and the bench frame.

4.8 Product usage

For the desirability of this concept, it is important that the company and potential customers can see the added value of the product. Users should understand the additional functionalities that this version of the product offers. For the company to invest in the development of this concept, it is also important that the added value and potential are clear.

In this chapter, the possible usage of the product will be presented. These visuals can also be used for market research to validate the customer desirability.

In the introduction of this project, the desired activities and the current situation for a small business owner were presented.

Figure 4.8.1 shows how the Flex cab + can combine all the desired activities for small business owners in one multi-purpose vehicle.

The product can be used to transport packages for commercial usage, to transport passengers for private usage and to go on short trips for leisure activities such as camping with the family, or outdoor activities with friends.

The Flex + allows the user to use their LCV for commercial, private and recreational activities. In figure 4.8.2 can be see how the product is can be used in different scenarios.

Figure 4.8.1 How the Flex cab + can be used for commercial, private and recreational activities

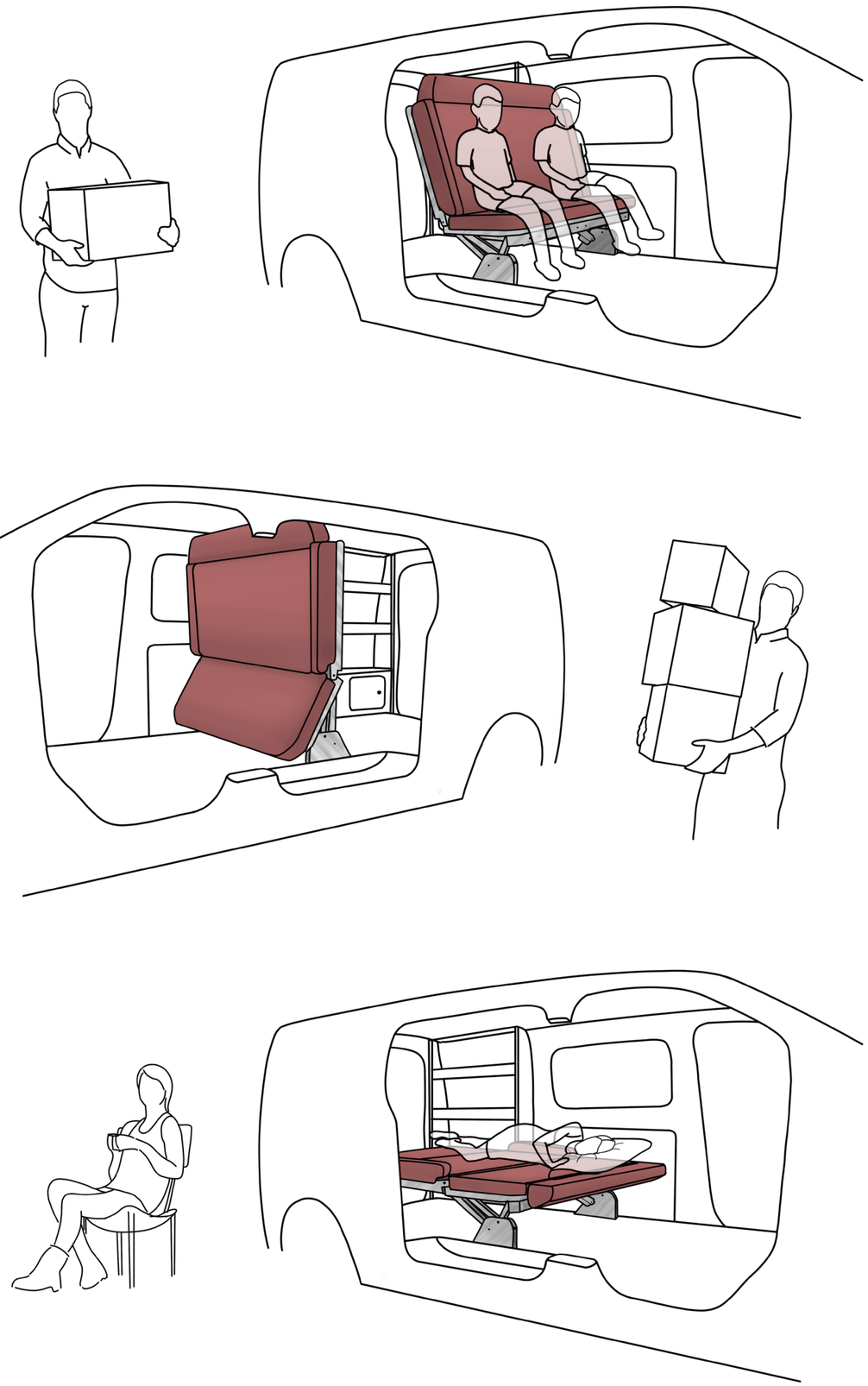
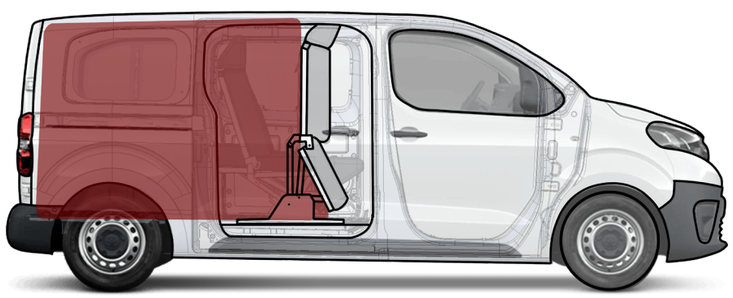
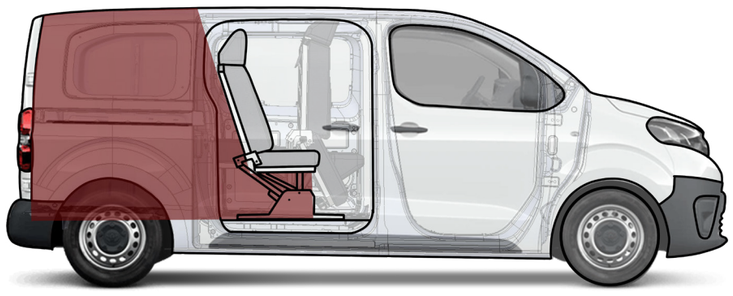


