Next
Generation
Long Distance
Coach

A thesis document by Jeroen Claus
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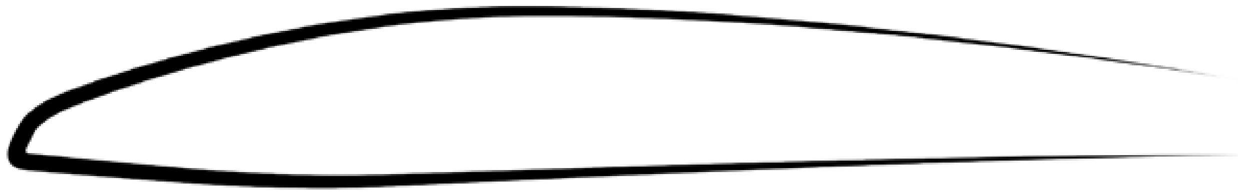


buse.

A thesis by Jeroen Claus, submitted in fulfillment of the requirements for the degree of Master of Industrial Product Development at the University of Antwerp, June 2014

Antwerp, Belgium

“Attempting to predict the future is both foolhardy and essential”

Donald Norman

Preface

Before I started my Product Development career in Antwerp, what I have been doing, basically all my life, from early childhood on, was drawing vehicles. Like most boys, I cherished a dream of becoming an automotive designer one day. I could not have imagined that almost five years later, I would end my Master's Degree in Product Development by designing a next generation coach concept. I wish to express my gratitude towards the University of Antwerp, for approving my project.

Writing a thesis is a constant battle, not in the least with yourself. Bringing the vast, multi-facetted task to a good ending would not have been possible if it hadn't been for some special people around me. First of all, I would like to say thanks to my family and parents, for supporting me in any imaginable way.

At college level, I would like to thank Jan Van Goey for giving me direction and feedback during the New Product Planning phase, and introducing me to the wonderful folks at VDL Bus & Coach Valkenswaard.
I am most grateful to VDL Bus & Coach and Ies de Rooij, in particular, for showing great interest and enthusiasm in supporting my project.

Special thanks go to my sister Elleen, for relentlessly reviewing and correcting my writing, Fabian Breës, for being a sounding board throughout the year, both in creation and moping. Last but not least: a heartfelt thank you to my girl, Stephanie, for being the most genuine and loving person I know - and for last minute double checking this file!

This document bundles the process of developing and designing the long distance coach for the future. Since the invention of the modern auto-mobile in 1885, energy and safety have been the most important topics. Reducing the impact of CO_2 emissions on the environment and ameliorating resource depletion, have increasingly gained importance worldwide ever since, and not in the least in the automotive sector. To cope with this responsability, "next generation" vehicles have come to see the light: hybrid, plug-in hybrid, battery electric, and fuel cell vehicles are being massively researched and developed. However, linking next generation vehicles only to energy-related innovation is an understatement of current developments in mobility: safety innovation is equally significant for all the obvious reasons. In this respect, the development of such next generation coach is meaningful. During one academic year, extensive research and meticulous designing was done to get to this final result: Next Generation Long Distance Coach.

I sincerely hope this thesis will inspire for what is yet to come.

Kind regards, Jeroen

New Product Planning

New Product Planning is the first phase of this Master thesis in Product Design. First, the challenge, containing the design brief, is formulated. Second, a plan for the multidisciplinary research is set up and then executed. The research is divided into domains of interest, which enable to process the vast amounts of data and will help to extract the most valuable variables. A threats and opportunities analysis will be initiated at the end of each research chapter: this will result in a detailed list of design drivers documented in this chapter, and which will form the ultimate stepping stone for the second phase: System Design.

1 Introduction

1.1 The Challenge

The seed for this project was planted in 2012, when a Belgian coach packed with children aged between 10 and 12 crashed in a tunnel in Sierre, Switzerland. Half of the passengers died. There is yet no evidence of why the coach got off its trail and crashed into a wall. This got the author of this thesis wondering of how it is possible that these kinds of horrible crashes keep occurring. In a time where safety standards are conquering the world, every few months a new catastrophic coach crash, killing a large amount of its passengers, is hitting the news. As a designer, I felt strongly about this issue. How can a sector driven by profit be transformed in one with top notch safety standards, without jeopardizing the position of coach operators worldwide?
In this document the design process of a near-future long distance coach (LDC) for the year 2030 and beyond is presented. It is the search to get an answer to the question how safety, efficiency and user-centered design (UCD) can influence the architectural design of a coach and how these three factors affect one another in a next generation world.

In the last few years, little has changed in terms of general bus architecture. For a long distance coach, it is relatively unknown or undocumented what benefits can come from tackling the three subjects: enhanced passenger safety, increased fuel-efficiency and financial advantages for travel agencies.
In order to get grip on the current issues involving road traffic and LDC-travel in specific, a multidisciplinary analysis will be conducted, including research on current active and passive safety features on present-day road cars and trucks, as well as a technology roadmap which enables to extrapolate a vision into the future of next generation technology for the Next Generation Long Distance Coach.

1.2 Relevance

This project was initiated in 2013 at the University of Antwerp as Industrial Product Devlopment thesis. Designing a coach concept for the future is a relevant subject as it requires insight in the three main domains of the Product Development course at UA: human sciences, technology and economics.

Fig. 1: A symbionic circle: how can safety, user-centered design (UCD) and efficiency alter the architecture of a long distance coach (LDC)? (Claus, 2013)

Cars can now read road signals, keep on track when a crash is imminent and even come to a complete halt when traffic stops or to avoid a collision with pedestrians.

1.2.1 Human sciences

The study of human sciences enables a deep analysis and generates insights into demographics, environmental issues and trends, and how they will evolve over the years to follow. These, along with European legislation provide a cultural framework to work within.

1.2.2 Technology

Technology is the backbone of this project. These days a lot of innovation is going on in the automotive sector. Cars can now read road signals, keep on track when a crash is imminent and even come to a complete halt when traffic stops or to avoid a collision with pedestrians. Scarce resources make for the need for new energy sources. The first usable battery electric vehicles (BEV) have recently gone on sale and are finally on the brink of breaking through to the market. These new technologies open up opportunities to alter the classic architecture of vehicles. For this project, it will be useful to understand and carefully map existing technology in order to project them onto the future.

1.2.3 Economics

Finally, economics will provide further background for the coach concept. Travel agencies need cost-efficient coaches. Cost-efficiency and profit of ownership have to be the unique selling proposition of the new concept. The new coach has to be attractive to both the manufacturer, travel agencies and the travellers it will be transporting to their much anticipated destination.

2 Research strategy

2.1 Sources

Future foresights are generally summarized in multiple probable scenarios. This enables one to formulate a plausible and more precise prediction for the future.

Non-mathematical predictions are mostly the product of different scenarios. In order to get the most precise foresight possible, the lows, mediums and highs have to be taken into account. This way an average is constructed in which – in this case – society and technology will evolve over time.

The word “scenario” is used in this paper in the sense of visions of future possibilities. Miles et al. (2003) explains this means, in particular, “visions that have been (a) derived and presented in a systematic way and (b) strive for some holistic sense of the circumstances in question. Typical with these kind of scenarios is that there will be a mixture of quantifiable and non-quantifiable components.” These will be documented in a narrative way or tabulated in the form of graphics or tables.

This thesis will mostly be based on European Commision reports and technical literature found on the web, in magazines, books, papers... R&D results and programmes from major automotive companies will also be taken into account. Assumptions and findings will be discussed with contacts in the industry. The broad spectrum of sources available covering one of the three domains tackled in this project will eventually lead to profound insights into the complex interlinking between technological innovation, scientific progress and society.

“The information needed to understand the problem depends upon one’s idea for solving it. That is to say: in order to describe a wicked-problem in sufficient detail, one has to develop an exhaustive inventory of all conceivable solutions ahead of time”

Rittel and Webber, 1973

2.2 Framing

Within the automotive sector, there are a lot of trends emerging. The most recurring ones are safety, ecology, efficiency, user-friendliness and affordability. These trends and the way they shape technology will determine the future road of the entire transportation sector.

Supportive of these trends and recent developments in technology and science are existing European legislation applying to the coach sector. Current laws will be investigated and ultimately assessed against prevailing trends and prospects involving European legislation.

The European Commission also provides an abundance of papers and case studies on contemporary issues of all kinds. Padded with actuality this material will define a clear scope.

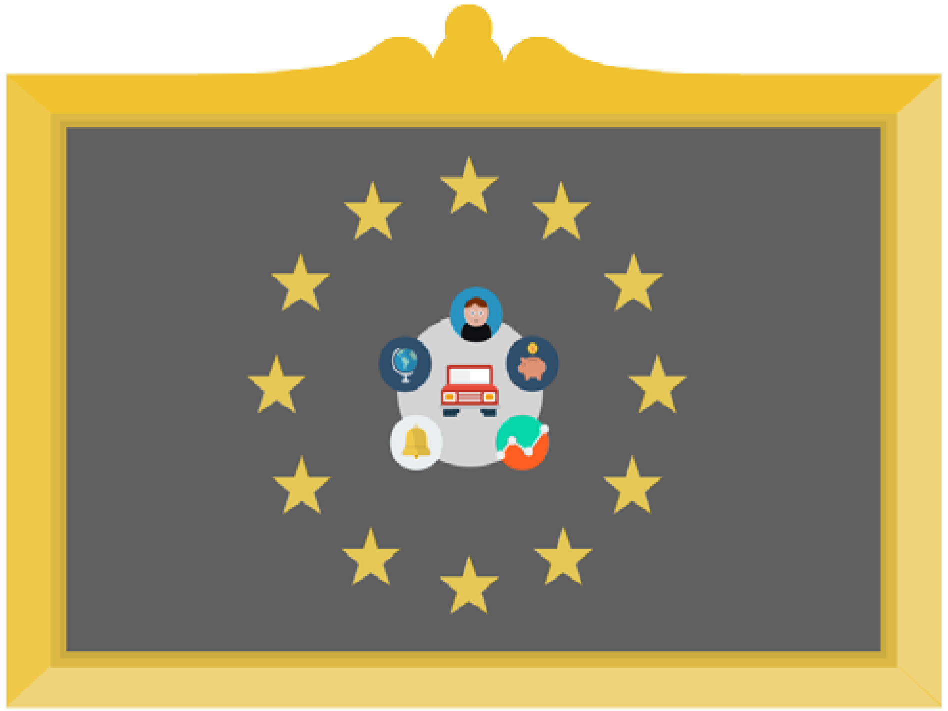


Fig.2: Trends within the automotive industry and their respective resulting new technologies are defined by European Legislation (Claus, 2013)

2.3 Approach

Forecasts are made because we believe that part of the future is predictable. If it weren’t, if there was too much uncertainty, attempting to predict any future would be pointless. One way to deal with uncertainty is to use scenario analysis (Moriarty et al., 2004). As Smil (2000) points out: “The use of scenarios explores the implications of possible futures.”
Accordingly, when working on social issues there is no correct or false answer, and it makes no sense to talk about an ‘optimal solution’. Designing a concept for the future does not qualify as a ‘tame problem’: there is no exhaustive formulation to be stated for it. Instead, the end result will always depend on the information the researcher or, in this case, designer will gather in view of the end result that individual has in mind from the very beginning of the project (Rittel and Webber, 1973).

When designing a concept for the future one is confronted with several issues, each having to deal with its own set of actors with their respective views and opinions. The first step in this research is identifying the different domains of interest. Secondly, the concept ‘coach’ or ‘bus’ will be investigated. How did it evolve throughout the decades? What can be expected for the future? What are the main market characteristics? How is the psychology behind the modern day bus?
Based on the three domains already specified in chapter 1.1: safety, UCD and efficiency, it became apparent that technology and the user are the two main actors in this project. On top of that, being a concept for the future, research on technnology and users only makes sense if society and societal change over the years and into the future is taken into consideration. This leads to the seperation of the research in four domains: the coach, society and how it will evolve, coach use(rs) and technology. Each of these research blocks will be concluded with a threats and opportunities analysis, which eventually leads to the formulation of possible future scenarios. Each block will elaborate on the historical background and future developments of the domain.

2.4 Research Questions

The next step in the process is to generate a couple of initial research questions which will eventually provide further insight into the subject. In order to get a clear view of what design-wise will be required for LDCs it is vital to investigate what defines LDC at present day and what might define them in the near future. That is how four specific questions were generated which will form a solid foundation to base the design process on.

What defines long distance coach?
How will society evolve?
What defines long distance coach use(rs)?
How will technology develop towards 2030?

2.5 Planning

The vast amount of information is divided into four manageable blocks, which will be analysed during one week each. Each block answers one of the research questions and will help, once the threats and opportunities are uncovered, to generate a future scenario. This scenario will result into a couple of design drivers, which will give direction to and steer the final design and concept development of the Next Generation LDC.

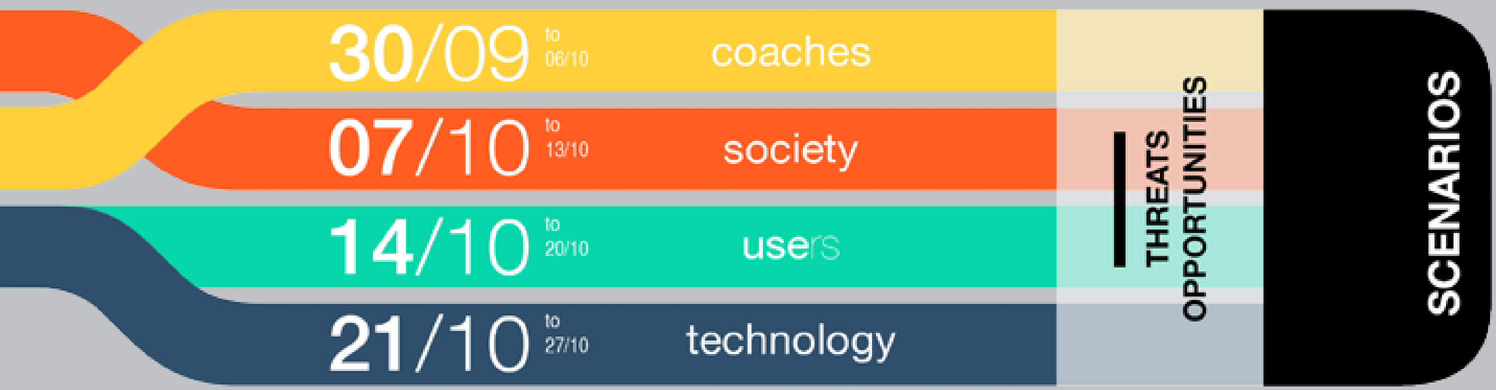


Fig.3: the research planning and how the processed information will enable to formulate a concept of a next generation LDC (Claus, 2013)

3 Research

3.1 What defines long distance coach?

In this chapter we will define the word coach as a concept. It only makes sense to describe a certain product when it is clear what the subject is, without linguistic confusion. To get a better understanding of the product, the sector and the variables influencing it will be provided, alongside a short history. This will uncover certain trends and how these are interwoven with global events, demographics and economy. Safety, an ever returning subject on coach transport, will be discussed through past events and current legislation.

3.1.1 Definition of a coach

What is a coach and what makes it distinct from a bus? Many statistics and languages do not make a difference between the two. Coaches are often confusedly referred to as buses and vice-versa. This linguistic and perhaps conceptual problem poses a greater problem than anticipated, as it renders a lot of data and statistics useless in advance (European Commission, 2009).
In order to make the difference between the two concepts clear for use in this project, a dictionary was consulted. In terms of a road vehicle, a bus is described as “a large motor vehicle carrying passengers by road, typically one serving the public on a fixed route and for a fare”. A coach, on the other hand, is defined as “a comfortably equipped single-decker bus used for longer journeys” (Oxford Dictionaires, 2012). So, a coach is by definition a bus with added luxury in order to make its passengers’ life more comfortable on longer trips. Additionally, vehicles with separate luggage compartments are often referred to as coaches (European Commission, 2009). This definition of the word ‘coach’ immediately explains the common use of ‘coach’ in the term ‘long distance coach’.

Fig.4: a double-deck Omnibus around 1845 (source: gail-thornton.co.uk).

3.1.2 A brief history

Early history and origins

Interesting to note is that the word ‘bus’ is derived from the Latin word ‘omnibus’, which translates ‘for all’. Needless to say, the word got shortened to ‘bus’ as the vehicles and the service of public transport became more popular. The first records of a vehicle which resembles a bus in the meaning of ‘a vehicle that can carry around 8 people’ date from the middle of the seventeenth century in Paris, France. Blaise Pascal, a French inventor, came up with the idea of providing some sort of public transport within Paris (Gould et al., 1999). The vehicles were pulled by horses and small fares were charged for the transport service. In a later stadium, the pulling horses were swapped for steam engines, which made the manufacter- and running costs incline steeply. Thus fares went up and bus travel became a privilege for the well-off.

Fig.5: motorized carabanc, early 1920s (source: The Book of Knowledge)

First coach services

When in the 1830s and 1840s railways and train services began to emerge, it was effectively over-and-out for the horse-pulled (long distance) coaches (Dyos et al., 1969). However, stagecoaches and carabancs (French: ‘car with benches’, a mostly open-topped horse-pulles or motorized vehicle for transporting people) stayed in business for short journeys or excursions until the early years of the 20th century (Anderson et al., 1970). Around the 1910s, these operators of horse-pulled coaches were the first to invest in new motorized coaches, in order to be able to compete with the popular railways (Gould, 1999).

Before and after the War

The coach industry grew rapidly in the years that followed. No less than 18 coach services ran between London and Oxford by 1930 (Flitton, 2004). It was a period of fierce competition. According to History of Royal Blue Express Services (Anderson et al., 1970), the original Royal Blue service from Bournemouth to London went from twice a week in 1920 to twice a day one year later, in 1921. The start of the War meant that, in Europe, coach services had to be suspended as from 1942, in the context of fuel savings. Services began running again in 1946. The 1950’s and 1960’s introduced prosperous times for the coach industry. In the UK, the former 30 mph limit was increased to 40-50mph on open roads (The Glasgow Herald, 1961). Lower speeds had cut fuel costs, but the increased speed limitation decreased the labor time to go from point A to B and thus made productivity raise. Changes in the bus industry were mainly characterized by innovation, fuel efficiency and improved passenger comfort. For example: diesel-powered buses had become increasingly performant and were easier to maintain since the early 1950s (Carnes, 1981).

The bus sector after the 1950s

Employment in the bus sector in the 1950s dropped steadily and advanced capriciously through 1967, after which it declined to the present level. Occasional spikes in productivity happened in years where energy shortage levels occurred. It is noticed how rising gas prices affects global bus travel. People tend to get on a bus more often as the gas for their personal vehicle is getting increasingly expensive. This was observed both in 1974 and again in 1979. Buses generally operate at lower costs than air or rail travel and the speeds are similar to those of an automobile. Over short distances, this makes for the ideal mass

Fig.6: Child boarding a 1950s coach bound for Eastbourne.(source: bbc.co.uk)

Fig.8: GM Futurliners on route during the Parade of Progress (source: silodrome.com)

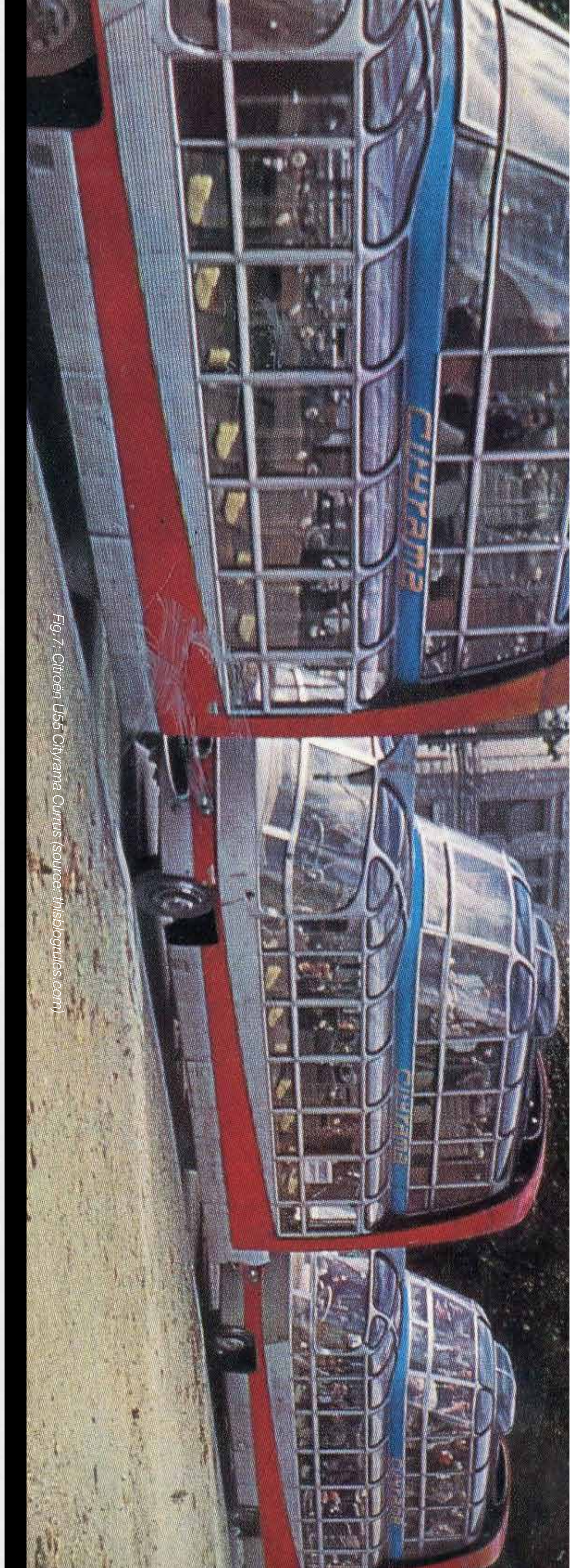


Fig.7: Citroën U55 Cityrama Currus (source: thisblogrules.com)

transportation vehicle.
In the US, the long distance coach sector regressed after 1980, partly due to governmnent subsidies to the AMTRAK rail-system. Still, statistics from 2007 suggest intercity buses carried at least over three times as much passenger miles as AMTRAK.