Figure 4.8.2 Flex cab + positions in use

The available cargo space depends on the positioning of the flex cab +, as can be seen in figure 4.8.3. For the largest possible cargo area the product is flexed forward and a significant amount of additional loading space becomes available as can be seen in the figure.

Even in the recreational sleeping position, there is still over 900L of available cargo space underneath the bed. Together with the additional storage possibilities in the cabinets on top of the supportive structure this is more than sufficient for a long camping trip.





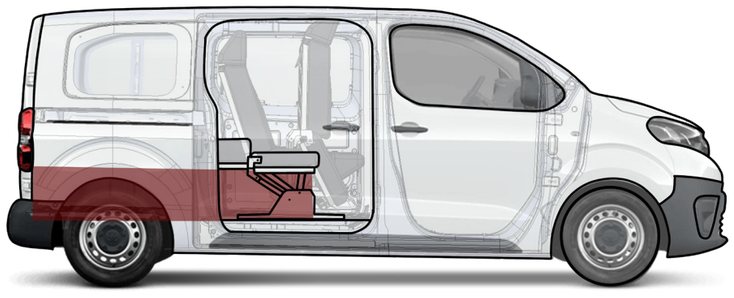


Figure 4.8.3 Cargo area for each position

In the folded out position, the headrest is used as the foot end of the configuration, as can seen in figure 4.8.4. with this module the concept offers a 1.34m x 1.97m bed for a comfortable sleeping experience.

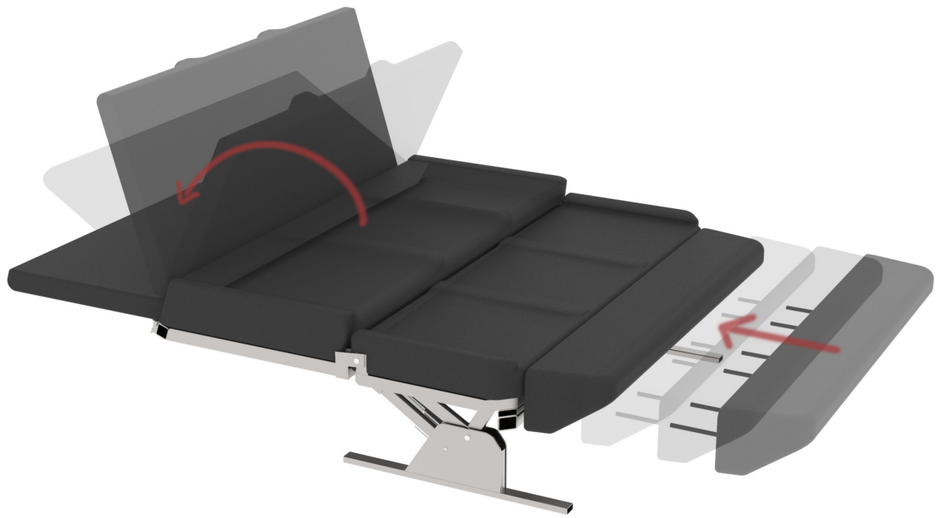


Figure 4.8.4 The modular headrest is used as the foot end for comfortable sleeping dimensions

With this product the most important functionalities for recreational activities are covered, and with some optional personalization the vehicle can be used for any preferred type of leissure activities. (figure 4.8.5)

Figure 4.8.5 Product usage for leissure activities

The framework around the wheelbase is used to support the backrest in sleeping position. The sides of the framework can be used as cabinets and the layout can be altered depending on the preferred functionalities.

Figure 4.8.6 shows a potential recreational layout of the cabinets. Figure 4.8.7 shows a possible commercial layout using the same supportive structure and cabinets.