Present day and future

A 2007 study conducted by transportation experts suggested that the intercity buses industry was experiencing a significant revival (Schwieterman et al., 2007).
Between 2007 and 2010, in the US, the sector grew by an estimated 22 percent. This made the sector the fastest growing in the whole of the Unites States (O'Toole, 2011). It is interesting that this growth came without any government subsidies, in contrast to the vastly subsidized US railways: AMTRAK. According to a report by Randal O'Toole, "The recent growth in bus ridership was driven partly by the Internet, which helped generate a new model of intercity bus service." Formerly, bus charter companies held expensive bus stations in expensive downtown real estate. These stations came complete with ticket agents, luggage rooms, waiting rooms and luggage handlers. Under this new model, tickets are sold over the Internet, buses pick up people on park & ride zones in cities and luggage is handled by the driver of the vehicle. On top of that, intercity buses are nonstop nowadays, where they used to stop in only a few couple of cities over the years. The new model thus makes for very low overhead costs. Combined with competition, this reduced fares, which ultimately made bus transport accessible to more people. New as well for this new model of bus transport, is yield management for pricing. In the old days there was one fixed price for a trip. Nowadays the first seats of a trip are sold cheaper than the last ones. And still, the highest prices are significantly lower than train or airplane tickets (O'Toole, 2011).
Current predictions estimate a 40 percent growth of the sector due to fuel shortages which will shortly hit the market. As it was observed in 1974 and 1979, the sector benifits from scarce fuel on the consumer market. Buses are comparatively more fuel efficient than personal road vehicles due to the amount of people it carries at a time. Demographic factors will also prove to be a positive factor. Smaller households and an older population will generate new oppurtunities for the sector (Carnes, 1981).The industry would ignore a vast growing and lucrative market unless charter companies expand their service and make buses more accessible for this segment of the population (COST 349, 2006).

Altough these signs are great for the industry, it has to be taken into account that the sector has a history of low productivity growth, lack of demand and reduced profit. This will prove a serious obstacle for the ability to attract the capital needed to improve the future performance of the LDC segment (Carnes, 1981).

3.1.3 Coach concepts in the Golden Age

In the pre-war years, the 1930s, the Streamline Moderne design movement appeared. This era produced a lot of design innovation, all with its main characteristic of streamlined volumes and surfaces. On the far left is a picture of a GM Streamliner coach concept from 1936. Eight of these custom-made vans were built and used in the Parade of Progress in Lakeland, Florida.
In the years that followed, GM continued their Parade of Progress, which visited numerous cities in the US. The Parade brought along bus concepts such as the GM Streamliner and the GM Futurliner in the 1940s. The Futurliner was designed by Harley Earl and was used to display technological innovations such as microwaves and televisions at the time. Also in 1950, in Paris, the Citroën U55 Cityrama Currus (left) was conceived by tour operator Cityrama and coachbuilder Currus. In a time where optimism and future vision were ever present, this creation actually rode through the city frequently, transporting passengers. The styling of the bus was so outrageous - even at that time - it got featured in a number of movies such as *Le Corniaud* with Louis de Funès. The Citroën U55 Cityrama Currus was a double decker bus with almost every side wrapped in glass. The roof could even slide open to provide open air touring in the summer.

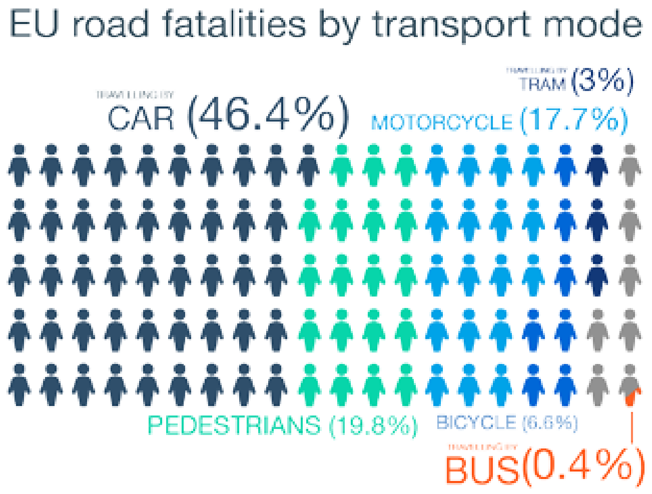


Fig.9: EU road fatalities by transport mode (source: EU CARE database 2012).

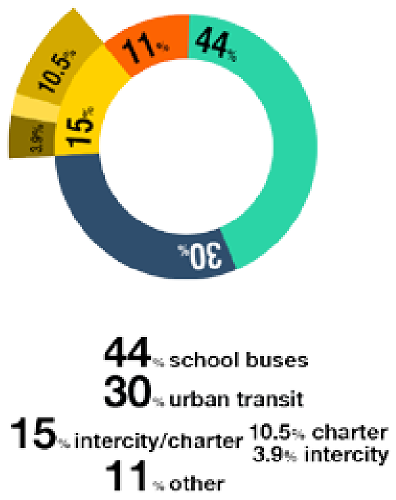


Fig.10: distribution of buses involved in crashes (source: Motor Carrier Type and Factors Associated with Fatal Bus Crashes).

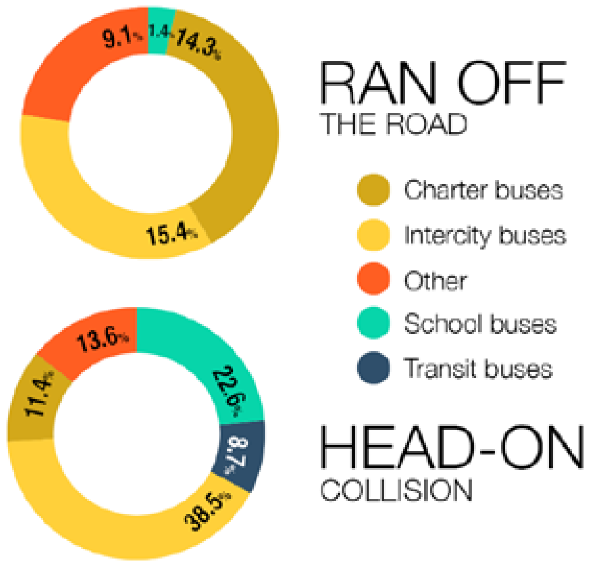


Fig.11: distribution of buses running off the road and colliding head-on (source: Motor Carrier Type and Factors Associated with Fatal Bus Crashes).

3.1.4 Safety issues

Safety Research Scope

For this thesis we will focus on the data of the intercity and charter/tour carrier type. In America, according to the University of Michigan, 15% of bus crashes are accounted for intercity/charter/tour buses. As this number is significantly lower than the fatalities for school buses (44%), safety improvements and innovations on intercity and/or charter buses can be interesting for school buses or other carrier types as well. Long distance coaches are the premier class of buses since they transport people in a degree of luxury unseen in other vehicle classes. This is why this type of bus should be the pinnacle of modern transport technology.

Coaches and Safety

Although a lot of decisive data is missing on coach crashes, fatalities and main causes of bus accidents, a study executed at the University of Michigan Transportation Research Institute states that 'the number of bus crashes is small in relation to other vehicle types' (Blower et al., 2004). This statement finds confirmation in the Final Report of the European Commission on Passenger transport by coach. The amount of coach accidents are only a small percentage of the totality of road accident fatalities in Europe: 2.5% in 2006 and according to CARE, bus casualties have been further reduced to 0.4% in 2009. The European document 'Traffic Safety Basic Facts' (2011) states that "the annual number of people killed in road traffic accidents (…) involving buses or coaches fell by more than 40% between 2000 and 2009 in EU-19." Even so, these figures are still significantly higher than permitted in the EC Statistical Pocketbook, which does not even include fatalities of pedestrians and occupants of other vehicles in crashes involving buses or coaches.

Safety per industry sector

There has however been an increasing effort on improving the safety of bus operations worldwide and gathering data of accidents in order to distil valuable information from past events. In the study mentioned above was the premise that there are different bus operating classes which can be associated with fatal carrier crashes. The substantial differences between the bus types are reflected in a lot of aspects of the crashes as they happen. These aspects being: "When and where the crashes occur, who is injured in them, the configuration of the crash, the previous driving record of the bus driver, and the frequency of driving errors related to the crash" (Blower et al., 2004). These findings make it clear that there is no discussing 'bus safety' without acknowledging the different segments of the passenger transport industry.

Safety Legislation

The amount of in-vehicle fatalities has continuously dropped since 1979 and has improved even further thanks to the introduction of EU legislation concerning the use of seat belts in cars, light vans and coaches (Directive 91/671/EEC) in 1991, which states that children under 12 years of age have to be restrained with a system suitable for the child's height and weight. This law was further extended in 2003, with the addition of mandatory seat belts in all minibuses and coaches. This legislation became national law by 9 May 2006 in most EU-countries (ETSC, 2006).

Working time and safety

Another aspect related to bus accidents is driver fatigue. For coaches, it is observed in various studies that driver fatigue is increasingly detected to be the cause of fatal accidents on high speed motorways, and this mainly in the early morning or towards the end of working days (European Commission, 2009). Time of day is the only noteworthy indicator of crash risks according to the CARE analysis (European road accident database). This in contrast with a study conducted in the US, which exposed a suspected link not only between driver fatigue and time of day, but with time of the year as well (Blower et al., 2004).

Driver fatigue may be more frequently the cause of accidents than the statistical data suggest (European Commission, 2009). It is very difficult to identify fatigue after a crash, as it is fairly straight forward to discover alcohol or drugs use (Blower et al., 2004). Driver error, either under the influence of illegal drugs or fatigue, is for intercity and chartered coaches higher than for any other type of bus. On top of that, the University of Michigan stated that intercity bus drivers also had higher proportions of violations or crashes on their driver records compared to other classes of buses and coaches. For comparison, over 12% of charter bus drivers had been suspended in the previous three years, compared to 2.1% for school bus drivers (Blower et al., 2004). This makes it somehow clear that a driver monitoring system and an electronic safety net is relevant when thinking about designing the LDC of the future.

The European Union acknowledges the importance of irregular driving shift patterns and the effects this has on driver fatigue during long distance transport. On the EC website under Mobility and transport, Road Safety, it's stated that 20-30% of accidents involving lorry drivers and coach drivers in Europe and the US are caused by fatigue. This forced the European Commision to strengthen driving and working time rules. It's now obligatory for lorry drivers to have a new generation of digital tachograph on board. This device records and stores all the vehicle's activity, speed, driving time and rest periods. The data on the devices can be checked by random road patrols and the lorry companies can be fined when the law is violated. The system should also help filling the current gaps in databases concerning road fatalities.

Long distance coach crashes

We have already established that coach crashes and fatalities are linked to the type of carrier and operations. For long distance coaches this means crashes mainly occur on high speed roads in the early morning or at the end of a working day. Long distance coaches are often used for tours in tourist places, which gets them to driving on local roads in urban areas as well. This makes for a higher amount of charter busses colliding with other vehicles in a head-on collision, compared to the intercity bus. Statistical information is scarce, but additional years of data-gathering should validate this relationship. As we take intercity and charter buses together for this project, head-on collisions are extremely relevant for the design of the 2030 LDC. Improvements on safety such as the introduction of seatbelts and laminated glass have drastically improved coach driver safety, as they were commonly ejected out of the vehicle before these safety standards were implemented. Still, the driver remains in a vurnerable position in the event of a head-on collision. This was painfully illustrated in the 2012

Sierre coach crash.

On the right, some still images taken from a Youtube-clip showing a frontal crash test of a 1999 MCI D-Series coach, executed by NHTSA (National Highway Traffic Safety Administration) in 2010. The initial impact speed of the coach was 35 miles per hour, which is only half the speed coaches commonly travel on a highway.
The results are nonetheless shocking: seat rows one to three were completely crushed on impact, leaving the drivers' compartiment unrecognizable. Overall, coach architecture and therefore structural safety hasn't changed much since this test was executed.

On the next page, an overview of the crash as seen from the inside. Some of the dummies had their seatbelts on, some others (blue shirt) did not. The effects of not wearing a seatbelt are clearly demonstrated: the blue dummy is literally catapulted out of his chair and hits the ceiling head-first, sustaining lethal injury. The seatbelts (2-point) did their job and held the 'passengers' in their seats, however all passengers hit their heads heavily against the seat in front of them. This results in heavy head, neck or spinal injury. This type of bus seats are not equipped with soft crash spots, so a collision with a seat is like hitting a brick wall. Another point of concern is that lights and the luggage compartment mounted on the roof completely desintegrated and fell down, hitting passengers on the head and upper body. A last observation from the crash is the amount of glass particles that is shot into the passenger cabin. These glass particles are sharp and can cause injury. All this accumulated makes for a very unhospitable wreckage that does not create an opportunity for safe evacuation.

This being said, the sector is steadily moving towards better safety standards, following the example of the personal car industry and the long distance freight truck industry. Of all automotive sectors, as told by E. Morelissen, Hybrid Team Leader at Volvo Buses (personal communication, Busworld Kortrijk, 21.10.2013), "The bus sector is the slowest adapting

Fig.12: still images taken from a Youtube-clip showing a frontal crash test of a 1999 MCI D-Series coach, executed by NHTSA (National Highway Traffic Safety Administration) in 2010.

and last of the automotive sectors to innovate". Therefore it will be useful to invest the safety equipment currently being introduced in the trucking sector, in order to be able to extrapolate which technology will be eventually be available for buses in the future. A brief internet research revealed that major truck companies such as MAN, Volvo and Mercedes-Benz are massively developing electronic driver aids specially for trucks. These electronic systems are closely related to those found on roadcars.
On another note, coach manufacturers are also investing massively in efficient drivetrains. Hybrid buses are slowly being introduced in the transit sector, as well as the use of fuel cell combined with electrical drive. This change is propelled by standards, set by the EU-government, to reduce emissions by up to 30% in 2020 (European Commission, 2007). Analists believe by then, plug-in electric vehicles (PEV) will become the standard and the European car fleet will evolve to being fully-electric or, at least, hybrid.
Powertrains, renewable energy sources and electronic driving aids will be extensively discussed in chapter 3.4 Technology.

Fig.13: still images taken from a Youtube-clip showing a frontal crash test of a 1999 MCI D-Series coach on the inside, executed by NHTSA (National Highway Traffic Safety Administration) in 2010.

Conclusions

In this chapter we investigated and defined the term 'long distance coach' (LDC), elaborated briefly on its history and created an image of how the current situation is with safety.

Buses come in many forms and sizes. We will only focus on the single-decker type which make long nonstop trips: the long distance coach.

The coach itself has a history with a lot of ups and downs. Nevertheless it rapidly proved a redoubtable opponent for railways, with its super-economic cost per passenger-mile. The arrival of the internet and online ticket sales erased the need for expensive infrastructure all together, which could crown the coach sector as the king of on-land travel. At least, in theory: the coaching sector has a history for low growth and innovation, which has it missing out on a lot of opportunities as they come. EU-legislation is pushing the automotive industry towards lower emissions, which will probably mean the end for low cost airtravel. Another big topic is the need for renewable energy sources. History has proven that fuel scarcity boosts the use of intercity bus travel. Emission rules and expensive fuel cost should theoretically create a window for coach companies to extend their services.

Statistically, buses are the most economic and safe mode of road travel. Improving safety even further is paramount if the future of the coach industry is to be a success. It is a fact that, when a serious crash occurs, the number of fatalities is significant. Statistics also show that intercity and charter buses account for half of the head-on collisions with buses. These accidents frequently have fatal endings, which stresses the need for even safer coach services.

THREAT	OPPORTUNITY
MOBILITY	
OVERLOAD	**SMART MOBILITY**
Roads clog up completely *On-land transport will be abandoned for travel purposes* *New transport modes threaten the use of a coach*	*Mobility gets smart and connected through a cloud service* *Coaches are subsitute for expensive aviation*
SECTOR	
DEFEAT	**SUSTAINABILITY**
The sector lives up to its reputation of slow innovation and profit-focussed approach	*Smart technology and efficient use of assets make for new ways to make profit and reduce GHG-emission at the same time*
TECHNOLOGY	
LOW TECH	**HIGH TECH**
Innovation and environmental design costs too much and reduces profit, nothing major changes and the sector slowly bleeds to death	*Technology merges the interests of humanity, ecology and economics, creating opportunities for eg. mobility*
POLITICS	
OBLIVION	**PUSH**
Railways and aviation get most of subsidies and land mass transport is forgotten *'The lost mode of transport'*	*Government subsidies help land transport sectors invest in durable and smart new ways to provide service*

3.2 How will society evolve?

When designing a product, it is directly influenced, defined maybe, by its context.
In the previous chapter, the need for affordable, safe and smart on-land transport was defined as a significant driver for the existence of the Next Generation LDC. We also discovered that mass transport has evolved over time. Where omnibuses were pulled by horses, now they are propelled by hybrid-electric power sources. The start of the evolution of coach transport was, around the 1910s, initiated by the arrival of railway systems, which operated faster than the horse-pulled omnibuses. This change of context thus forced the product 'bus' into making a radical change: it had to reinvent itself. This leads to the conclusion that analysis of social development is crucial as this will influence the LDC and general mobility into making changes, which will ultimately result in better transport.

"Slight changes in context can have a big impact on the acceptance of products"

Gladwell, 2000

3.2.1 Global forecasts

Demographics

One of the greatest drivers for change is the global demographic evolution. The United Nations have predicted that, by 2030, world population will reach an estimated 8.5 billion. Twenty years later, in 2050, the world will have welcomed an additional billion people (United Nations,

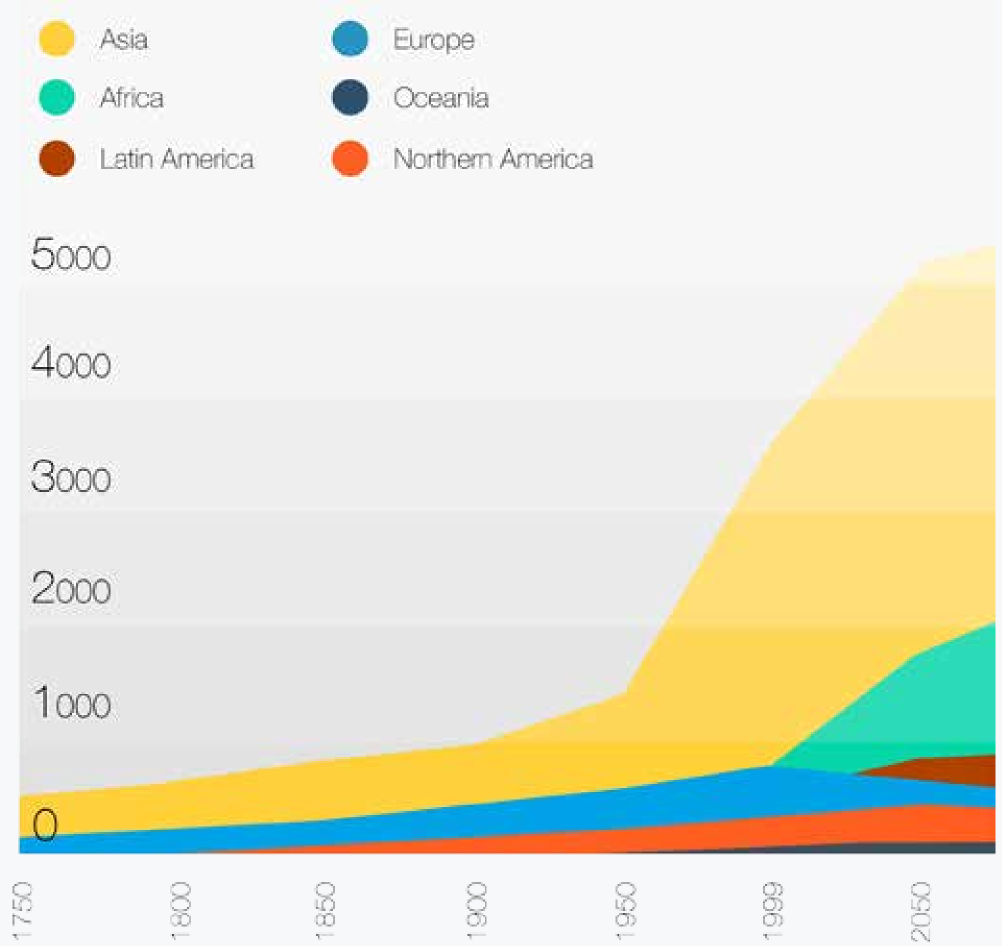


Fig.14: regional divergences in population growth 1750-2050, medium scenario (United Nations, 2011)

2012a). Compared to 2013, this is almost 2 billion people more. Of course these are predictions, be it the medium variant. The United Nations expects the majority of the growth to come from developing nations, such as Asia, Africa and Latin America. Developed nations will face an increasingly ‘old’ age structure. The population of these regions will grow a little or remain stable, relying on the effects of immigration. As fertility declines and people live longer, by 2050, it is expected that the number of people aged 60 will be equal to that of children aged between 0 an 14 (Weinberger et al., 2012).