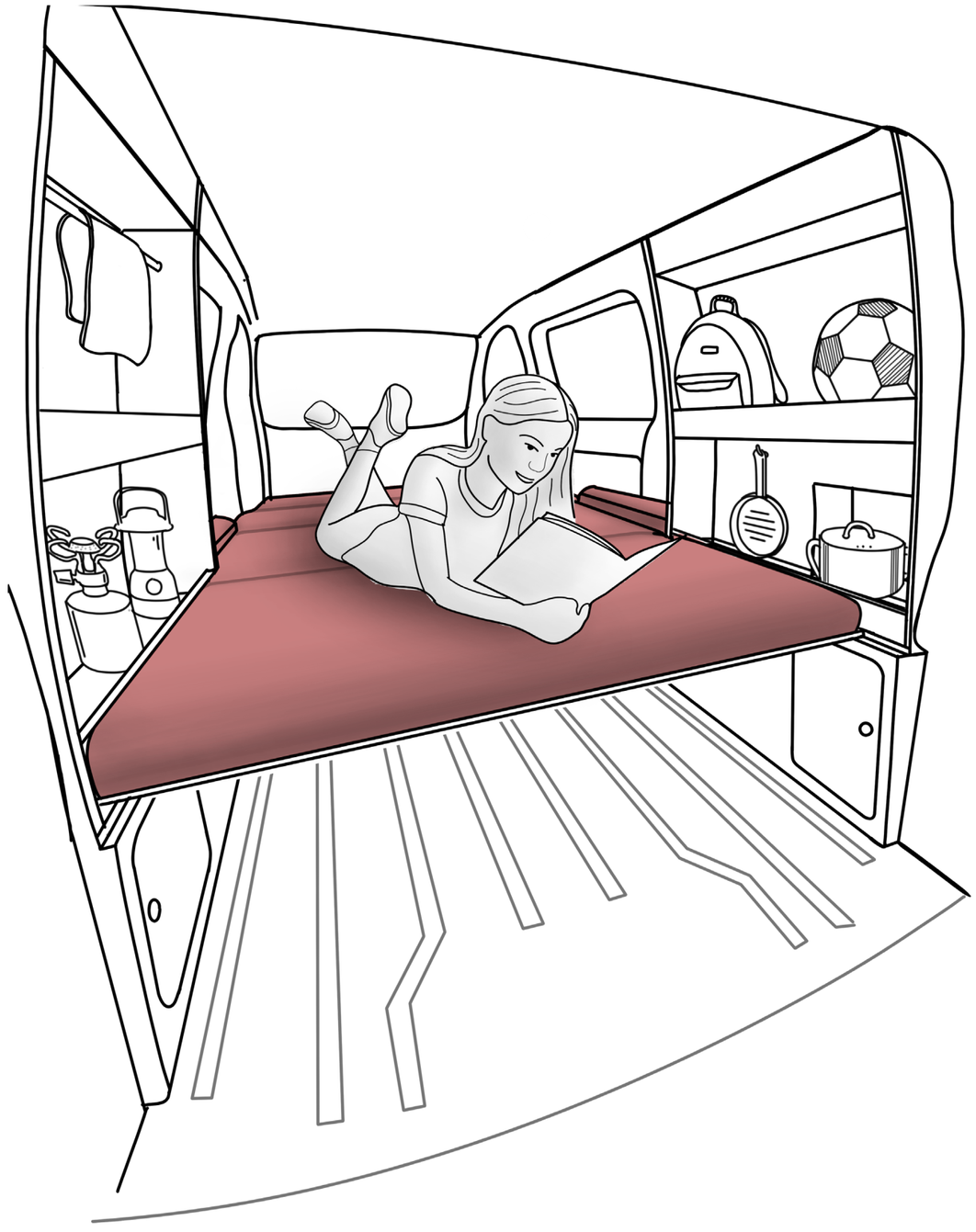


Figure 4.8.6 Recreational layout of the cabinets

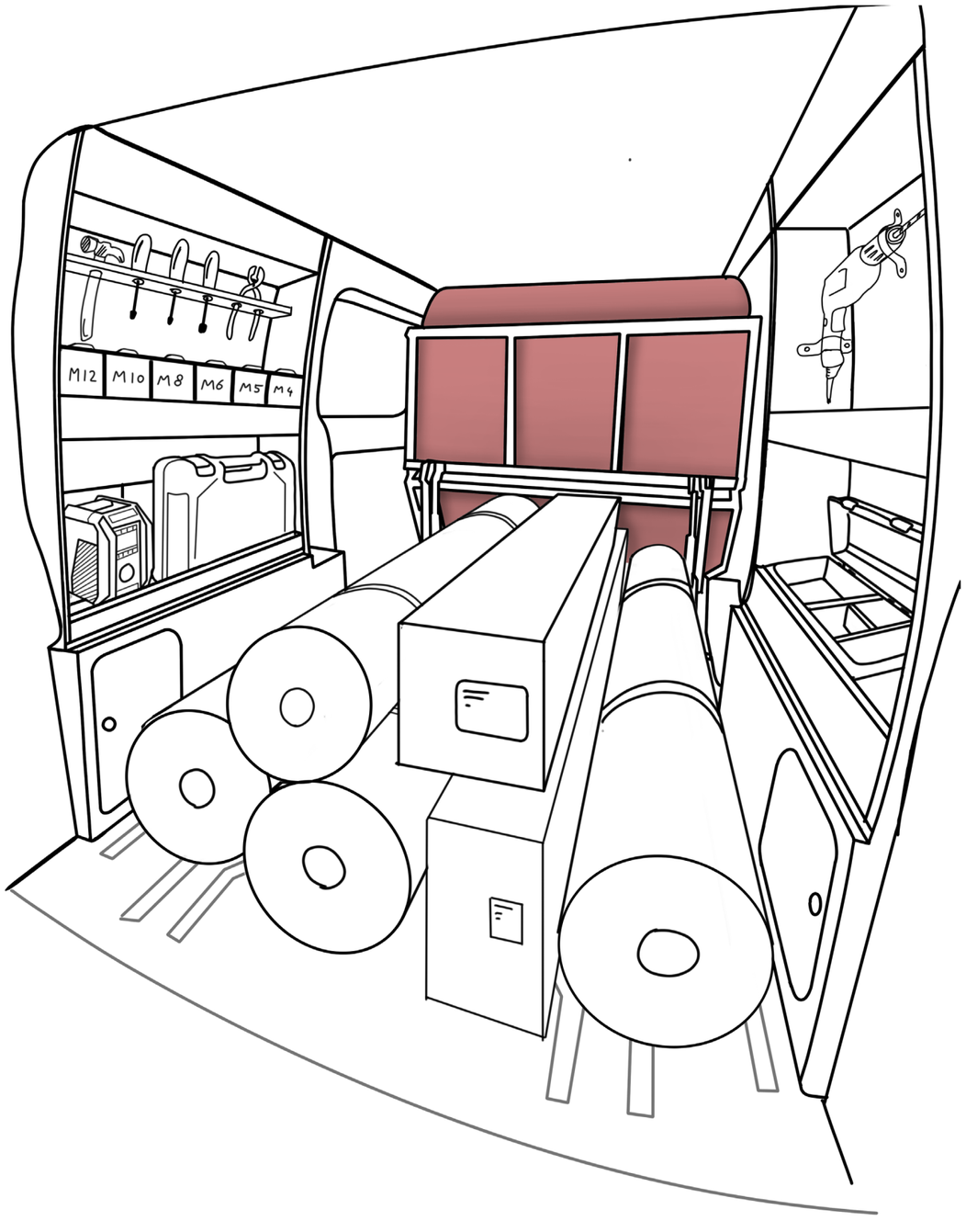


Figure 4.8.7 Commercial layout of the cabinets

5 Recommendations for Further Development

With the prototype, the technical feasibility of this concept has been confirmed. It is therefore proved that with relatively minimal engineering, the Flex Cab can be improved with large impact. For the further development of this concept, several recommendations can be given based on the research of this project and the evaluation of the physical prototype.

These recommendations will be divided in functional recommendations, safety & technical recommendations, marketing recommendations and future recommendations.

5.1 Functionality Recommendations

Several functionalities have been analysed in depth and some other functionalities are still in the idea phase. Recommendations will be given based on insights of the prototype and functionality research.

Sleeping

For the sleeping functionality, it is important to assess the sleeping comfort. The suggested thickness of 70mm HR 65-70 foam is well considered, but not assessed in reality. As multiple foam experts mentioned, the comfort is highly dependable on preference, body posture, progressive pressure and more. It would be advisable to have multiple user tests with the target group, preferably with a range of different body types and postures. They can be asked if they perceive the bed as comfortable enough for one night of sleeping, and if they believe that this product combined with a topper mattress could offer them comfortable sleep for multiple nights.

Transition Usage /use cues

The usage of the product should be tested and evaluated with the target audience. How do they perceive the switch between seating and flex, and seating and sleeping position? Is it clear how these transitions need to happen? Is it clear that the headrest should be moved to the front of the vehicle and how do they perceive this step?
In the current prototype, the mechanic transition from seating to sleeping position takes around 25 seconds. Do users believe this transition is too slow and is this a dealbreaker? It is recommended to do these validations in an early stage and use that feedback as early as possible