This evidently poses some challenges for generations to come. Global economy will be affected by the ever increasing number of people living on the planet. More people means more mouths to feed and, according to Weinberger (2012): “an older population holds important implications for government policies, such as health care, pension schemes and economic growth.” Energy needs will rise as well: as households become smaller this can cause a doubling of the total global energy need (IEA, 2011).

All this is fairly concerning in the knowledge that planet Earth’s resources are limited. The WWF (2012) has predicted that we would need approximately four planets to fulfill our needs in the future (if the world would consume at the average rate of a US citizen). Since the 1970s humanity has passed the historic point at which our Ecological Footprint matched Earth’s annual biocapacity. This ‘ecological overshoot’ has increased ever since. As explained by WWF (2012): “An overshoot of 50% means it would take 1.5 years for the Earth to regenerate the renewable resources that people used in 2008 and absorb CO_2 waste”. This means humanity used an equivalent of 1.5 planets Earth to support their activities in 2008 (WWF, 2012).
Apart from the depletion of our renawble sources, greenhouse gasses (GHG) form a major threat to everybody’s lives. According to the IPCC forecast for global warming, even if the goals for GHG emissions are met by 2050, the average temperature on Earth will rise around 1°C (IPCC, 2007). This will result in flooding of lower areas on coastsides worldwide. Global warming will change the whole ecosystem of our planet, creating problems in food and water supplies. The negative effects are beyond imagination. Acting now is paramount if humanity wants to stand a chance of meeting the goals (i.e. Kyoto 2020 for GHG emissions) and limiting the damage already done to our planet. It is the task of our generation to think ahead, in order to understand what is at risk and how we can work together with our surroundings to make life better. Thinking ahead and creating future concepts with technology predictions is useful, as it gives direction to thinking processes. A future concept which addresses the many environmental issues can inspire an entire industry. Thinking has helped humanity get further for decades, it makes us able to tackle hurdles and it separates us from our fellow Earthly inhabitants in the animal kingdom. This is a great power which should be used to our advantage, but should be applied with great care and mindful for the resources we are given by nature.

Future Goals

The European Union has been a pioneer in international negotiations on climate change. A few organisations stimulated by the EU are for instance the UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. The aim is

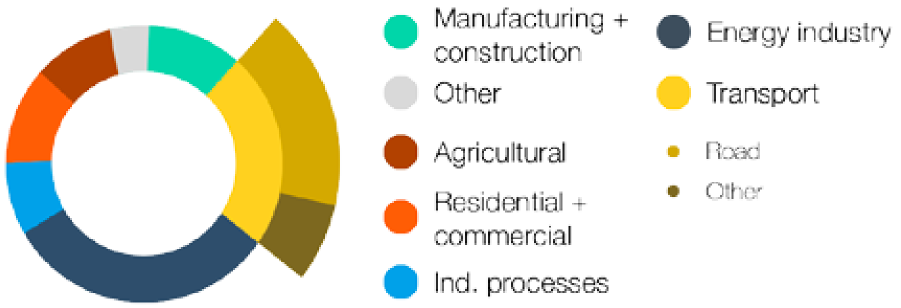


Fig.15: greenhouse gases emission by sector and mode of transport, 2007; no percentages given (European Commission, 2007)

to keep global warming below 2°C from the temperature at the time of pre-industrial times. Plans are set up to transform Europe into a energy-efficient, low carbon economy. The goal for 2020 is to bring emissions down by 20%, below 1990 levels. If other nations commit to undertake their share of emission reduction, the reduction could be increased even further up to 30% (European Commision, 2012 b).

For the EU, around a quarter of all GHG emissions comes from transport (fig.16). This makes it the biggest producer of GHG together with the energy sector. Interestingly, emissions for other sectors have been falling, while those from transport have increased by 36% since 1990 (European Commision, 2012 c). The transportation sector has become more efficient over the years, but an increase in personal and freight transport accounted for the rise in emissions.
Because of this, the EU has a programme of policies ready to make sure future emission goals will be met. For instance, a strategy is made to reduce the emissions from cars and vans. Mandatory tire pressure monitors on new cars should help make cars travel more economically and it is believed that by 2020, all new cars will be plug-in hybrids by default. Aviation has been included in the EU Emissions Trading System (ETS), which mean cuts in emissions for the following years. The aviation sector is vastly growing, so controlling emissions now is adamant. It is uncertain what the consequences will be for the aviation sector, but it is not entirely unthinkable that travel prices will rise, which would be - theoretically - in favour of the coach industry.

3.2.2 Urbanisation

Things will, however, be a little more complicated than depicted in the previous paragraph. Worldwide, urbanised areas will grow even bigger, resulting in mass air pollution and imposing major traffic issues to the already clogged up infrastructure. UN graphics (fig.16) show that the majority of urban population growth for the following 50 years is to be found in Africa and Asia, which is no surprise when fig.15 is taken into account: population growth is the largest in Asia and Africa (United Nations, 2011b).

Regional governments will have to come up with plans in order to make sure people can commute in and out of future metropolises. Infrastructures will have to be rethought and new modes of travel will have to be introduced. The use of cars in big cities is currently being discouraged and across Europe, Low Emission Zones (LEZ) and Zero Emission Zones (ZEZ) are starting to emerge. Low Emission Zones are urban zones in which specific polluting vehicles are banned, or in which only low emitting vehicles such as (plug-in) hybrids or fully electric vehicles (EVs) are allowed. ZEZs are LEZs in which all vehicles with internal combustion engines (ICE) are restricted. Around 70 cities across 8 countries in Europe have begun establishing such zones. The largest one in the category of LEZ is in London, which has one of the worst levels of air-pollution worldwide.

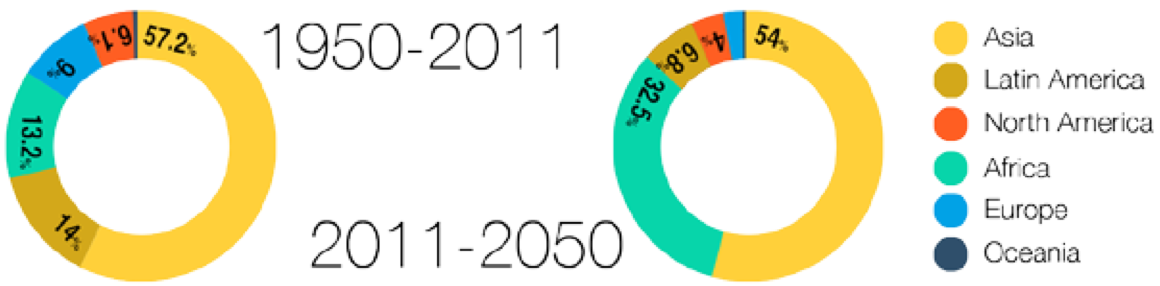


Fig.16: Increase in urban population by major regions, 1950-2011 and 2011-2050, percent of total urban increase (UN, 2011)

These solutions will only temporarily solve some of the traffic issues. Car manufacturers are nowadays starting to sell their first EVs which have an autonomy that ranges up to 200 km. In a matter of time, roads will reach over capacity once again. It is thus the task of urbanites, governments and visionaries to reshape the cities we work and live in. It is not entirely unthinkable that bike sharing services and public transport (bus, metro...) will take the upperhand in modern mega cities. Nowadays a lot of European cities have this bike sharing infrastructure in place and are preparing the next step: e-bike sharing.

In order to fight traffic jams and the ever increasing commuting time, companies will encourage working from home and introduce flexible hours. Cars will become more connected with each other and numerous online services: real-time traffic information will be accessible from the inside on the dashboard. All vehicles will be localizable, which will result in more accurate traffic and congestion predictions. Road signs will vanish and be replaced with in-vehicle signalisation. Cars will no longer equal freedom: speed limits will be tracked or imposed at all times, penalties will be given immediately without police intervention.

3.2.3 Future IC transport: the Shareway

Due to the complexity of the matter, two examples of future transport in and between future mega-cities will be discussed in this thesis. This will provide an image on how specialists see the development of urbanized areas and mobility in the future.

The first case study won the 2012 Audi Urban Future Award, a competition by the Audi Urban Future Initiative. The five international architecture firms which participated in this competition were briefed to visualize their home cities in the year 2030. The Audi Urban Future Initiative, as cited from their website, “aims to establish a dialogue about urban mobility and sustainable and enjoyable ways to move from one place to another” (Audi Urban Future Initiative, 2013). The oncoming mobility challenges are addressed collectively and within a multidisciplinary context. Audi believes this is the only way to meaningfully reflect on the future and the changes laying ahead.

The winning 2012 concept was conceived by Boston based Höwler+Yoon Architecture. This company reimagined the ‘highway’ concept and created what they call the ‘Shareway’. The Shareway effectively combines the I-95 corridor between Boston and Washington D.C., which is by then a megaregion called “Boswash”. The highway infrastructure in Boswash is well developed, but as the cities were each built seperately, there is minimal connective tissue and very little shared resources. The Boswash region, by then, counts over 53 million people. This makes the need for ultra efficient mass transport.

The Shareway is a way to bundle all existing modes of transport: high speed transportation trains, freight trains, commuter trains, personal cars, bikes and pedestrians. The multilevel track ensures that all transportation can coexist without forming traffic jams. It is designed in such a way that everyone can reach their destination at any given time, regardless of rush hours. During their commute, travellers can book cars based on the desired en-route activity they wish to do. A clever interface offers to choose between quiet, social or business cabins to ones specially designed for doing yoga or lectures.
The Shareway forms a sustainable eco-system: kinetic energy from braking commuter and freight trains is channeled to cars in storage. These cars are available for commuters when they reach their final station. The cars are in fact some sort of last mile transportation vehicle.

Höweler+Yoon Architects took the concept a little further from transit only. They introduced a concept called ‘Sharestay’. The model reduces the montlhy rent to an average of $10 per month, when residents only pay for the time they spend at home. This concept of house-sharing is, in Western world, some sort of foreign notion: taking strangers in your home is simply not done. However, Höweler stated that “the younger generation doesn’t have the same dreams we’ve inherited from our parents.” The younger generations don’t feel like they have to own anything and certainly don’t see buying a house is necessary in their lives.

The jury eventually had some trouble imaging time sharing a house, but acknowledged that “the Sharestay was an exploration to see how far you can take collective consumption” (coolhunting.com, 2012).

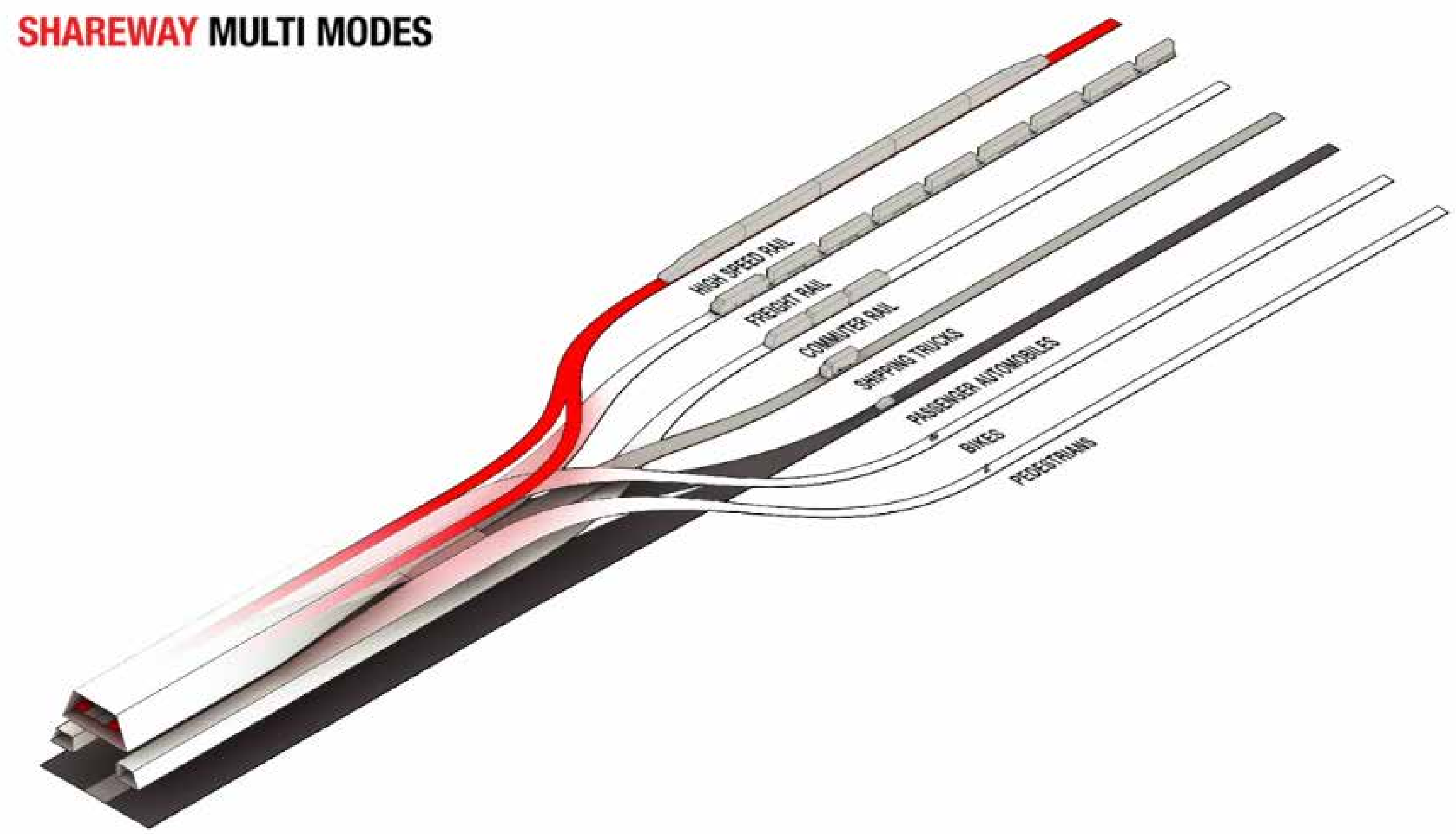


Fig.17: the Boswash Shareway Multi Modes scheme (source: Höweler+Yoon Architects)

Fig.18: the Boswash Shareway render (source: Höweler+Yoon Architects)

3.2.4 Future IC transport: the Hyperloop

The second case study presented in this paper is the Hyperloop, conceived by Elon Musk, known for his EV brand 'Tesla' and the SpaceX programme. To manage these businesses, Musk travels a lot between San Francisco and Los Angeles, and spends an awful lot of time doing so. And so, he invented a whole new, faster way to travel between cities: the Hyperloop.

The idea for Hyperloop was similar to the vacuum tubes used to shuttle the check from your car to the bank. Maintaining this level of vacuum over long distances is however a problem. Musk put a dozen engineers from Tesla and SpaceX on the issue to play with the concept. They created the concept with existing technology. The tubes get pressurized on the inside, and according to Musk's engineers, half a bar would suffice.

The aluminium capsules will travel through two tubes (one for each direction) with a velocity of 800 mph. This will make for a trip between LA and San Fransisco of 35 minutes. The tubes are elevated, which decreases environmental impact as farmers can still use their land. The enormous pilons will be able to withstand eartquakes with the same technology used in skyscrapers. On top of the tubes, solar panels will be placed. The total surface area of these solar panels will generate more power than needed for the system to run, thus creating an additional power source for citizens along the route. Cited from Wired Magazine (2013): "Inside the tubes, each pod would be mounted on a pair of skis made out of inconel — the same metal that SpaceX uses to handle high heat and pressure — with air being pumped through small holes in the skis to create an air cushion. Combine that with magnets and an electromagnetic field, and you've got levitation with very little drag."

Musk states that the Hyperloop pods could also transport cars and that the system will be able to regain brake energy from decelerating pods. The system could be made in reality in 3 to 4 years if someone would endorse the project: the Hyperloop is based on current day technology (Wired, 2013).

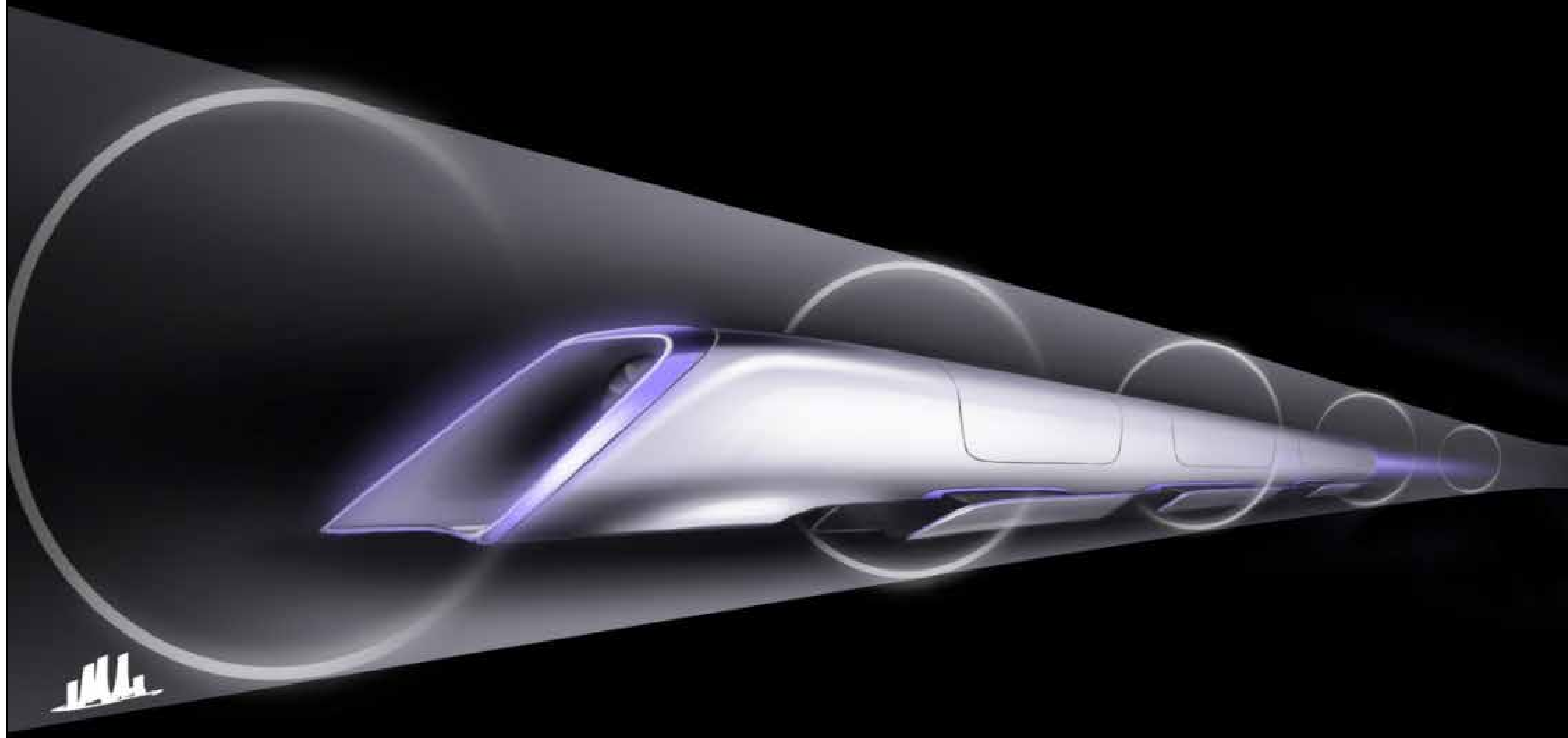


Fig.19 and 20: Elon Musk's Hyperloop rendered images (source: Wired.com)

3.2.5 The future of holiday travel

Travel can make regions flourish and develop, and makes peoples lives richer and more diverse. Experts believe that spending on experiences makes people happier than spending on stuff. Where all this is great and favourable, the world of travel is facing a couple of dilemmas. The growing environmental awareness is starting to protrude to the global travel industry, with aviation accounting for a large share of carbon emission and global warming.