Living room area

It is recommended to review the additional cost/difficulty that is required to install rotating chairs. This could enable the users to make optimal usage of the interior space of the vehicle and can create a seating area for up to five users. For commercial usage this could be used to have lunch with colleagues, or during recreative usage to play games with friends or family.

The implementation of a foldable table in the door frame would be desirable to enable these possibilities.

Sliding rail

The implementation of a sliding rails should be considered as this could highly increase the user friendliness and possibilities. By creating a sliding rail, the available leg space for users could be increased if preferred. The flexed forward bench could be moved as far forward as possible to allow the largest possible cargo space, and the bench could be moved backwards to increase the living room area during recreational usage, as can be seen in figure 5.1.1.

What should be checked is how this matches with the regulations of France, safety regulations and how this could affect the bed position

Cabinets and storage

The implementation of cabinet storage above the wheelbase frame could offer beneficial storage space in both commercial and recreative usage. Tools or small items can be stored or attached to these cabinets, and possible additions like a cooking facility could be installed for recreative purposes.

The configuration of these shelves should be considered. For some users, it might be desirable to have smaller shelves or hooks, when others might want a large cabinet, or nothing installed at all. All of these options are possible, but it is recommended for Snoeks to make a well-considered choice as for what options they will make available.

Pop-top roof

The opportunity to stand in the vehicle and potentially sleep in the vehicle with up to four people can be highly desirable for families or groups of friends. Installing a pop-top roof on the vehicle enables these possibilities. Rather than doing this themselves, Snoeks could have the vans converted and known Pop-top installation companies and offer them within their product range as well.