The desire of people to visit foreign cultures will have to be put alongside a conscience that calls for a reduction in carbon emissions. Travel agencies are currently debating around these issues in order to ensure a sustainable future for travel and tourism. For that, a vision is needed.

Trophy-tourism

In 1971, the first low cost carrier airplanes emerge. Low cost aviation made long distance travel accessible to more people. This led to a general believe that travel is about jetting off to sunny destinations packed with sand, sea and souvenirs. For the majority, travel became a race to "tick off trophy experiences and destinations" (Francis, 2012). This phenomenon was reinforced by the rise of social networks such as Facebook, Twitter, Instagram... A person's cool-factor is often determined by the amount of 'hip' places he or she has been visiting, according to the many photos shown on their social network profiles. Social media reinforced this behavior, but was not the cause. Showing off photos and passport stamps have always been a human characteristic. In many Western countries, travel has become a symbol of wealth and status.

Nowadays, travellers are focussed too much on the 'where' in contrary to the 'why' and 'how' of their choice of destination. It is as if people don't even take the time to listen to their inner-self to decide the location of their travel. Travel in the sense of 'holiday' ought to be organised so that a person's batteries can 'get recharged'.
All this may be at the brink of a revolutionary change: the cost of flying continuously increases as aviation fuel cost rises, taxes increase and emission rules are imposed. In society, a feeling of 'carbon-guilt' will gradually set in. People will no longer feel completely comfortable to brag about their expensive overseas holidays, as they increased their carbon footprint. This is believed to cause a shift in travel habits: as the 'where' of holidays is limited by carbon-guilt or extreme costs, the 'how' and 'why' can suddenly become more important. Travel in the future will be travel with a purpose, balanced with the personal needs and those of the destination.

Deep-travel

Deep-travel is, just as carbon-guilt, one of many buzz words in sustainable tourism. The change of travel-purpose will invoke a new way of travel often referred to as 'deep-travel'. Deep-travel is about getting under the skin of a place. Cultural authenticity is already a requirement for holiday destinations, but travel in 2020 and beyond will go further. Details and local distinctiveness will be brought to the forefront. People will try and get to the special unique elements of a place which makes it distinct from other geographic areas.

Future transport for holidays

Due to the issues the aviation sector is facing, travel will undergo an evolution parallel to the slow-food movement (Francis, 2012). The journey towards a destination will gain importance and will ultimately be as significant as reaching the destination itself. People will enjoy the journey, not endlessly strive for the next destination. This changing mindset will bring new or vastly improved modes of transport. Trains and timetables will improve, railway tickets will be bought through an international website linking all fast trains between countries.
New websites will offer to choose between various travel routes, which allows travellers to select the lowest-carbon emissive route.

Travel and global warming

Climate change poses a threat to every aspect of life on Earth, and this is no different for the travel sector. The effects are in fact already visible, with aviation productivity threatened by emission regulations. Shifts in climate will cause extremely high temperatures in, for instance, Southern Europe. These areas will thus lose vital revenues in July and August, when Northern Europeans ignore what once was their summer holidays refuge.

In many countries, global warming will cause changes in water supplies, crop failures, etc... These factors will lead to mass migrations and political instability in areas that depend on tourism the most (Francis, 2012). Coastlines will flood as sealevels rise, forcing areas to change their tourism-focus. The traditional holiday destinations will gradually disappear and tourist seasons will shorten due to extreme weather events.

Certain effects on climate change can be predicted, which should allow destinations to proactively plan ahead in order to attract the right type of tourists and travellers, in a sustainable and cost-effective way. The same goes for transport modes which get tourists to their destinations. The interlinkage between climate change, detinations and travel will result in a smarter travel world in which great attention is given to carbon emissions and optimalisation of personal interests and economic benefits.

Geo-local travel

The mindset of travellers worldwide will alter over time. As mentioned before, low cost aviation will disappear or at least diminish. At the same time, we established that the relapse of long-haul air transport will be actuated by carbon-guilt. These factors introduce the term 'geo-local travel'. People will look closer to home for places to spend their holidays. Trans Atlantic travel will become less frequent: holidaymakers will begin to travel more within their home countries, regions or continents. This is a change that can already be observed in India and China: hotels that once hosted Western tourists now see the amount of domestic guests steeply incline, to the point in which it overtakes the number of foreigners.

Within this geo-local travel trend, it is believed and predicted that hotels will increasingly get their employees, materials, products... from local sources within a radius of ten kilometres. Guest will also pay for the exact amount of energy and resource they consume during their stay at a hotel. This is somewhat analogous to the Sharestay concept discussed on page 24: people get charged for the time they use a space or certain resources. This will ultimately raise societal environmental awareness. Other than with the Sharestay concept, tourists in hotels can be offered discounts as they keep their energy and water usage below a given average.

Conclusions

In this chapter we investigated the social context of the LDC. Firstly, in order to get sufficient insight into current and future socio-demographic issues, global forecasts on demographics were addressed. Secondly, we explored the future goals set by governments, in order to protect the environment for future generations. Thirdly, urbanisation was briefly cited, along with two case studies dealing with the themes of urbanisation and future mobility. Finally, a brief future of travel and tourism was discussed.

With a growing and ageing population, planet Earth is reaching its capacity limits. Developing nations will account for the largest share of population growth, as the Western population will remain the same. More citizens means increased use of resources and energy needs. Goals are set for diminishing GHG-emissions by 2020 and 2050, however it is unlikely so far that these standards will be met in time.
Growing populations poses great issues and challenges for urbanised areas, as ever increasing traffic leads to longer commuter trips. These problems make it relevant to reflect about new ways of travel and transport. The Boswash Shareway and the Hyperloop are only two examples of what might be possible solutions for the future.

Travel will experience major changes propelled by growing environmental awareness. Trophy-travel will reach its end and will be replaced by deep, geo-local travel. People will look closer to home for places to spend their holidays. Trans Atlantic travel will become less frequent: holidaymakers will begin to travel more within their home countries, regions or continents. Carbon-guilt will make for tailored travel, beneficial for both tourists and destinations. The world is already moving slowly towards sustainable travel. Emission regulations in aviation will presumably push this trend forwards into the next generation.

THREAT	OPPORTUNITY
DEMANDS	
OVERLOAD	**SUSTAINABLE TECH**
Earth's limits exceeded *Scarce resources and climate change result in wars* *Cities grind to a halt due to ever growing traffic issues*	*Solutions for resources, energy, ageing population* *Worldwide elevation of living standards*
CLIMATE	
DEFEAT	**SUSTAINABILITY**
GHG-emission standards fail to meet premised goals *Sustainability equals costlier infrastructure* *Destinations lose market* *Extreme weather events cut in on tourist season revenues*	*Solutions for resources, energy, ageing population* *Worldwide elevation of living standards* *Solutions for sustainable tourism, living and mobility* *Geo-local and deep travel*
TECHNOLOGY	
LOW TECH	**HIGH TECH**
Larger issues prevent ecology to be addressed and solutions to be implemented *Sustainable technology is not profitable and is left behind*	*Technology merges the interests of humanity, ecology and economics, creating opportunities for e.g. mobility*
POLITICS	
FIXATION	**PUSH**
Costs rise as regulations need to be met *Subsidies for breakthrough technology is cut to a minimum* *Governments lose interest in pushing economics into sustainability*	*Governments continue to push industries worldwide into designing better ways instead of cheaper ways*

3.3 What defines LDC use(rs)?

The maximum weight for coaches is regulated by European government: the weight limit for three axled coaches is fixed on 26 tonnes (with air suspension). Although these rules exist, they are commonly and consciously ignored. In this chapter we try to uncover why it is that touring coaches are often too heavy and what impact it has on general use. Or, whether it has something to do with different purposes given to touring coaches. In the previous chapters, we uncovered what changes can come from societal development: we established that a product is defined by its context. Context is shaped by change and societal development. A product cannot be seen without the user. The relation between these actors is a symbionic circle, as each party influences each other. The user influences the product by using it, and the product influences the user by its existence. It is a given that coaches are the most efficient on-land travel mode when loaded at full capacity. This may well be the sole reason for coach use. In this chapter we will elaborate briefly on the general use of the LDC.

3.3.1 Macro and micro level

In order to better understand the bigger picture of touring car use, the subject will be devided into macro and micro levels. Macro levels will explore general LDC use, micro levels the more product-specific use.

Given the time buses are present in our society -for over a century- the relation between the coach and its user has defined a context. Mobility and travel have been shaped by this context.

3.3.2 Macro level

The general use of coaches can be grouped by trip types. Most sources define the following five types: domestic occasional service, domestic regular service, international occasional service, international regular service and airport feeder service. The latter is part of a multimodal transport chain, which takes care of short trips from and to the airport and certain final destinations. This is defined to be an occasional service.

The following definitions are derived from “Council Regulation (EC) No 11/98 of 11 December 1997 amending Regulation (EEC) No 684/92 on common rules for the international carriage of passengers by coach and bus”:

“Regular services” means services which provide for the carriage of passengers at specified intervals along specified routes where passengers are picked up and dropped off at predetermined bus stops. Regular services are open to all, subject, where appropriate, to compulsory reservation. The regular nature of the service shall not be affected by any adjustment to the service operating conditions. Regular services require authorisation.

“Special regular services” means regular services which provide for the carriage of specified categories of passengers, to the exclusion of other passengers, at specified intervals along specified routes where passengers are picked up and dropped off at predetermined stopping points. Special regular services include: (a) the carriage of workers between home and work;
(b) carriage to and from an educational institution for school pupils and students;
(c) the carriage of soldiers and their families between their homes and the area of their barracks.
The fact that a special service may vary according to the users’ needs does not affect its classification as a regular service. Special regular services do not require authorisation if they are covered by a contract between the organiser and the carrier. The organisation of parallel or temporary services, serving the same public as existing regular services, requires authorisation.

“Occasional services” means services which do not fall within the definition of regular services, including special regular services, and whose main characteristic is that they carry groups constituted on the initiative of a customer or of the carrier himself. The organisation of parallel or temporary services comparable to existing regular services and serving the same public as the latter shall be subject to authorisation in accordance with the procedure laid down in Section II of Regulation (EEC) No 684/92. These services shall not cease to be occasional services solely because they are provided at certain intervals. Occasional services do not require authorization.

3.3.3 Micro level

It is increasingly observed on road checks in Europe, that touring coaches often exceed the maximum weights at full capacity. 25.5% of European tested vehicles exceeded the weight limit for one or more of the max. wheight indicators. Some single-deck 2-axle buses even are already too heavy when used at 2/3rd capacity (Schoemaker, 2007).
Part of the problems are due to a lack of definition in the European legislation sector. The definitions are off and harmony is missing. For example: in certain countries, only a half-full fuel tank is considered to be included in the total standard mass of the vehicle. The additional half tank of fuel and full water tank is considered “additional load”.
On top of that, Schoeman (2007) argues that “vehicles have become significantly heavier due to the application of environmental and safety-related technical legislation (...) and the installation of comfort features.” The table on this page shows the added vehicle mass in compairison to the previous two decades. The problem is that the majority of 2-axle coaches had an empty weight which was 72% of the total maximum allowed weight (18 tonnes).
Added with the following conclusions, also by Schoeman (2007), it becomes painfully clear why buses are overweight: by cause of demographic evolution and new travel patterns, passengers and their luggage have become heavier: “The study shows that the average passenger weight is 75 kg. This is 7 kg higher than the 68 kg laid down in the EU Directive 97/27 on masses and dimensions.”

It is thus safe to conclude two factors need rework badly: coach builders have to approach and make the switch to lightweight, hightech materials and structures for their vehicles, and the demographic data in the EU Directives about vehicle mass need revision. Accurate legislation is a first step towards increased efficiency and, in this case, environmental awareness. As vehicles are overweight and tire pressures are not within the advised range, it is possible that buses use more fuel than would normally be the case.

Item	Situation 1980-90's	Current situation	Additional weight
Engines (Euro I, II, III)	260	400	140
Engines (Euro IV, V)	260	100-300	40
Noise reduction	15	50	35
Retarder and brake systems	70	200	130
Strength of the body (UN R 66)	110	200	90
Safety belts and superstructure	80	200	120
Double glazing	200	220	20
Toilet, water tank, kitchen, comfort	300	450	150
Total (Euro I-III)	1,035	1,720	685
Total (Euro IV & V)	1,035	1,420-1,620	485-585

Fig.21: Increase of empty weights of coaches through time (source: IRU and several vehicle manufacturers)

Conclusions

In this chapter we defined the macro and micro use of coach transport.

The general use of coaches can be grouped by trip types. Most sources define the following five types: domestic occasional service, domestic regular service, international occasional service, international regular service and airport feeder service.

Touring coaches often exceed the maximum weights at full capacity. 25.5% of European tested vehicles exceeded the weight limit for one or more of the max. wheight indicators. Some single-deck 2-axle buses even are already too heavy when used at 2/3rd capacity. Interesting to note is that vehicles have become significantly heavier due to the application of environmental and safety-related technical legislation and the installation of comfort features. This adds to the fact that people and their luggage have become increasingly heavy over time.

It is safe to conclude that a switch to lightweight, hightech materials is needed in order to reduce empty vehicle mass.

THREAT | OPPORTUNITY

DEMOGRAPHICS

HEAVY WEIGHT
People and their luggage get increasingly heavy, putting stress on infrastructure and the environment

NEW SPECS
Changes in demographics make for a new set of vehicle weight rules, benificial for the transport sector, allowing for more room to play with

TECHNOLOGY

LOW TECH
The coach sector lacks initiative and resources to implement new technology- nothing changes

HIGH TECH
New materials and smart solutions will help bring the standard weight of coaches down
New road materials allow higher vehicle weight

POLITICS

FIXATION
The government forces coach builders to increase weight even further, trying to reach environmental goals

HEALTHY LIVING
Governments promote healthier living in a bid to decrease average population weight
The rulebook gets adapted, coaches are not longer on the verge of being overweight
The government forces coach builders to increase weight even further, trying to reach environmental goals

3.4 How will technology evolve?

Technology is one of the main enablers of products. It has often occurred that ideas arise and remain just that - ideas - for long periods of time, because technology is not ready at the time the idea is conceived. This happened for instance with the invention of the laptop computer: around 1983, Steve Jobs fantasized about portable computers the size of books, easy to take with you and accessible to everyone. At the time he predicted it would take about 20 years for technology to catch up with the idea. He proved right, when in 1999, Apple presented their clamshell iBook (Isaacson, 2011). It goes without saying that products are characterized by the technology available at their time. We established before that the first Omnibuses in 1848 were pulled by horses, as, at the time, there was no engine small enough to fit in a coach. The continuous improvement of technology ensured that, over time, buses became better, more efficient and safer.

Technology enables a product to perform as desired. Over the last century, oil based internal combustion engines (ICE) made up the stacking order. Today, at the dawn of a new energy era, the search for a durable energy source that transforms energy into motion was never greater. The first hydro-electric or hybrid-electric buses are starting to emerge, in a bid to contain the damage GHG-emissions have already done to our ecosystem.

This chapter will elaborate on the challenge laying ahead in selecting a desired power source for future long haul transport and how traffic will become safer thanks to electronic aids.

3.4.1 The engineering challenge

Engineers, designers and urbanites are facing a number of challenges on the long term: growing demands for energy, climate change due to GHG-emissions and clogging up of road infrastructure. The increasing energy demands are top priority along with the deminishing of GHG-emissions. According to IPCC (2007), 13% of all GHG emitted worldwide is accounted for by the automotive industry. It is expected that by 2050, car sales will rise approximately to about 180 million a year (IEA, 2012). By then, the car fleet will have doubled to about 2 billion cars (Kauw, 2012). These numbers taken into account, GHG-emissions from cars will double if emission standards won't drastically improve.

To avoid this from happening, governments have their instruments in place, as discussed in 3.2 Society: Future Goals. The European government is aiming to drastically reduce the GHG-emissions of their fleet. China as well is thinking about taking action.

Fig.22: distribution of GHG-emissions worldwide (source: IPCC, 2012)

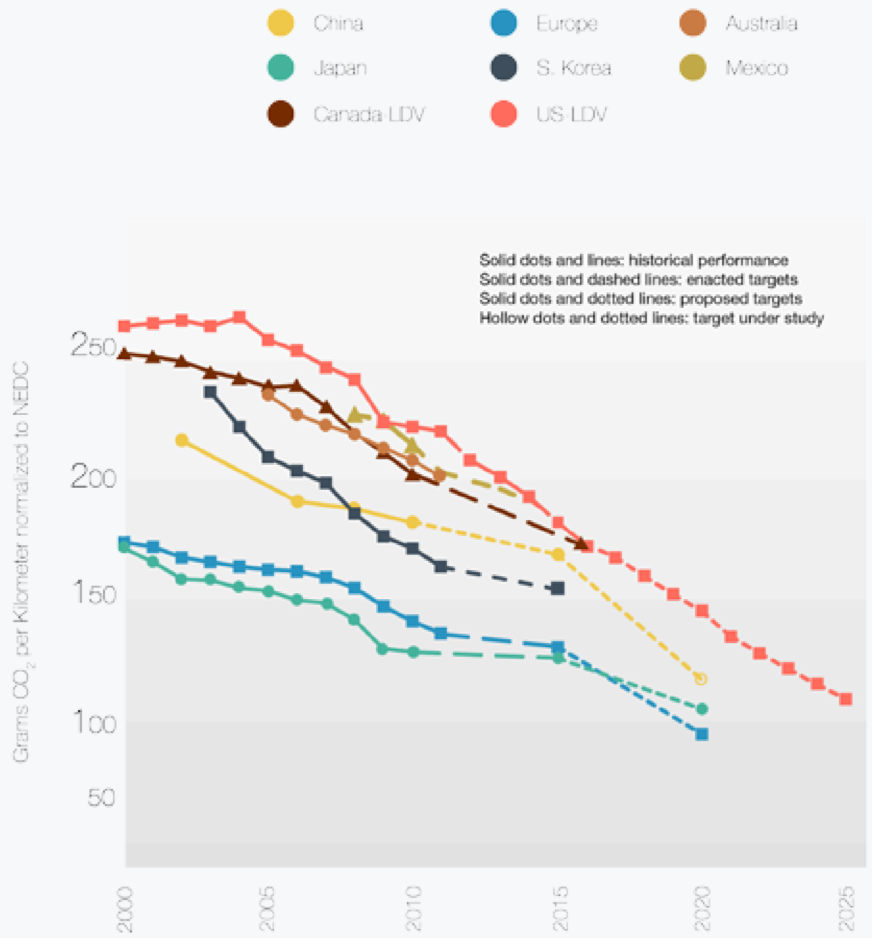


Fig.23: Global comparison of car CO2 emission standards (source: ICCT, 2012).

The graph above shows a comparison between nations worldwide and how their emission standards evolved over time and what is to come in the future up to 2025. It clearly shows the pioneering role the EU has taken upon. If the current EU trend is extrapolated to 2030, chances are the European Union is aiming at a zero emission goal. In fact, the White Paper on Transport (European Commission, 2011) states all ICE cars will be banned from entering cities by 2050. This in order to stimulate consumers and car manufacturers to make the shift to EVs.

Freight transport and touring coaches are not immune in this search for sustainability. 2013 marked the introduction of the EU6 emission standard for buses. Coachbuilders are even trying to be ahead of the emission reducive trends and try to produce engines that even outdo the new EU6 standard. A lot of experiments on hybrid and fuel cell buses are going on and are being tested in cities all over the world. This is only a logical step as a big change in technology is needed if the 2050 goals are to be met. More on this topic is discussed further in this chapter. Due to a lack of information concerning touring coach transport, the effects of emission goals will be discussed with information for the car sector. This is relevant because it stimulates innovation in the long haul freight and transport sector.