As the product has no attachments to the roof of the product, no interference is expected and offering this version should not result in any additional research or development costs. The additional cost of a pop-top with instalment can simply be added to the total price and this would allow Snoeks to offer another trim level. They could choose to offer this edition as a luxury trim level and potentially add a few other luxury features as well.

Power

It is recommended that a few power outputs are installed within the vehicle. This is beneficial for both commercial and recreative usage as phones can be charged, tools could be used, and enough light would be available.
The power source can be installed underneath the passenger seat. Installing an external power socket is recommended as this could allow users to connect to campground power grids.

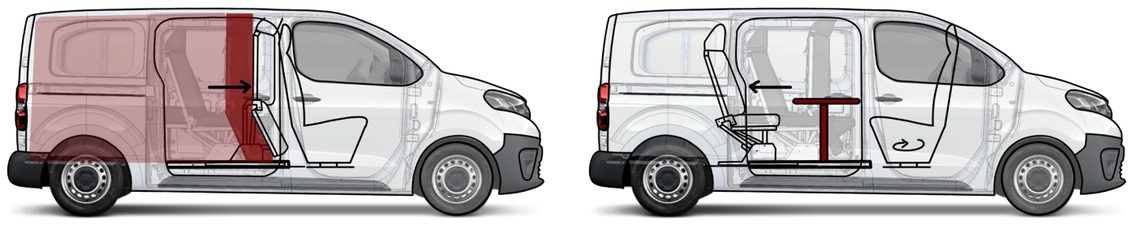


Figure 5.1.1 Sliding rail positions with increased cargo space or living room area

5.2 Safety & Technical Recommendations

User safety
This concept works with a rotating mechanism and actuators. For this to be safe, several aspects must be reviewed. It should be prevented that someone could get their hands stuck between the mechanism or is pinched underneath the back frame. This could be done by implementing resistance sensors and emergency stops. It can also be prevented by making sure there is enough distance between the mechanism. (This can be done using a plastic casing around the critical elements.)

A risk analysis (DFMEA) must be done to evaluate any potential risks and prevent them. The product also needs to meet the ISO 26262 Road vehicles Functional safety regulations.

Passenger safety system
If the product is placed in the sleeping position or under a slight angle to create a comfortable reading/relaxing position, the passengers are not separated from the cargo area. To guarantee the passengers safety, a safety mechanism should be installed that makes it impossible to drive without proper separation.
A similar system to the current Seatbelt reminder system could be installed to prevent users from driving in an unsafe situation.

Locking mechanism
Some kind of locking mechanism must be installed to keep the product fixed in the seating and flexed position. This is required to offer a safe product that does not transform or move in case of a possible crash or sudden impact

The locking mechanism can also be used to prevent that all forces work directly on the actuator. It is recommended to analyse this during further development. A simple locking mechanism should be able to fixate the module in one of the positions, lowering the forces on the actuators and increasing the product safety.

Product safety
The product must be tested according to all EU safety regulations. It is recommended to do FEM analyses regarding the partition wall and the bench frame, as the connection of the concept to the floor might not be strong enough to withstand these forces. If this is the case, several brackets could be developed to attach the product to the C-pillar of the vehicle, spreading the forces over a larger area, shortening the lever length and lower the torque.
As the forces pull the seat forwards with 30kN, a large torque will be applied at the legs of the product (see figure 5.2.1). The legs need to be developed in a way that they do not bend or press straight through the floor of the vehicle. Placing a crossbar at the bottom front of the framework (figure 5.2.2) or creating a larger surface area could also help distributing the forces on the body of the vehicle during the seatbelt test, but further analysis are required.

Modular headrest
For the final product, a new headrest would have to be developed and evaluated. With this development the main aspects that need to be considered are the safety, comfort and transitioning between bed and headrest. In the current prototype it was found that the transition of the modular headrest is not very smooth due to the long distance between the pins. To improve the transition, possible solutions could be to place to tulles closer to each other or to use less pins.