The effects on GHG emissions with the doubling of cars as said on the previous page, is, of course, not representative if future goals are taken into consideration. Based on these goals, the International Energy Agency (2011) formulated a couple of scenarios in their Baseline Scenario (next page, Fig.24). The BLUE Map predicts a 50% drop in carbon emissions of new cars compared to 2005. Given the challenge ahead, a change in powertrain is inevitable if tailpipe emissions are to be history. A number of technologies is available or under development, but not a single technology to date is perfect. Today, our energy

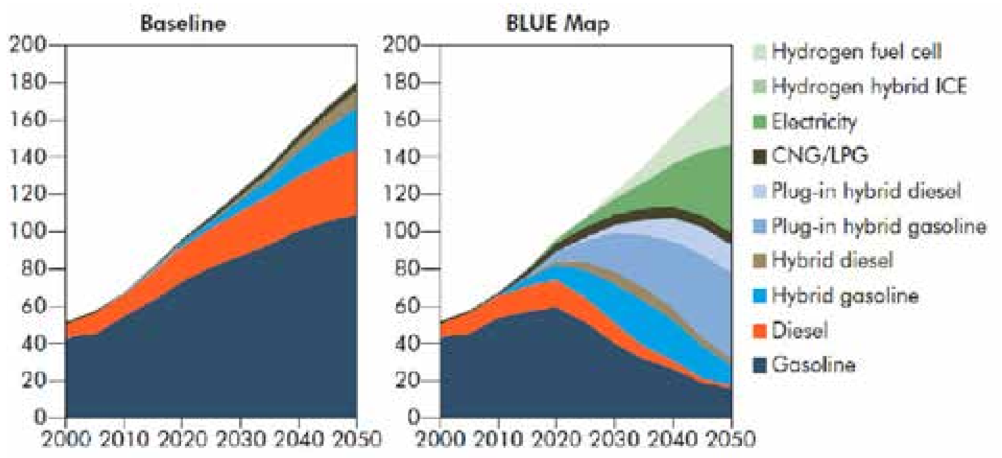


Fig.24: Global cars sales (millions/year) by technology type and scenario. The BLUE Map scenario predicts a 50% reduction of carbon emissions by new cars (Source: IEA, 2011)

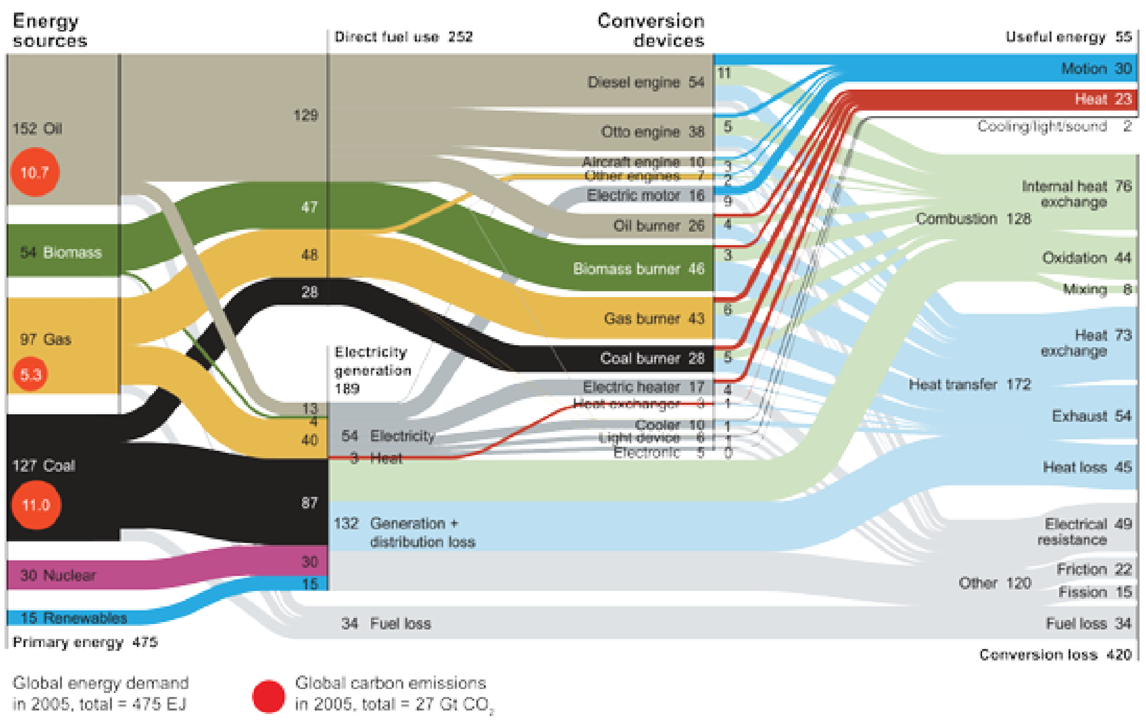


Fig.25: Global cars sales (millions/year) by technology type and scenario. The BLUE Map scenario predicts a 50% reduction of carbon emissions by new cars (Source: IEA, 2011)

production is not as efficient as desired. For electricity as well as the production of hydrogen, the advantage of having a fleet of EVs is second to none if production methods of the two latter won't get more efficient. In a study conducted by Cullen and Allwood (2008), it is said that "4/5th of primairy energy is lost in the current global energy system. In this system, the efficiency of ICEs is 12% in comparison to 17% for EVs."

The worrying conclusion of a study made by Davis et al. (2012) is that the sources of most threatening emissions have yet to be built, as current energy infrastructure will be outdated by the time we reach the IPPC's scenario window. The graph on this page shows "the decline of carbon dioxide emissions in gigatons (billions of tons) from existing energy and transportation infrastructure (red wedge) over the next 50 years, compared to three emissions scenarios (dotted lines) from the Special Report on Emissions Scenarios" (Davis et al., 2010). So it is clear that current methods of production won't be sufficient to provide in the needs of future energy supply, and that this infrastructure is not built to meet the future emission goals set by our governments.

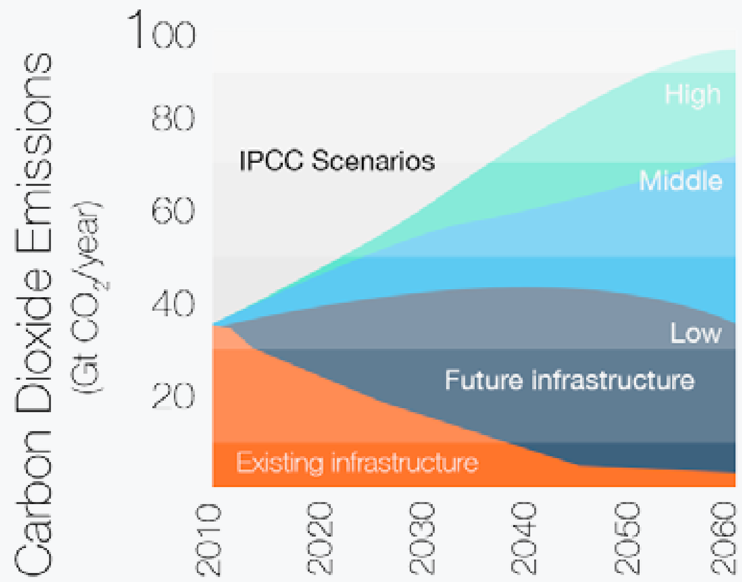


Fig.26: Graph shows the projected decline of carbon dioxide emissions in gigatons (billions of tons) from existing energy and transportation infrastructure (red wedge) over the next 50 years, compared to three emissions scenarios (dotted lines) from the Special Report on Emissions Scenarios (SRES) Intergovernmental Panel on Climate Change (IPCC). High, middle, and low emissions projections correspond to the SRES A1G-FI, A2, and B1 scenarios, respectively. (Source: IPCC)

3.4.2 Technology development models

Technology constantly evolves and the ability to predict these (r)evolutions will be of much help during this thesis. A number of theoretical models are at our disposal. We will discuss two methods on technology evolution foresight. The first one is extrapolation of historical data, the second is the analysis of goals and expectations of state of the art R&D.

Fig.27: Wikipedia: "An Osborne Executive portable computer, from 1982 with a Zilog Z80 4MHz CPU, and a 2007 Apple iPhone with a 412MHz ARM11 CPU. The Executive weighs 100 times as much, is nearly 500 times as large by volume, costs approximately 10 times as much (inflation adjusted), and has 1/100th the clock frequency of the smartphone." (source: Casey Fleser photography)

The first method, extrapolation of historical data, can not be discussed without mentioning the Law of Accelerating Returns (Kurzweil, 1999). Kurzweil's book 'The Age of Spiritual Machines' describes the way evolutionary systems have a tendency to develop in an exponential rate during time. The Law of Accelerating Returns was further elaborated on in an eponymous 2001 essay. Kurzweil argued for the extending of Moore's Law to describe a variety of technological progress, instead of just focussing on integrated circuits. Kurzweil believes that, when a certain technology reaches a barrier in its development, a new technology will be invented to help solve the barrier problem. A citation of the begin of the essay:

"An analysis of the history of technology shows that technological change is exponential, contrary to the common-sense 'intuitive linear' view. So we won't experience 100 years of progress in the 21st century—it will be more like 20,000 years of progress (at today's rate). The 'returns', such as chip speed and cost-effectiveness, also increase exponentially. There's even exponential growth in the rate of exponential growth. Within a few decades, machine intelligence will surpass human intelligence, leading to the Singularity—technological change so rapid and profound it represents a rupture in the fabric of human history. The implications include the merger of biological and nonbiological intelligence, immortal software-based humans, and ultra-high levels of intelligence that expand outward in the universe at the speed of light." (Kurzweil, 2001)

As briefly mentioned in the previous paragraph, there is some public confusion between Moore's Law and the Law of Accelerating returns. Many people, scientists or futurists refer to Moore's law as 'the law which predicts the development of all kinds of technolgy'. Moore's Law states that the number of transistors on integrated circuits has doubled every two years, taken over the history of computer hardware. The prediction was first made by Intel co-founder Gordon Moore and proved to be accurate. Interesting to note is that this accuracy partly comes from the implementation of Moore's Law in target setting for R&D in the computing sector (Disco et al., 1998).

It is believed that the exponential technological improvements will lead to technological singularity: a time with almost continuous improvements (Kurzweil, 2005). The expectations are that by 2020 the improvement curve will steepen and not increase exponantially anymore (Kanellos, 2005). Kurzweil however argues that new technologies such as quantum and DNA computing will replace integrated-circuit technology and ultimately keep Moore's Law alive for years after 2020 (Kurzweil, 2001).

The second technology forecast methodology is the Hype Cycle, developed by Gartner Consulting. The Hype Cycle is a graph which shows the adoption curve of new technologies.
The first phase is a potential technology breakthrough which kicks things off. Early proof-of-concept and media attention triggers interest in the technology. At this point it is still unproven whether the new tech is viable for commercial succes.
The second phase is the initial enthusiasm when a new technology emerges. Some companies adopt the technology and give it a chance, others ignore it for the time being.
The third phase is characterized by a decline in interest as early experiments and investments fail to deliver. The only way for these investments to conitnue is if the product/service is improved and approved by the early adopters.
The fourth phase sees a 'slope of Enlightenment'. As the technology is better understood, companies are starting to understand the added value that can come from the technology, and they start to understand how it can be commercially implemented. At this point, products are in the second or third generation.
After this, the fifth phase begins: the mainstream adoption. The relevance and applicability of the new product is starting to pay off, helped by a beter understanding of the criteria for provider assessment viability (Gartner, 2012).

Different technologies can be set out on this generic curve. The Hype Cycle is a tool to understand in what phase a new technology is in. In reality, the length of the curve varies by technology. A lot of new technologies require up to ten years of development before a commercial breakthrough can be realized (Gartner, 2012).

The two models presented on these last two pages make it clear that technology improvement can be achieved through planning, whereas the Hype Cycle shows the time needed for technology to actually be significant for society is not to be underestimated. No technology is an instant hit as everything needs time for perfection and finetuning.

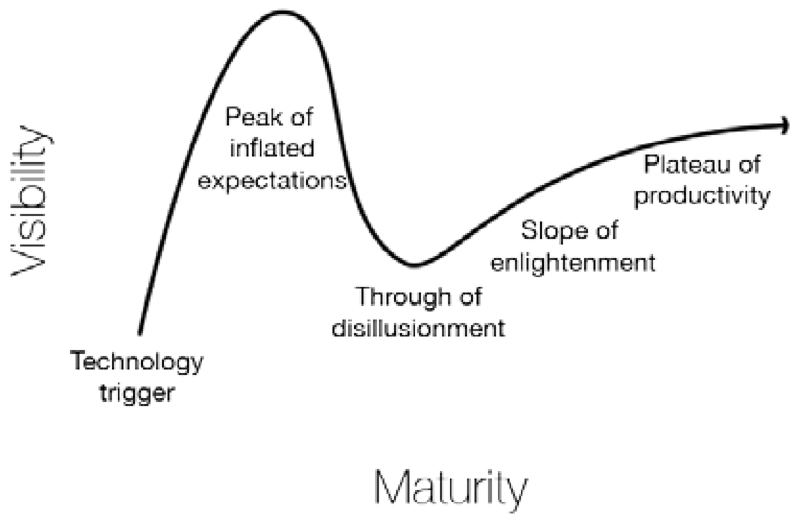


Fig.28: The Hype Cycle of new technolgy (source: Gartner, 2012)

3.4.3 Future technologies

Today, product designers imagine products based on current-day technology. Without technology, there is no product development. Technology has the power to change the way we think of solutions for certain problems. Some of this technology is being developed as we speak: for instance, at Volvo Cars Group, there is a lot of innovation around eco-friendly mobility and safety going on. The technology discussed on this page is the result of a EU-funded 3.5-year project with Volvo Cars Group, which goal is to develop a prototype material which can store and discharge electrical energy. The material also has to be strong and light enough to be used for car parts. Volvo Cars Group has developed two parts to examine the technology: a trunk lid and plenum cover made out of a nanomaterial. This material consists of extremely thin carbon fibre, which should ultimately replace the car's steel body panels. The idea is that, as illustrated below, to reduce car weight from battery packs, the car's body could be used to store energy in. This would effectively reduce the amount of battery packs or increase the driving range of an EV.

Volvo Cars Group states that at this point, a car's weight can be reduced by up to 15%, with still a large margin to cut weight even further. The range of the EV when doors, roof and bonnet are replaced is 130 km. This is 85% of the normal range of cars with conventional lithium-ion battery packs these days.

The materials used are carbon fibre and polymer resin, combined into an advanced nano material, and supercapacitors. The material can be molded into any shape, to fit the car's bodywork and design perfectly. In one of the papers related to the subject, it is stated that producing truly multifunctional composite materials is the route to follow for the future, as these materials would "simultaneously and synergistically provide structural and electrochemical energy storage functions" (Qian et al., 2013).

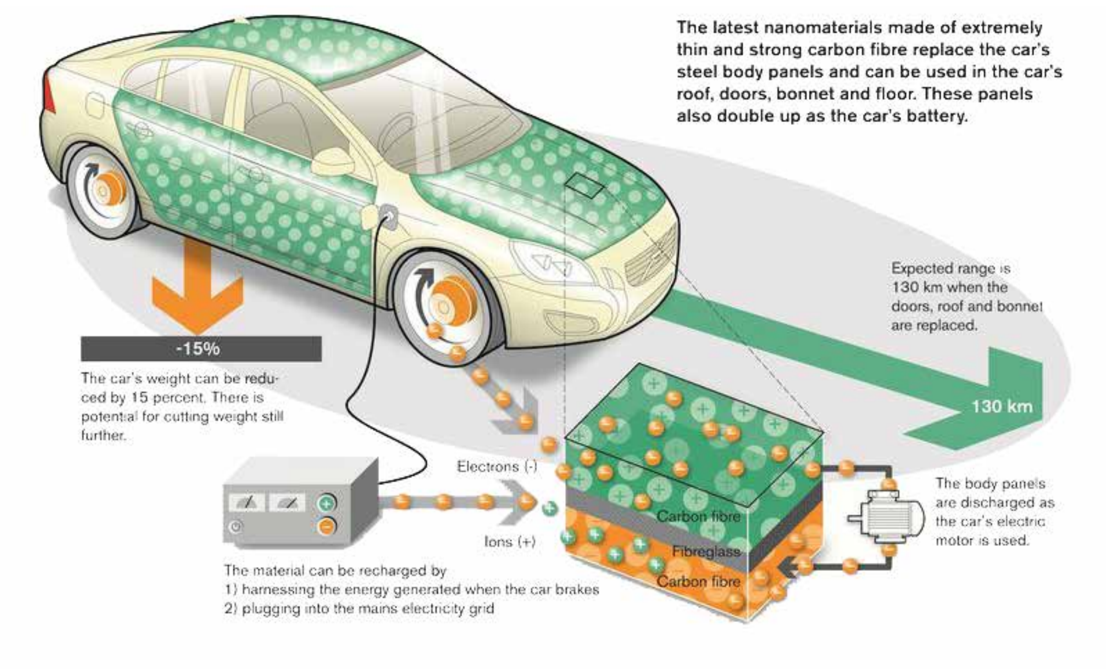


Fig.29: a composite material made out of carbon fibre and polymer resin developed by Volvo Car Group and is said to be able to stare and charge energy faster than conventional batteries can (source: Volvo Cars Group)

Fig.30 (top): a close up of the nanomaterial (source: Volvo Cars Group)

Fig.31 (bottom): Plenum cover in place, which replaces 3 previous items in a standard car: the rally bar, traditional plenum cover and the start-stop battery, which alone saves more than 50% of system weight.(source: Volvo Cars Group)

Another future technology, not that far away from the innovation from Volvo Cars Group, is batteries. Innovation involving batteries and driving range is going forward at an incredibly fast pace. As the need for bigger capacity and lightweight batteries increases due to the prediction of EV sales domination in 2020 in the EU, car manufacturers are investing massively in battery R&D. On this page, a few exerpts from a quick internet scan are presented, illustrating how fascinatingly complex and fast this sector is. All articles are quoted from electric-vehiclenews.com.

<u>Toyota developing next-gen sodium-ion EV batteries (2013)</u>

"Toyota has developed a positive electrode material that can significantly boost the capacity of sodium-ion batteries, and says the new material could lead to the development of batteries that can power electric vehicles for 500 km to 1,000 km on a single charge.

The automaker has created a prototype battery utilising the new material, The Nikkei reports. Shaped the size of a coin, the battery functions at room temperature, and is able to generate an electric voltage value – which is used to calculate the maximum mileage of electric vehicles – that's 30% higher than that of lithium-ion batteries."

<u>Molten-air battery offers up to 45x higher storage capacity than Li-ion (2013)</u>

"Researchers at George Washington University have demonstrated a new class of high-energy battery, called a "molten-air battery," that has one of the highest storage capacities of any battery type to date. Unlike some other high-energy batteries, the molten-air battery has the advantage of being rechargeable.

Although the molten electrolyte currently requires high-temperature operation, the battery is so new that the researchers hope that experimenting with different molten compositions and other characteristics will make molten-air batteries strong competitors in electric vehicles and for storing energy for the electric grid.

This ability to store multiple electrons in a single molecule is one of the biggest advantages of the molten-air battery. (...) The researchers experimented with using iron, carbon, and VB2 as the molten electrolyte, demonstrating very high capacities of 10,000, 19,000, and 27,000 Wh/l, respectively. The capacities are influenced by the number of electrons that each type of molecule can store: 3 electrons for iron, 4 electrons for carbon, and 11 electrons for VB2. In comparison, the Li-air battery has an energy capacity of 6,200 Wh/l, due to its single-electron-per-molecule transfer and lower density than the other compositions while a typical Li-Ion battery has a capacity of approx 600 Wh/l."

<u>Toyota to commercialize solid-state batteries by 2020 (2013)</u>

"Toyota aims to commercialize solid-state batteries around 2020 and lithium-air batteries several years later, as successors to today's lithium ion batteries.

The solid-state batteries will be three or four times more powerful than lithium-ion batteries, while lithium air will achieve a fivefold increase in output for the same weight.

Both technologies have advantages over the lithium-ion and nickel-metal hydride batteries used in hybrid and electric vehicles. They are smaller, use fewer costly materials such as rare earths and have lower internal resistance.

Toyota unveiled a prototype of its all-solid-state battery in Japan in 2010. In solid-state batteries, engineers replace the liquid electrolyte used in lithium-ion batteries with a solid one.

The positive electrode, negative electrode and solid electrolyte of the prototyped cell are made by using lithium cobalt dioxide (LiCoO2), graphite and sulfide, respectively. That makes the battery more compact and more stable, allowing a higher voltage to be packed into a smaller package, Shigeki Suzuki, managing officer for material engineering said.

In lithium air batteries, the lithium cathode used in lithium-ion batteries is replaced with one that interacts with oxygen. This requires less material and allows for lighter packaging. They have much higher energy density than current batteries.

"Next-generation battery cells need to exceed the energy density in lithium-ion batteries significantly," Suzuki said. "We've been accelerating our development of those next-generation batteries technologies since 2010.""

Conclusions

In this chapter we elaborated on the challenge concerning future energy supply and emission goals, seen through an engineering perspective. Two models of technology prediction were discussed, respectively the Law of Accelerating Returns and Moore's law. A brief insight on future technologies was presented concludingly.