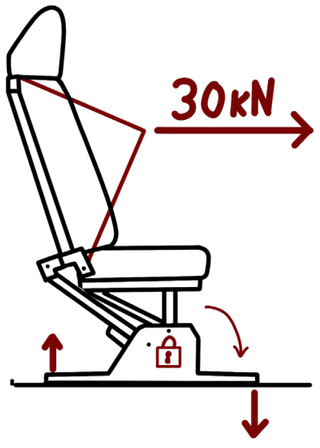


Figure 5.2.1 Forces applied during a seatbelt safety test

5.3 Marketing Recommendations

Market viability and desirability
To really understand the viability and desirability of this concept, market research should be done.

The focus on a new market could be a great market opportunity, but due to the many uncertainties about the demands and aspirations of this new target market, the risk is high. To really understand the viability and desirability of the concept, market research should be done.

This could be done by speaking to many LCV users with different professions and identifying their needs and willingness to pay for a solution like this. Alternatively, dealers or conversion specialists could be contacted to find out if they hear a demand or see potential in this concept (direction).

Due to the complexity of the project, the limited time and some confidentiality issues, these options were not be available during this research. It is therefore highly recommended to use the results of this project as a proof of concept and validate the concept on its viability and desirability by using the prototype while speaking with potential users or conversion stations & Dealerships.

Concept viability
In order to decide whether it is wise to continue with the development of this concept or not, a cost estimation should be done. The expected development cost should be compared to the acceptable risk to introduce a new product to the market.

There is currently not enough knowledge to make a reliable estimation within this project as there are too many uncertainties. A few rough estimations can be found in Appendix W.
These estimations are based on the known LCV and RV market, combined with Snoeks current sales.

It is recommended for the company to make a calculation based on either the amount of expected sales, or the expected additional development cost, as is further explained in Appendix W.

Direct contact with customers
It is recommended to see if direct contact to potential customers can be created to increase the knowledge of their desires and preferences, rather than focussing on the demands or suggestions of OEMs alone. This direct contact can help to get a better view of the user and to make adaptations accordingly. This would also be beneficial for other future projects.

Figure 5.2.2 A crossbar could help distributing the forces applied on the body of the vehicle

5.4 Future Recommendations

Electrical vehicles

The creation of this concept is initially done for a diesel-powered vehicle. In this specific research, the basic regulations and considerations are based upon diesel powered vehicles. This has to do with the viability of the concept at this stage and because the physical vehicle that can be used for proof of concept is a diesel-powered LCV. It is the designer's strong intention that as soon as this concept proofs to be a viable product, a version for an electric LCV will be developed as well. This might require some further research and testing but should absolutely be the next step in the development of this concept. Electric vehicles are the future, and this concept should fully support and contribute to that innovation.

As these electric vehicles use the same base as the diesel-powered versions, the development of this electric versions should not be too difficult to apply. The fiscal regulations should be reanalysed, but in most cases, this could only result in larger benefits due to the many financial benefits for electric vehicles.

Ford/VW platform

The collaboration between Ford and Volkswagen will probably be one of the most impactful new entries on the LCV market in the upcoming few years. This one-ton cargo van would be a logical first step to simultaneously build a regular flex cab and the Flex + concept. The entire development and evaluating can happen at the same time with the Flex + concept as a trim level of the product.

The OEM RV experience of VW and the Westfalia collaboration experience from Ford, combined with the continuous innovations of both companies on large fairs like the IAA, these two companies could both be an interesting partner to pitch this new product to the market.

6 Personal Reflection

Process Reflection

The research phase went pretty well for me. I quickly learned a lot about the LCV and RV Industry and which aspects and regulations to focus on. I believe that I managed to get a good grip on the material in a relatively short time, and that this really helped me with the rest of the project.

It was shortly after the ideation phase where I found my first setback. I envisioned an idea that could both improve the commercial and recreational usage, but after several consultations within the company I developed some hesitation. Developing a concept like this would be too complex and the development costs would be too expensive to continue with this project. This is something I wanted to avoid as I wanted to develop something that could actually be feasible and viable.

I strongly believed that it had to be possible to combine these functionalities in a way that it could be useful for the company. This is where I decided to alter the focus of my project a bit. I decided to spend some more time on the validation that these functionalities could be combined in a way that is still viable for the company and to focus on the main aspects that could convince the company to continue with the development of this concept.