A worrying conclusion was made about the energy supply of tomorrow, with Davis et al. (2012) stating that the sources of most threatening emissions have yet to be built, as current energy infrastructure will be outdated by the time we reach the IPPC's scenario window. Energy infrastructure and the the production of hydrogen has to be made much more efficiently. Without adaptions, the shift to EVs and fuel cell cars will be useless in terms of decreasing global carbon emissions. For example: the energy needed for making hydrogen massively outweighs the benefits of the fuel cell itself.

We learned from the two technology development models, extrapolation of historical data and analysis of goals and expectations of state of the art R&D, that technology develops exponentially and is expected to keep developing this way up to 2020 and further. The Hype Cycle of new technology showed the phases new technologies go through on their way from breakthrough to commercial adoption.

It is interesting to note that, during the course of this research, it became apparent that the rate of innovation quickly spikes when funds are raised. This somehow obvious conclusion makes it difficult to predict future technologies, and in what direction innovation will concur. For the next genertion LDC concept, technologies that are currently developed and that are predicted to make an impact on future mobility will be implemented.

THREAT	OPPORTUNITY

DEMANDS

OVERLOAD	SUSTAINABLE TECH
Earth's limits exceeded	*Solutions for resources, energy, ageing population*
Scarce resources and climate change result in wars	*Worldwide elevation of living standards*
Cities grind to a halt due to ever growing traffic issues	

CLIMATE

DEFEAT	SUSTAINABILITY
GHG-emission standards fail to meet premised goals	*Solutions for resources, energy, ageing population*
Sustainability equals costlier infrastructure	*Worldwide elevation of living standards*
Destinations lose market	*Solutions for sustainable tourism, living and mobility*
Extreme weather events cut in on tourist season revenues	*Geo-local and deep travel*

TECHNOLOGY

LOW TECH	HIGH TECH
Larger issues prevent ecology to be addressed and solutions to be implemented	*Technology merges the interests of humanity, ecology and economics, creating opportunities for e.g. mobility*
Sustainable technology is not profitable and is left behind	

POLITICS

FIXATION	PUSH
Costs rise as regulations need to be met	*Governments continue to push industries worldwide into designing better ways instead of cheaper ways*
Subsidies for breakthrough technology is cut to a minimum	
Governments lose interest in pushing economics into sustainability	

4 Design approach

At this point, the initial research phase is over. As the subjects, touched over the last few pages, are fairly complicated and impossible to completely analyze and conclude given the short time frame of this thesis, a bundled mapping was made. Looking back on the preceding four chapters, we sought for 'drivers for change'. Drivers for change are catalysts for societal, technological and economical change. They initiate processes that cannot be undone and alter the course of history, at the extent that the effects are still visibly present to this day.

The focus of the timeline is on the coach sector, however, as this is a mostly undocumented sector, we turned to the complete automobile sector for clues involving change. Changes implemented in the personal car sector or freight truck sector eventually find their way to the coach sector. On the following page, a timeline is presented including some of the change drivers. The yellow line includes technological and societal change which directly or indirectly reflected on the bus or coach travel industry. The green line is about emissions and power sources from 1971 on. The red line is about traffic and safety. The explanation is made chronologically and can be read as a whole, or by colour.The plan for this thesis is to propose a concept for the coach industry, involving a radical change and up-to-date with technologies that will be available around the year 2030 and further. In these times of environmental change and carbon emission regulations, investments need be made to keep up with global emission goals that are set to preserve the future of our planet's resources and mobility in general.

The Drivers for Change Timeline concludes with a couple of question marks, possible trends for the future which could turn out to be opportunities for the Next Generation LDC.

On the page after the Drivers for Change Timeline, an infographic about coaches is presented, giving an overview of bus architecture, issues and general statistics. It also was a first personal exercise on getting a feel of coach architecture, its dimensions, the way the seats are placed and the amount of space is needed for passengers to sit.

4.1 Drivers for change

through history and into the future

In 1830, the heavily subsidized railways forced the horse-pulled coach sector into motorizing their vehicles. After the war, nothing major happened for the coach industry. Cars however became accessible for 'the normal people', inducing a boom in car numbers in the West. Through 1951, Diesel engines became more and more efficient, allowing coaches to transport more people over longer distances, for the same cost as before. 1971 saw the arrival of the first low cost carrier airplane, making long haul travel accessible to the masses. In that same year, the planet reached a historical turning point: the ecological overshoot. In short, this means that from this year on, Planet Earth's citizens used more resources than the planet can produce in one year. In 2008, humanity used an equivalent of 1.5 planets Earth to support their activities (WWF, 2012). In 1974 and 1979, energy shortages provided spikes in coach sector productivity. This happened a few times throughout the years, but the 1974s and 1979s stand as clear examples of this phenomenon. Also in 1979, in the US, the NCAP was founded: the first organisation which goal was to improve vehicle safety. In 1991, the European Union imposes the first of many emission standards on carbon and GHG-emissions: EU1. We jump forward to 1995. In this year, Internet Explorer became the most popular internet browser worldwide. Internet became increasingly established in modern households, enabling travel agencies to start transferring their services -at least partially- to the internet. Online ticket sales made for cheaper travel, without consessions made to the service. This, again, broadened the amount of people travel was accessible to. In 1997, 18 years after the foundation of the NCAP in the US, the European Union founded their own roadcar safety organisation: Euro NCAP. At the time, carbuilders worldwide complained that it was impossible for anyone to build cars that met the 'unusual high safety standards'. Only 4 years later, Renault scored the maximum of 5 stars with their Laguna, setting the standard for the whole automotive industry. Ever since, all European carbuilders have produced 5 star vehicles. Even for pedestrian safety, 5 stars is now the benchmark to work towards. This is proof that innovation is a self fulfilling prophecy, when goals are properly set and resources are made accessible (Disco et al., 1998). The boom of social networking, initiated by Facebook in 2007, stressed the current trend of trophy-travel. 2013 marked the introduction of the 6th European emission standard. The EU predicts that, by 2020, every car sold in EU countries will be plug-in hybrid EV or full EV. By then, most major European cities will be Zero Emission Zones. ICEs will have nowhere to go inside cities. It is to be expected travel will undergo changes which can be related to the slow-food movement: slow-travel. The journey itself will become as important as the destination. Even though cities will evolve to mega cities, mega regions even, it is plausible that traffic issues can be solved mostly by implementing smart managing technology. Car-to-car communication is a first step towards this solution. The first experiments have already begun and it is expected to see huge leaps happening in a few years. A connected mobile world is the direction we are heading to. One of the greatest questions of our time is how the mobile energy should be stored. Using electricity as our main power source for driving is the favourable solution, but storing this electricity remains an issue, as batteries are heavy and use up precious raw materials. Fuel cells offer a solution, only that the production of hydrogen requires ridiculous amounts of energy, which should be used to power our cars in the first place, instead of producing the molecules.

The combinations of these events and factors will determine the requirements for the Next Generation LDC. Determining the possible future of Electric Driving will be the first chapter in specifiyng these requirements. The drivetrain is such a controlling factor it will dictate the entire design direction and structure of the Next Generation LDC. After this, the design drivers for the concept will be laid out in accordance to the scenario. The scenario (big question mark) is the combined product of all question marks about future travel, mobility, ecology and society.

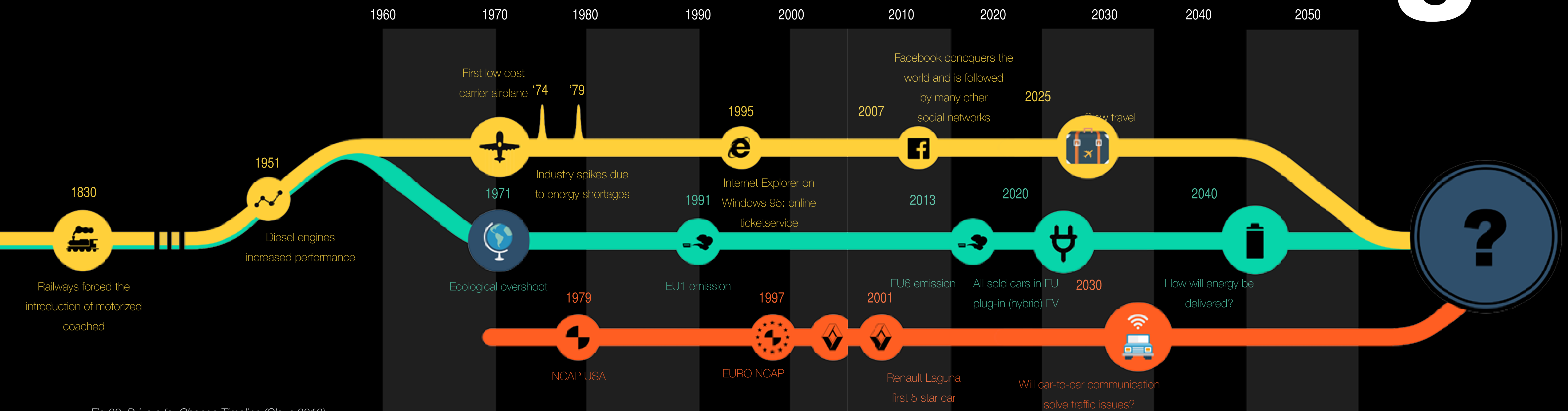
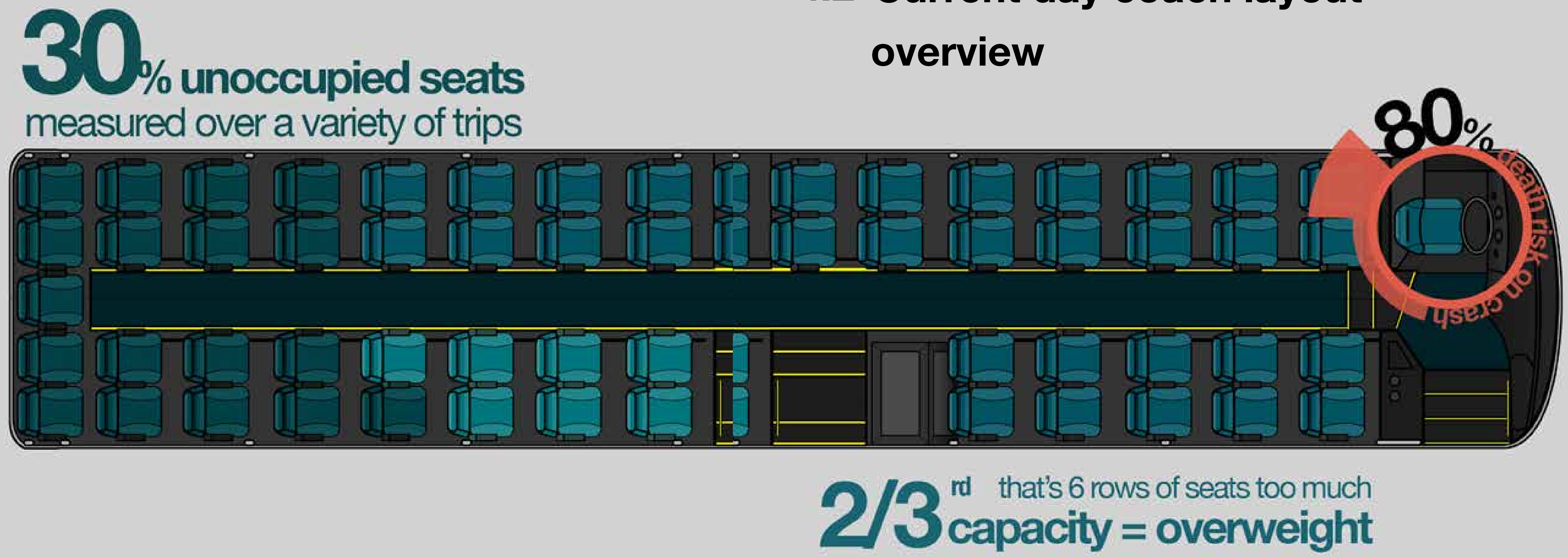


Fig.32: Drivers for Change Timeline (Claus 2013)

4.2 Current day coach layout overview



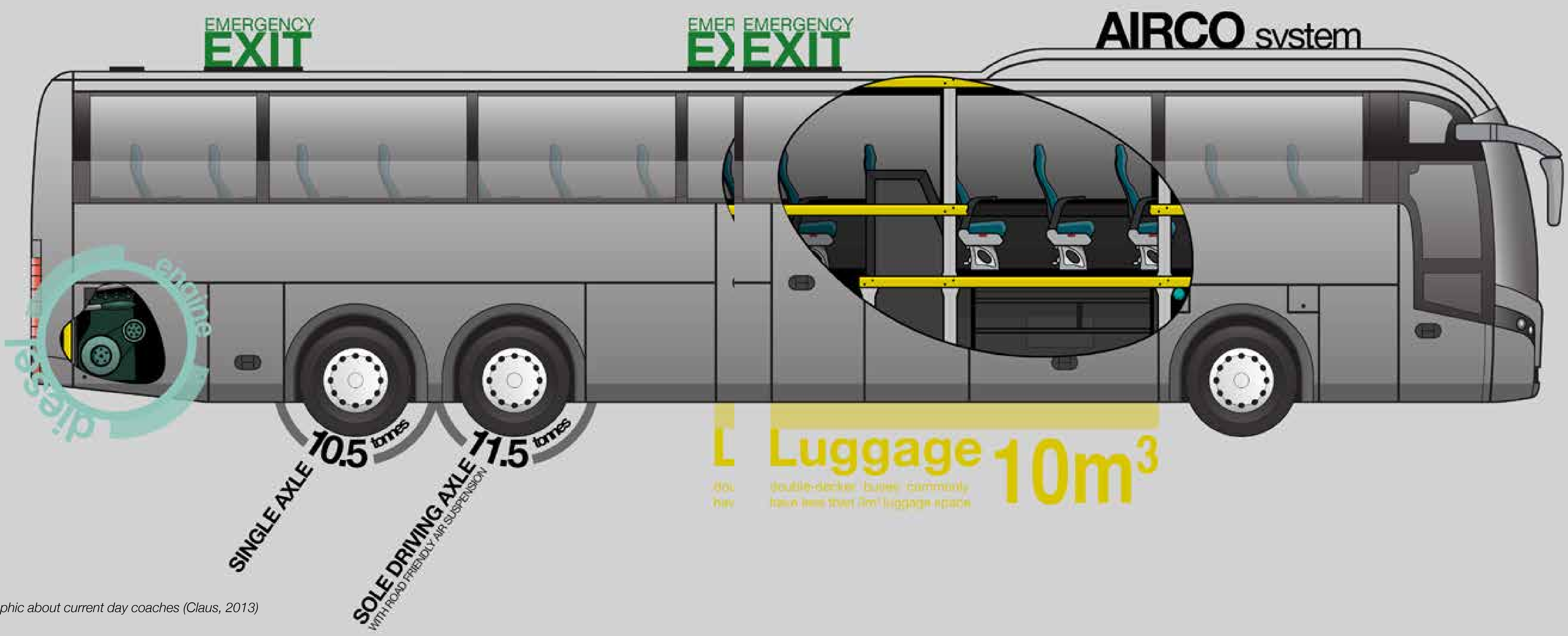


Fig.33: infographic about current day coaches (Claus, 2013)

5 Design Drivers

This project was initiated by a symbionic circle which questioned in what manner safety, UCD and efficiency would alter the design of a Next Generation LDC from 2030 on. A multidisciplinary analysis of four domains was executed: the coach, society, use and the progress of technology were all briefly discussed. The final findings were concluded in the Drivers for Change Timeline. We established that the Next Generation LDC will require a full electric drivetrain. This change from ICE to EV dictates the whole design of the concept: a lot of architectural and design changes can be made possible due to this alteration. The change of drivetrain is relevant, as the prediction is that by 2020, all new cars will be PHEVs and by 2050, Europe aims at a Zero Emission Mobility infrastructure, based on battery electric vehicles (BEV).

Zero Emission

Europe is pushing towards a Zero Emission Mobile Infrastructure by 2050, in the context of making the European Union more climate-friendly and less energy-consuming (European Commission, 2013). In 2020, the EU wants every new car sold to be PHEV. To achieve this goal, investments in technology and infrastructure are needed, as green vehicles and infrastructure won't develop itself (ERTRAC, 2012). Green Hubs or Corridors will be built on the main European axes, providing a solution for the limited range from battery packs in EVs. LDCs could share these Green Corridors with HDTs. On roads without Green Corridors, it will be possible to make use of dedicated charging driving lanes.

Efficiency

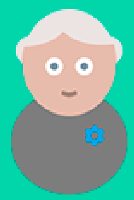
As touring coaches in occasional service often drive on 70% capacity and coaches in regular services even transport mostly empty seats, the need for a flexible means of mass transport is not that far fetched. On top of that, most coaches are already overweight at 2/3rd passenger capacity. The Next Generation LDC also has to be able to adapt to the task it is assigned to: different kinds of destinations require different solutions. On top of that, driving should be more efficient in the future, with the eye on environment and the depletion of resources.

5.1 Design Drivers

The chosen Design Drivers are a direct product from the symbionic circle which initiated the project, and the findings in the research phase. Each Design Driver will steer the final design and will be discussed individually below. The Design Drivers are: Zero Emission, Efficiency, Accessibility and Safety. Not by coincidence, these drivers embody four strong trends witihin future mobility thinking and design.

Safety

Bus and coach transport is already the safest mode of on-land travel. However, when a crash does occur, the amount of fatal casualties is significant. For instance, the driver has an 80% chance on fatal injury in the event of a collision. On board crash footage also showed that head and neck injury are common in a crash. Future technologies and the internet of things may come as a solution, in a world where vehicles are connected with each other and can anticipate crashes. Because no system is completely foolproof, the structure of the Next Generation LDC has to be improved as well.



Accessibility

"Accessibility describes the ease with which something can be reached, obtained, used, or understood by as many people as possible" (bmwguggenheimlab.org, 2013). As people live longer and stay active longer, touring coaches are not very friendly to the disabled or elderly. Current wheelchair lifts can be optionally installed on touring cars, but put a lot of weight into the balance and are not user-friendly. Inside, the space is cramped and luggage has to be lifted above the headw. As travel habits change and the journey becomes as important as the destination, a lot of thought has to go into the accessibility of the Next Generation LDC.

5.1.1 Zero Emission

The drivetrain

The optimal drivetrain for the Next Generation LDC will be discussed before elaborating on the essence of the concept. As explained before, the drivetrain will dictate the general outcome of the concept. It is a delicate matter and will be, in any case, be a balance act to cleverly fit the components into the chassis. Given the assumptions of future Zero Emissiveness by 2050 in Europe (European Commission, 2013), the internal combustion engine (ICE) is not an option for the Next Generation LDC. It is a commonly accepted notion that electric vehicles (EV) will experience a significant boom from 2020 on. One of the main issues with EVs this day is their relatively short (200 km) range. The further one wants to travel with an EV, the more batteries are needed. Current generation litium-ion batteries weigh a lot in comparison to their volume. The heavier a vehicle, the shorter its range gets. Range and weight are thus the main issues for EVs and the design of the Next Generation LDC. With this in mind, the future of long haul (passenger) transport will be briefly discussed.

European Roadmap

A technical roadmap of future drivetrains is laid out by ERTRAC, the European Road Transport Research Advisory Council (next page). This roadmap for green vehicle infrastructure elaborates on the possible powertrains of specific transport types over the short, middle and long term. According to this scheme, it is expected that the long distance coaches will experience a growing use of biofuels in the first years to come. Biodiesel is yet being succesfully used in numerous cities worldwide to power city buses. Some experts believe biofuels will be the next big thing, however, it is generally believed that a significant expansion in the use of biofuels will be "too much of a good thing" (UNEP, 2009). The danger lays in the environmental impact due to the increased use of land and water. Land and water are limiting factors if a large percentage of biofuels is to come from agriculture. Negative consequences involving GHG balances can occur when forests or grasslands are destroyed in order to make room for the cultivation of biofuels. This would evoke a significant risk of biodiversity loss. The other limiting factor, water, could potentially lead to conflict or some form of competition with food in areas with scarce water resources. Agriculture now uses up to 70% of all fresh water globally. This figure will rise even further as mass biofuel cultivation is to become reality (UNEP, 2009).

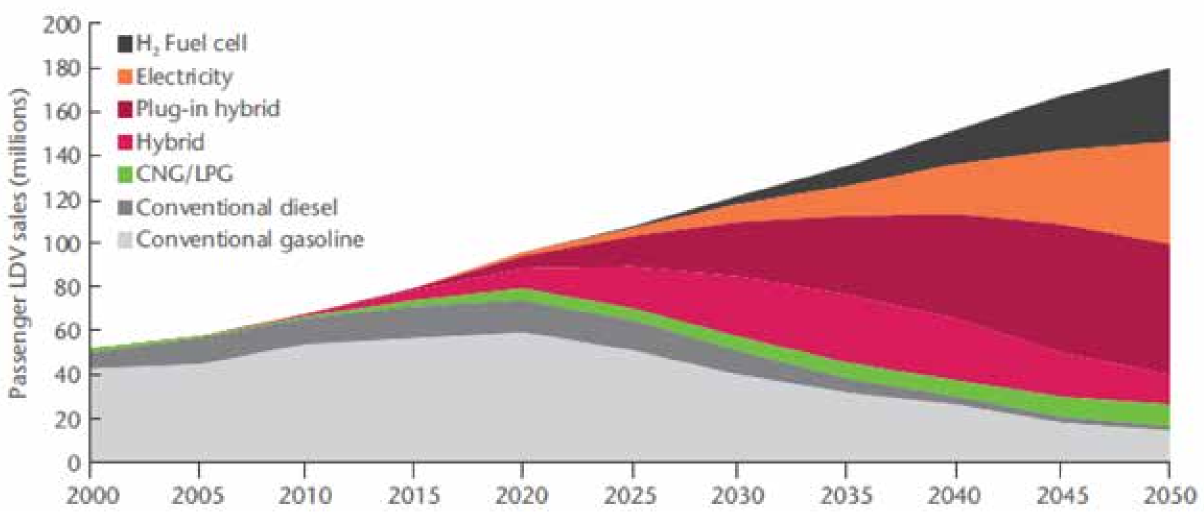


Fig.34: annual light-duty vehicle sales by technology type, BLUE Map scenario (source: IEA, 2010)

Type of transport			Short term	Medium term	Long term
City / Urban	**Personal mobility**	**Private cars** – City cars & 'city movers'	ICE as main powertrain. Increasing share of bio-fuels	Will change to electric power (PHEV, EV). Wireless charging for electric vehicles in main cities and dedicated regions	
		Public transport – city buses, urban buses	ICE as main powertrain. In some cities electric 'trolley' buses and pilots with fuel-cell buses	Plug-in and wireless charging electric buses in main cities and dedicated regions. Fuel-cell powered buses in dedicated cities	
	Goods transport	**City transport for goods** – 'city transporters'	ICE as main powertrain. Increasing share of bio-fuels and hybridisation	Will change to electric power (PHEV, EV). Frequent (e.g. wireless) charging available for electrified vehicles in main cities and dedicated regions	
Intercity / region	**Personal mobility**	**Private cars** – intermediate / regional distances cars	ICE as main powertrain outside cities. Increasing share of bio-fuels		
				Plug-in hybrid electric vehicles, Range Extender	
				Gaseous hydrocarbons (e.g. natural gas, biogas) will be an appropriate solution in medium-term. As replacement for diesel-fuel, natural- and bio-gas it is fast applicable	
		Public transport – regional distance buses, intercity buses	ICE as main powertrain outside cities. Increasing share of bio-fuels and hybridisation		
				Will gradually change to electric power (PHEV, EV). Frequent (e.g. wireless) charging available for electrified vehicles in main cities and dedicated regions. Range extender outside cities	
	Goods transport	**Regional goods transport**	ICE as main powertrain outside cities. Increasing share of bio-fuels and hybridisation		
				Gaseous hydrocarbons (e.g. natural gas, biogas) will be an appropriate solution in medium-term. As replacement for diesel-fuel, natural- and bio-gas it is fast applicable	
				Will gradually change to electric power (PHEV, EV). Frequent (e.g. wireless) charging available for electrified vehicles in main cities and dedicated regions. Range extender outside cities	
Long distance	**Personal mobility**	**Private cars** – long distance passenger cars	ICE will be mandatory. Increasing share of bio-fuels		
				Plug-in HEV, Range Extender	
					PHEV, Fuel-Cell, Hydrogen. Wireless charging on main European axis, possibly shared with HDTs
		Public transport – long distance buses, coaches	ICE will be mandatory. Increasing share of bio-fuels		
				Plug-in HEV, Range Extender	
					PHEV, Fuel-Cell, Hydrogen. En-route charging on main European axis
	Goods transport	**Long distance goods transport** – 'High Capacity transport Trucks'	ICE will be mandatory. Increasing share of bio-fuels. Biomass based fuels is important for long distance and intermediate transport in long term		
				Some hybrid components, Fuel-Cell auxiliary power unit (APU)	
					Continuous grid connection on 'green corridors' and highways for HDT hybrid systems

Fig.35: European Roadmap - Infrastructure for Green Vehicles (source: ERTRAC, 2012)

In the medium term, Plug-in hybrid electric vehicles (PHEV) will start to be implemented into service. Range extenders in the form of small turbocharged diesel engines (running on biofuel) will be calling the shots in long haul people transport.

In the long term, PHEVs and fuel cell are predicted to be the main power sources. Fuel cell will, by 2030, have an approximate market share of 25% (ERTRAC, 2012). Experts are sceptical about fuel cell driven heavy duty trucks (HDT) and people carriers, because a lot of the storage space will have to be used for accomodating hydrogen fuel tanks. A theory which finds a lot of acclaim is the introduction of Green Corridors on the main transport axes in Europe. Touring cars could share these Green Corridors with HDTs. Efficient transport interfaces will be developed, resulting in so called 'Green Hubs'. In this context, efficiency means "high operational performance, effective use of resources, limited impact on the surroundings and the environment" (ERTRAC, 2012). The electric power will be transferred from the Green Hub to the vehicle, using inductive charging or Wireless Power Transfer (WPT). Experiments have been conducted and an efficiency of 80% has been achieved, with reasonable air gaps between the inductive coils (ERTRAC, 2012). This technology could even be implemented on dedicated lanes on highways, where passenger cars could benefit from. This opens perspectives for the Next Generation LDC: when an en-route Green Hub is not available, a dedicated charging lane could provide additional charging of the on board batteries. An other option for en-route charging is contact charging. An abundance of experience is available from trolley buses and trams around the globe: sliding contacts have been used on a massive scale. Siemens is testing a 'trolley system' for truck application. This might as well become an option for implementation in Europes Green Corridor axes. Another system, tested by Volvo for trucks and already implemented on trams in Bordeaux, is a slider contact system located in the road surface.

Electricity sources

Electricity comes from many sources. A range extender in the form of a turbocharged diesel engine can generate power to charge batteries, and the same goes for a fuel cell. However, it is said that fuel cells will be merely used to power electrical sub systems, such as airconditioning, on HDTs and touring coaches. This finding was established on Busworld, Kortrijk, in a chat with Erland Morelissen, Volvo Hybrid team leader.

Fig.36: city corridors for different transport modes (source: Volvo)

Fig.37: Green corridor for long journeys (source: Volvo)

The problem with fuel cells is that the hydrogen, used as fuel, requires a lot of energy to produce in the first place. Fuel cells in vehicles require large pressurized tanks. It would be more desirable to use electricity, made by large fuel cells on an industrial scale, out of the socket to power vehicles instead of letting the vehicle produce its own electricity.
The same applies for solar panels: charging a complete vehicle battery will not happen anytime soon. Instead, solar panels on road vehicles can be a way for extending the range of the vehicle, by letting the solar panels provide electricity for low current on-board systems. The excess power can of course be stored in the battery packs. Touring coaches experience a lot of stationary time. For instance, when a group of tourists are dropped off at a tourist attraction the bus usually waits for the travellers to return and then continues to bring them elsewhere. This stationary time could be used to store energy into the batteries, and in case the batteries are charged, the vehicle could return electricity into the elctricity grid.

Another method already being used is the regeneration of braking energy. These systems can regenerate up 40 to 90%

Fig.38: electric truck on a Siemens test track north of Berlin (source: Siemens-Pressebild)

Fig.39: Alstom APS system (on a tram in Bordeaux) which is currently being adapted to heavy trucks (HDT) (source: Alstom)

of the braking energy (Boerboom, 2012).
Energy regeneration is not just about recovering braking energy anymore. R&D for harvesting shock absorber energy is in an advanced stage and said to be ready for mass production (Gizmag, 2009). A regenerative electromagnetic shock absorber converts repetitive intermittent linear displacement motion into electricity, using an electromagnetic generator. A classic shock absorber transforms the linear motion in heat, transferred by oil. The heat is lost energy, which could, when harvested, charge batteries or be used to power aironditioning systems. Another, hydraulic shock absorber regenerative technology exists, but will not be discussed in this thesis as this technology is not relevant for an EV.

5.1.2 Efficiency

Flexible Capacity

The ultimate coach vehicle provides a system which enables travel operators to tune the capacity or layout of their tour buses to the demand for a trip.

The Next Generation LDCs will be available in a diversity of seat configurations. The idea is that travel companies will be able to lease coaches for their planned trips, which enables them to provide the passengers with the best possible infrastructure for their travel plans. Travel agencies will sign a multiple year contract with the LDC manufacturer, and will lease the desired coaches for every trip. This way, travel companies do not own the vehicles and are not burdened with maintenance costs. The electricity use however will be charged per vehicle mile to the travel company. This system of leasing vehicles provides travel agencies with a flexible fleet and enables them to pay for the amount of usage. This concept is analogous with timesharing, introduced in the chapter about the Boswash Shareway. Trends are changing, "owning a product" will likely transform into "being subscribed to a service". This notion allows people to pay for the amount of time they actually use a product or service.

As mentioned in the previous paragraph, the coach trims will be accustomed to a variety of travel types. For instance: commuter vehicles will have a maximum capacity of seats, added with small luxuries such as onboard WiFi, music and video streaming, charging points for their electric devices etc. Coaches for long distance travel (over 1000 km) will be equipped with more spaceous and luxureous seats, which can adapt to varying passengers morphologies, providing a snug seating capability. The seats will be lined with self-cleaning nanomaterials, which also reduce vibrations. Vibrations cause stress over longer periods of time. The use of new materials will help make the interior a more hospitable place during its entire lifespan. For snow holidays, extra room could be put to good use as it is common for the passengers to put their ski of snowboard clothes and gear on in the coach.

Weight control and aerodynamics

We established that current coaches are often overweight at 2/3rd of their capacity. This issue can be resolved by purpose-building coaches and using multifunctional nanomaterials. Cleverly designed, lightweight components will replace multiple components as they would be found in current day vehicles. Clustering components into one smart, multipurpose component would help deminishing the empty weight of the vehicles. As we also established before, the weight of batteries will decrease whereas the capacity will increase. An autonomous driving range of 200 km without adding too much weight should not be a problem in 2030, taken into account innovations such as the Volvo Cars Group electricity storing nanomaterial, which is both strong and lightweight ànd functions as the bodywork. Complementary, the bodywork should be more streamlined in order to decrease drag and therefore ameliorate power consumption. In this respect, nature can be a valuable source for inspiration: animals like whales, penguins, birds... are all optimized in their streamline through billions of years of evolution. It is a growing trend to explore lessons learned from nature and incorporate them into our daily lives.

5.1.3 Safety

Smart mobility

Mobility problems can be resolved by smart-mobility infrastructure, such as the Green Corridors and Smart Highways. Expectations are that "platooning" will be common for future mobility in the city, and on these Green Corridors.

Grouping vehicles in platoons is a theory for increasing the road capacity, without having to build additional lanes. Other benefits are the decrease of drag forces experienced on vehicles in a platoon, fewer collisions, shorter commuter times and reduced congestion. Vehicle-to-Vehicle communication (V2V) or automated highways are proposed technologies for accomplishing this (Zabat et al.,1988), and would make it possible for cars to automatically join and leave these platoons. Platooning decreases the distances between vehicles, predictably using some form of electronic coupling. In theory, this would allow vehicles to accelerate or brake at the same time. This system eleminates human reaction times in traffic jams. For instance: when a traffic light goes green, a synchronized platoon could accelerate as one, making for a fivefold increase in traffic throughput (Princeton University, 2013). It is not unthinkable that this technology and the implementation thereof would require special driver licences. New skills and responsabilities are due when platooning becomes a reality, for example when a car is leading a platoon, the driver needs to be endorsed for taking the lead of 24 or more cars.

Overall, traffic will become much safer. Vehicles will communicate with each other about their whereabouts and predicted trajectory, and a car will be able to anticipate on other traffic ahead, planning the most efficient and safe route. When all cars in a 5 km radius will be connected which each other, the amount of accidents can be reduced to virtually none.

Route planning and the digitalisation of maps (e.g. Google Maps) will also enable cars to anticipate on geographical factors such as steep road inclinations or hairpins. Anticipation could mean activating the brakes on certain wheels, in order to make a turn without crashing into the barriers.

Driver's workplace

Although the coach will be able to drive autonomously in certain situations, the driver's workplace and the monitoring of the driver still are important factors. The Next Generation LDC aims at a secure, safe and comfortable working environment for the driver, as they spend up to eight hours per day behind the wheel. Improving work conditions is "a key element in developing better service, performance and industrial relations between employer and employee" (UITP, 2008).

Vision: "...A future energy supply may be organised in a decentralised manner with a large amount of renewable energy sources. Due to the fact, that the energy supply of this facilities is partly difficult to plan and foresee, the demand for regulating energy in the grid would rise..."

ENCO, 2007

The goal of the new workspace is to enhance a safer, simpler and more intuitive driving style. The redesign will include the bundling of buttons and functionalities into clusters on one or more touch screens, positioned around the steering wheel. The windshield will function as an information screen, on which important information will be shown. For example: the maximum allowed speed, the actual speed, the selected driving mode, the trajectory, etc. The driver will also be noted at any time about vehicles in the direct surroundings of the coach. All blind spots will be electronically covered in order to ensure safe mobility, even for vehicles not connected to the V2V system, such as bicycles or other vulnerable road users.

Driver's tasks

Nowadays, the driver's job description is clear: drive the bus to a destination, wait for passengers to return and continue to drive them around until they are safely returned home. In the meantime or afterwards, it is the driver's task to keep the bus clean and check whether or not the vehicle requires maintenance.
With the arrival of car-to-car communication and autonomous driving, the role of the driver could develop in a different direction. The tasks of the "driver" could be supplemented with additional tasks, such as onboard stewarding, offering passengers refreshments, even guiding and commenting en-route or at touristic spots.

It is, however, clear that bus drivers of the future require a different training than is the case today. The added responsability when in the lead of a platoon will require a new set of skills which will need to be endorsed or licensed. Coping with a vehicle equipped with artificial intelligence will result in a different way to operate the machine. The driver has to retain a sense of 'controlling the vehicle' instead of it controlling him. A suffcient knowledge of the onboard systems and software will be required, in order to be able to anticipate on how the vehicle will react on some occasions.

5.1.4 Accessibility

Accessibility for all

A bus should be designed to make people's lives easier. Unfortunately, a small minority of people is left behind: the elderly and physically challenged. This (first) minority will grow, by 2030, to a significant amount of people when ageing reaches its peak. It is thus relevant to imagine ways to comfort this group of people.

The location of bus and coach terminals is highly important and "contributes to the role of a terminal as a passenger logistics hub" (Smart Move, 2009). Furthermore, if people with reduced mobility are to be encouraged for using coach travel, accessibility improvements should be on top of the to-do list. Accessibility starts with boarding and coach terminals: escalators, elevators, assistance and special training for supervisors are needed to provide a flawless service. In the coach, all forms of steps need to be replaced with oblique planes. The step from the terminal onto the bus needs to be gapless, and stepping off the coach when no terminal is available should not be an issue when the Next Generation LDC is a low floor coach (LFC) with a ramp, providing flawless entrance to disabled or elderly people. Another question remaining, is how the course of technological innovation will change healthcare: will disabled people still need wheelchairs in 2030? Will exoskeletons or bionic limbs ensure better quality of life? The investigation of future healthcare is, however, beyond the scope of this thesis. For the remainder of this document, we will assume that quality of life will incline, but the use of wheelchairs, in any form thinkable, will remain in existance.

Passenger flow

Boarding the Next Generation LDC will be more relaxed. In boarding terminals, luggage will be handled by personnel and stored into the LDC's luggage compartment. Only small items (hand luggage) can be taken into the coach. People tend to keep their bags with them or between their legs nowadays, so, instead of lifting bags into the overhead luggage racks or holding them between the legs, personal space underneath the seats is provided. It is unlikely that the next generation LDC will crash, but in the event of a major mishap, the positioning of the luggage under the seats will eleminate suitcases flying around in the passengers compartiment, hitting people in the heads.

Large doors with smart ramps will provide easy acces to the LDC. People will be able to move faster in and out of the vehicle, as there are no stairs nor steps. The smart ramp will be able to adapt the entrance of the vehicle according to its surroundings. The system will be a flexible means to board the coach, regardless of any physical limitations of passengers.

Life on board

During a short half an hour brainstorm session at the University of Antwerp, Product Development, a group discussion on the topic "Life on board" was held. The aim was to initiate a debate on how life on board of a LDC would preferably evolve over time. The panel consisted of ten young product developement students. A wide range of items were discussed, reaching from onboard social networking to luggage handling or comfort modes. Some of the most interesting and relevant findings will be discussed accordingly. Almost everyone present at the discussion agreed on the fact that LDCs these days lack a sense of openness. They are, despite of the rather large windows, experienced as being too dark inside. This can cause claustrophobia on longer journeys. Also, the arrangement of seats makes it difficult to interact with fellow-passengers en-route, which can add to the sense of isolation during a trip. On the contrary, the brainstorm panel was adamant that, however openness and social interaction aboard the coach is desirable, there has to be a way to be able to shut oneself off of the outer world and social setting on board, creating a feeling of a cocoon to duck into. Life on board of the Next Generation LDC hence needs to be flexible and provide an opportunity for physical and psychological customisation. These findings neatly bring us to another hot item: comfort customisation. The majority of the panel agreed on the willingness to pay extra for added comfort, such as space, entertainment, antropometric customisation. The idea of a socalled 'traveller's profile' quickly rose. This profile would contain personal traveller's preferences, physical dimensions and other personal characteristics. This would enable touring operators to provide a tailored on board service to each customer. Some extra services would be charged extra for, but the traveller will always be able to select any desired option from his or her traveller's profile. Another great frustration by the panel was the boarding process: narrow entrances and high steps, cumulated with the inside pettiness make for slow and irritating boarding. Widening the entrance was the obvious solution, but the conversation at one point led to a concept in which the entire side panel of the bus was in fact the entrance, allowing large streams of people to board directly to their seat.

5.2 Product architecture

A basic abstraction of the Next Generation LDC's system architecture is depicted below. On this scheme, the energy flow within the system is shown. All systems are built around the main drivetrain concept: battery electric propulsion. The battery consist of a battery pack and electric storage in the chassis nanomaterial. The coil is the gateway to and from the grid: wireless charging on Green Corridors or in a parking spot. A regular charging plug is available as backup, for instance when the wireless charging coils should malfunction. Solar cells, fitted on the roof of the vehicle, continuously generate electricity during the day. These cells mainly power the onboard airconditioning systems. The solar cells are assisted by the regular power source (battery) when necessary. Regeneration of energy is an important element in the LDC system: energy from the brakes and shocks are converted into electricity. The Central Processing Unit (CPU) controls all energy flow within the system (grey lines) and informs the driver of all system performance through displays in the dashboard.

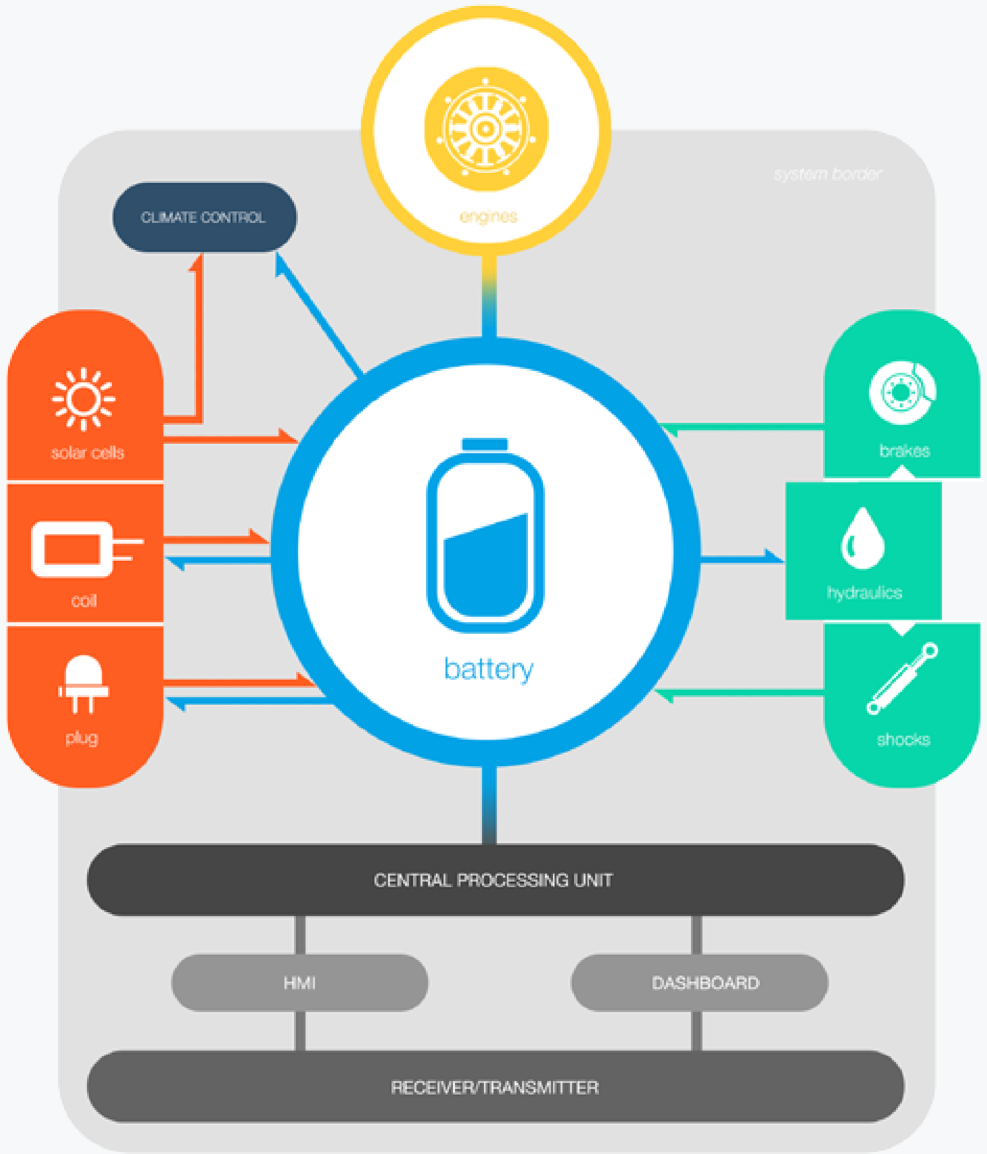


Fig.40: next generation LDC product architecture (Claus, 2013)

5.3 Design Brief

The design brief of the next generation LDC is documented in a project description, a list of specifications and a number of development items.