From the start of this project, I stated that I wanted to make a physical prototype. Even though the validation of this idea took a bit longer than planned, I was willing to go the extra mile to really prove the technical feasibility. I took me a lot of effort and dedication, but I managed to convince the company of the added value of a full-sized model. Despite the low capacity in the workplace I was offered the opportunity to develop a physical prototype. This helped me a lot to verify the feasibility of my concept idea. With the prototype I managed to evaluate the concept with other departments and to convince the company of the potential of this idea. This was confirmed by the embargo request in the final stage.

At the beginning of this project, I noticed that some departments had some doubts about the initial project and the usefulness for Snoeks. The way I have seen this doubt transform into enthusiasm let me to believe that I developed a promising concept that fits well with the company. I managed to turn a “we will never do this” mentality that was found at the start of the project into a “We need to show this on the biggest vehicle exhibition”. For me this was one of the biggest achievements I could have hoped for.

I am satisfied with the overall process of this project. I believe that I managed to do what I wanted to achieve and that the company is satisfied with the work I delivered. As a project manager I managed to keep my stakeholders up to date and to really involve every department in this project.

On a more critical note, there are also aspect that I believe can be improved. I understand the cautiousness to spread confidential information, but I do believe that the level of reluctance could weaken the strength of the project execution. By not being able to speak with stakeholders outside of the company, I believe the integrity of the product is somewhat limited to the vision of the company. For future projects, I would recommend to offer a bit more freedom in the execution of the project and to allow conversations and validations with potential customers and stakeholders to get a better understanding of the target market viability and desirability.

Personal Reflection

During this project I learned a lot about the Automotive Industry and about the complexity of designing with strict regulations. I learned how the business world works differently than the academic world that I am used to and about my personal strengths and weaknesses.

I believe my motivation and dedication in this project motivated the company to also invest in me and to allow me develop my concept idea. Overall, I am very satisfied with my work. I am happy that I managed to push this project to a next step and prove the feasibility of my concept. On the other side I did not manage to achieve all my initial learning goals to the same extend. I have to say that I am not too disappointed about this. During this project I altered my believes. Rather than focussing on the aesthetics of the project, I really felt the need to prove the technical feasibility and as I wanted to create a prototype, I was happy to make this my main focus.

I am still very interested in improving my design aesthetics, but I believe this is something I will pick-up in the upcoming years.

What I learned is that CAD modelling is not really my strong suit. Working with metal constructions with accurate dimensions is very different from the SolidWorks constructions that I was used to and the development of the CAD model took me more time and effort than I imagined. I learned that I prefer to work on the creative aspects of an idea, rather than working out the details in a CAD environment. I learned that within the CAD environment I really prefer clay modelling over precise or parametric modelling.

I also learned about the importance of understanding the corporate culture. At the start of this project I was too invested in researching all functionalities and regulations. In doing so I failed to understand the doubt of certain departments regarding the overall project. After learning about the corporate culture, I understood how the development costs are big issue in the Automotive Industry and how this is the largest risk could affect a concept idea like this. In the future I will put more focus in understanding the corporate culture first so I can directly access the most important aspects.

Finally, I believe there was a bit too much dependency during the execution of this project. I fully understand that the workshop capacity was occupied and that the commercial projects are granted priority, but the uncertainty of development made it difficult for me to commit to a planning. I learned that planning is a critical factor in the automotive industry, and that dependency on one specific person can be dangerous for the project execution. In future projects I will make sure to anticipate on possible schedule changes and to have backup alternatives ready in case of unexpected changes.

The dependency on others is something I want to reduce in the future. As I want to become a hands-on designer, I am now seriously considering taking up some metal and woodworking classes as I believe that this could help me a lot with the development of prototypes in the future.

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Next to these resources, the following companies have been contacted & visited during this project:
Camper expo Houten
Pop-top campers
Kampeercentrum de Jong
Vancreators
Snoeks Wonen
Royal Health Foam – Chris Nederhorst

Additionally, calls have been made to the following companies for more information about their products:
Joan's comfortschuim BV
Draka Interfoam
Vitalo

Finally, Snoeks Automotives internal expertise, current and older projects and a few confidential reports have been used during this project.

Image References

The large majority of the figures included in this report and the Appendix are personal drawings, photo's, figures, or tables. The figures that are not considered personal work are listed below.

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Appendix

See attached file