The project description is introductory to the design brief. It describes the project and the main design goals. The list of requirements or specifications translates the design goals into quantifiable objectives for the final concept. As with every aspect of this thesis, the specifications will also cover the human, economic and technological aspects of the LDC concept. The synthesis of the project description and the list of specs will be the development items: these are aspects of the concept that need further examination and will ultimately structure and steer the next phase of this project: system design. When all development items are solved, the next generation LDC will take shape.

5.3.1 Project description

This thesis documents the development of a next generation long distance coach (LDC) concept for the future. The future is defined as "from 2030 on and further". This is chosen because of the socio-economic and environmental changes that are said to have impacted the world by then. The initial question of how safety, efficiency and user-centered design (UCD) can influence the architectural design of a coach, led the analysis of the term "coach". Its history, societal change, coach use(rs) and technological evolution led to the formulation of four Design Drivers, around which the next generation LDC is developed: Zero Emission, Efficiency, Safety and Accessibility.

5.3.2 Product Requirements

The list of requirements is based on elements found through research. The elements and technology used for the Next Generation LDC concept is well-documented and carefully selected to fit within the future context described in the next chapters: the timeframe of 2030 and further. However, as specific values or certain requirements for the future are hard to predict and/or discover, estimations or substitute values will be used. This is mainly due to a lack of information or sector transparency and the ignorance of how fast technology will continue to leap forward. Estimations will be based on extrapolation of the state-of-the-art. This approach will provide the LDC concept with a sense of realism, even though it is a future concept.

Zero Emission

1. Energy efficient system, materials and components

- use of multifunctional composite materials
- additional battery pack to support storage from the composite storage material
- autonomous driving range of 200 km (in case of en-route charging)
- endless driving range on Green Corridors via ultrafast wireless charging
- ultrafast back-up charging capability both wirelessly and via socket
- airco system mainly powered by solar cells: >50% efficiency
- active noise and vibration reduction

2. Better environmental performance

- Zero Emission EV
- optimized traction technology through pre-planned routing
- energy recovery: (1) brake energy: >90% efficient
  (2) shock absorber energy
- intelligent on board energy storage and management
- drag coefficient lowered by est. 40%
- weight reduction by est. 30%
- optimal tire-asphalt interface (eco driving)
- optimalisation for platooning on Green Corridors
- societal service: electric grid network buffer

3. Lifecycle control

- use of recycled construction materials
- modular architecture to enable easy upgrading or swapping of vital components (engines, batteries, tanks, compressors, mainframe, electrical components, ...)
- design for assembly/disassembly

Efficiency

1. Flexible capacity

- select number of pre-configurated coaches available:
  (1) commuter trim (52 fixed seats, basic comfort)
  (2) business trim (23 fauteuils, business comfort)
  (3) holiday trim (46 variable seats, long haul comfort)
- coach leasing per trip, occasional or long term contract with OEM
- possibility to increase LDC capacity: additional seating modules (pre-configurated trim)
- possibility to enlarge luggage capacity: luggage aeropod

2. Payback when idle

- electric grid network buffer: vehicle to grid (V2G) two-way inverter
- communication infrastructure between network-operator, vehicle battery and load-infrastructure

3. Adaptation

- active aerodynamics and luggage aeropods ensure the vehicle is actively working towards lower power consumption
- optional air brake reduces braking distance in case of emergency situation

Safety

1. Driver aids

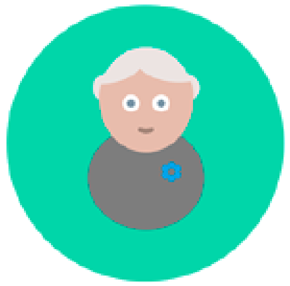
- pre-planning of the route towards a destination
- real-time projections on windshield (route, highlights, alerts)
- geographical anticipation:
    (1) enhanced traction
    (2) moving along in bends
    (3) steering corrections
    (4) Lane Guard System
- car-to-car communication:
    (1) automated braking
    (2) automated distance-to-front runner guard
    (3) blind spot alert
    (4) join/leave platoon
- automated driving: in traffic jams or platoons
    (1) physical sense of transferring control to vehicle
    (2) vehicle drives autonomously
    (3) vehicle comes to a halt when driver falls-out
- connected with the internet of things:
    (1) traffic network: V2V and V2X connectivity
    (2) energy network: smart grid connectivity (V2G)
    (3) commercial networks: Entertainment System
- driver monitoring:
    (1) eye movement and blink rate monitoring
    (2) heart rate monitoring (via camera)
    (3) driving style analysation (mood control)

2. Structural safety

- lightweight crash shell for passenger compartiment
- Gorilla Glas windows with built-in explosive wire (emergency exit creation)
- windows are smashable at any given point in case of explosive wire failure
- frontal impact crush zone minimal 785 mm from driver's center point

3. Passenger safety

- Isofix compatible 3 point seatbelts on each seat



Accessibility

1. Entrance and interior

- wide 1000 mm entrance in the middle of the vehicle (one 1000 mm entrance suffices for vehicles under 14 m in length, according to future EU legislation: 52 seats requires at least 1 entrance and an 4 emergency exits. Estimations are that legislation will alter over time allowing different solutions than today)
- all doors minimum 1650 mm high
- no steps nor stairs in passenger compartments
- adaptive ramp system integrated in entrance, providing stairless accessibility at any given location (platform/no platform, curb/no curb)
- adaptive ramp offers stairs for entrance as well
- ramp slope 12° max
- integrated ramp functions as an elevator platform for wheelchairs
- interior head clearance 1900 mm at all time

2. Luggage

- luggage storage under each seat in commuter and holiday trim
- business trim provides personal space with seat to bed configuration, table and option to rearrange space into conference room
- luggage compartment volume 6 m^2
- no stairs nor platform needed to retrieve luggage

Additional specs

1. Dimensions and weight
- max vehicle width: 2550 mm
- max vehicle height: 3000 mm
- due to changes in vehicle architecture and new technologies, weight per axle and length per vehicle legislation may differ from current laws

6 NPP: Conclusions

The NPP phase was initiated by the question of how safety, efficiency and user-centered design (UCD) can influence the architectural design of a coach and how these three factors affect one another in a next generation world. The final result of this phase is to explore the subject and generate a product candidate specified by Design Drivers and product requirements. The subject exploration led to the formulation of a future context for 2030 and beyond.

Firstly, the term 'coach' was defined and its history researched. It turned out that the evolution of motorcoaches is neatly linked to societal change. Secondly, society was investigated, providing insight on how the next generation LDC will respond to future demands. Thirdly, general coach use was described using macro and micro levels. To finalize the research phase, a chapter on technological evolution was written down.

The research phase resulted in four Design Drivers: Zero Emission, Efficiency, Safety and Accessibility. These specifications were each specified by a set of requirements for the final product. The drivetrain and other crucial aspects of the Next Generation LDC will be further examined and specified in Phase 2: System Design.

System Design

The second phase of the process, System Design, bundles a review of the concept generated in the previous phase, New Product Planning. The result of this phase is a proposal for a platform, consisting of all specified innovative features, on which the Next Generation LDC will be based. Defining these features will ultimately lead to the final phase, in which the Next Generation concept will take shape.

7 Reviewing the concept

The concept, as was generated during the New Product Planning phase (NPP), will be developed into a plausible touring coach platform, on which the Next Generation LDC will be based. This platform will include all major innovations which will make the Next Generation LDC stand out from its current day counterparts.
In order to take hold of the next phase with a clear, uncluttered view, it makes sense to deconstruct the concept before initiating the designing process. Following the example of Muyllaert's 2012 dissertation about the 2050 family car, a framework to meaningfully prepare the designing phase will be set up utilizing the methodology of Vision in Product design (Hekkert and van Dijk, 2011). The main advantage of applying this methodology is that it highlights the interaction pattern and the context of the future product (Muyllaert, 2012).

Muylaert (2012): "The framework by Hekkert and van Dijk consists of a deconstruction and a designing phase. In the deconstruction phase, the product and its interaction pattern is related to context from the past/present. The design phase consists of the same three elements - product, interaction and context - in opposite order. The contextual changes that characterize the future, reflect in a new interaction pattern. The elements of the new interaction pattern essentially shape the future product."

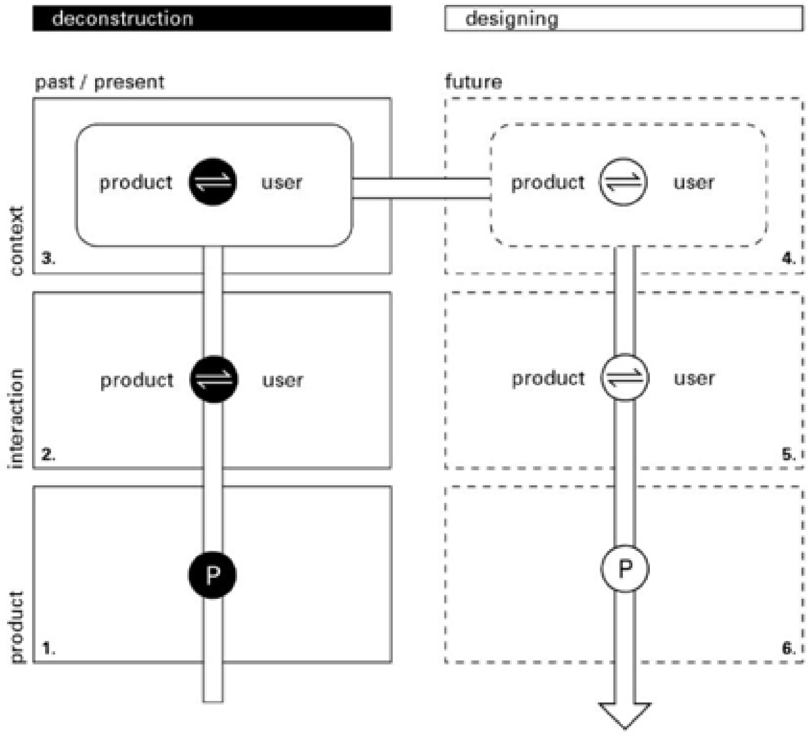


Fig.53: The Vision in Product design methodology consists of a six step deconstruction and a designing phase (Lloyd et al, 2006).

The Next Generation LDC concept will be discussed according to the six steps of the model, as shown above. The result of this exercise will result in a better understanding of the product, the context and functions. The deconstruction phase will be assessed by means of the status quo, whereas the designing phase will be analyzed as the concept vision.

7.1 Deconstruction of the LDC

During the NPP phase, the current state of long distance touringcoaches (LDC) and the likes were discussed in-depth. Along with that came a brief elaboration on next generation technology and what can be expected from it. The Vision in Product design will effectively mean an overview of the project so far, making use of the findings from the previous phase.

7.1.1 Deconstruction on product level

During the NPP phase, we established that buses have not always looked like they do today. We also discovered that the physical architecture of the coach as such, is driven by multiple factors. In general, we distinguish three factors: society, technological innovation and usage.

Looking back at the Drivers for Change Timeline (pp 50-51), it is clear to conclude that societal change and technological evolution intertwine in terms of the effect they both have on consumer products or services. It was societal change that brought the idea of a horse-pulled bus, but it was technology -or the lack thereof- which pushed the invention of 'the bus' into the direction of it being pulled by horses. The same goes for the second great radical change the coach as a concept was forced to undergo: the implementation of diesel engines, enforced by the rapid rise to fame of the railway system in the 1910s. This change was enabled by new technology and dictated by society, when travellers no longer accepted slow on-land transport. This is why we labelled technology in chapter 3.4 as the main enabler of products.

Societal change is strongly dependent on governmental regulations. These are implemented in order to guide demographics or push technological innovation. The aim for these sets of rules are to restrict or to stimulate certain aspects of life. Be it for safety, financial gain or the preservation of the planet, governmental regulations are the ultimate driving factor for technological innovation. For instance: the introduction of the EU emission and EURO NCAP crash standards proved that certain aspects of automotive technology can develop at a faster rate when pushed by government law. Rules and regulations can, however, reach the opposite: the ruling out of innovation. A little anecdote by Ies de Rooij (development manager at VDL Bus & Coach) told the story of the design process of the interior of a touring coach. VDL Bus & Coach designed a version and outsourced the same project to a third party, in order to have multiple options to choose from. The end results from both companies were identical, seperated by a dissimilarity of a couple of millimeters.
For touring coaches and on-land travel, infrastructure is also an important factor. For example: petrol stations made it possible for internal combustion engine (ICE) powered cars to reach a breakthrough. The continental installation of coach boarding terminals could theoretically mean a boost for the sector, creating opportunity for radical innovation, for reshaping the travelling by coach. Concludingly, we can state that regulations can be a driving force for technological innovation, although one must keep a keen eye on regulation overlap or discriminating rules that inhibit innovation.

The use of the coach also dictates some of the architectural elements. A coach for nightly transport can offer accomodation for sleeping, the capacity can vary according to the size of the group to be transported, etc. Touring coaches differ for instance from public transport buses, because of how the product is designed to be used. The passenger's level on a touring coach is elevated to create space for a luggage compartment. Public transport buses don't need this functionality, thus are they optimized for passenger flow.

7.1.2 Deconstruction on interaction level

The interaction between user and touring coach can be divided into interaction between traveller and bus on the one hand, and interaction between travel agency and bus on the other hand.

Interaction with products acts on a psychological level. Positive emotions, like joy, love, pride or amusement improve individual and collective functioning, psychological well-being and physical health (Fredrickson, 2003). These emotions are the product of certain provoking conditions, and influence our behavior in specific ways (Roseman & Smith, 2001). People also act according to symbolic and affective motives. The importance of this is stressed by a number of researchers (Steg, 2005 and Anable, 2005). These motives explain why aspects like prestige and kicks have such influence in people's lives and society in general. It explains why people buy larger, more powerful cars than they actually need, it explains, for instance, why travel agencies invest in Airbus' enormous double-decker airplane, the A380.
To illustrate social stratification, we turn again to the family car level. Diekstra and Kroon (1993) state that cars are the ultimate 'device of psychological superiority'. This satement certainly applies considering the fact that the car as such is the oldest of material status symbols in society. When climbing up the social ladder, the theory of 'bigger is better' or 'the more luxurious the better', continues to apply. The products in higher social circles are then boats, planes or other extravaganza. The same rules apply in the business sector, where bigger assets equals status: it is size as a parameter for sales volume.

Size and luxury, as being the only two factors in social status, may seem a little blunt at first. The question is: what does status come from? According to German sociologist Max Weber, stratification comes from 'property, prestige and power'. Property refers to a person's material posessions and consequential chances in life. Someone in control of property has power over others and can use his or her property accordingly. Prestige refers to "the reputation or esteem associated with one's social position" (N/A; Boundless.com). Power is about the ability of an individual to do whatever he or she wants, regardless of what others want. Applied to Weber's three factors, this means that the possession of, for example, a big airplane, equals an increase in prestige. Large and luxurious products have the perception of being expensive, which adds to the sense of power the company in question has within the industry. If a lot of what is going on in the professional world is psychological, it explains a lot of how the customer's perception is made, and how travel companies worldwide practice Weber's three P's to tout themselves.

Put short: coach-traveller interaction is about getting from point A to point B. These days, very little prestige comes from taking a touring coach to a destination. Touring coaches are oftenly used by groups of children or elderly people, assessed on occasional observations done by the author. These trips usually limit themselves to short in-country excursions. Youngsters also book a bustrip when going abroad on snow holidays, given the excellent price to service ratio bustravel is renowned for. In other European countries, such as Poland, bus travel is a common thing, as the country is vast and wages are fairly low. Nevertheless, airplane travel is, and has been since 1971, the most prestigeous means of travel worldwide. Opening the skies meant the ability to travel to far, exotic places. The question remains how public perception of travel and the according prestige that comes from it, will alter through time. As expressed in chapter 3.2.5, trends such as geo-local and deep travel can emerge through societal and economical change, completely altering people's perception on travel as we know it today.

A certainty which remains is that travellers will not give up the level of (travel) luxury that they have acquired up until today. Travel can be related to the top three levels of Maslow's pyramid: social needs, self esteem and self actualisation. For the traveller, the touring coach -which covers the whole or some of the travel distance- only applies to the bottom two levels: physiological and safety needs. For the travel agency owning the coach, the pyramid can be fully applied in terms of owning the vehicle.

7.1.3 Deconstruction on context level

A product only makes sense in its appropriate context. Context generates reason for a product to exist. Hekkert and van Dijk (2011) defined principles, states, developments and trends as four different categories to attribute these reasons to.

Principles

Hekkert and van Dijk state principles as 'stable patterns of life and nature' (2011). As we found out in chapter 3.1.2, bus travel increases when gas prices incline. It is proven that travel by motorcoach is the cheapest way of motorized travel. Bustravel is thus seen as a cheap way of travel.

States

States are defined as "things that are relatively constant" (Hekkert and van Dijk, 2011). 'Constant things' are possibly the greatest problem of the coach industry. For years, bus architecture has remained the same: elevated passenger level, an open, unorganised luggage compartment underneath, a motor compartment in the back and the vulnerable driver's position. The typical shape of coaches has also remained largely the same for over decades: an extruded rectangle with no eye for streamline whatsoever.

Developments

Slowly but surely, the sector is moving towards environmental and safety solutions for their buses, with the latter being the last evolution. Following the example of the family car branche, safety systems such as automated braking and lane assist systems are finding their way to production buses and even driver monitoring systems are emerging. Environmental developments come in the form of the new EU6 emission standard, and numerous experiments with biofuel and hydrogen buses, introduced in a bid to reduce particulate matter in city centres and reduce fuel costs in general.

Trends

Trends originate from changes in the behaviour of people, as a result of developments (Hekkert and van Dijk, 2011). Environmental awareness and the clogging up of roads lead to political plans to redirect traffic around the city borders, banning all vehicles from the inner city. First steps are being undertaken, in the form of ZEZs (Zero Emission Zones). Seperate rules and boarding areas for travel coaches may become a necessity in the near future.

7.1.4 Conclusions

Following the Vision in Product design methodology, the status quo of motorcoaches was brought into relation with today's context. The elements that come from this analysis are of great importance to the design of the 2030 LDC. It is certain that, however we aim to radically reshape the architecture of the coach, some aspects will remain largely the same in the year 2030. We established that the coach is shaped by its context, from which it derives a right to exist. Interaction is a psychological given, as travel and transport remain a luxury item, the interaction between traveller and coach acts on an emotional level. The deconstruction on context level brought along some results from the earlier NPP phase.

Fig.55: VDL Jonckheere JHD-140 (source: VDL Bus & Coach)

7.2 2030: Next Generation Long Distance Coach

The Vision in Product design methodology offers a second part, which will serve as a framework for the design phase of the 2030 LDC. The starting point is formed by the future context, which will result in a design vision. Based on this, a scenario containing the coach-user interaction for the concept will be generated.

7.2.1 The 2030 context

As in the deconstruction of the context phase (7.1.3), the three contextual categories principles, states and developments, will guide us through the design phase of the 2030 context. For this, results and findings from the NPP phase will be applied.

Principles

- people tend to take a coach or bus when travelling continentally and in group
- people mostly travel by bus when all other options seem more impractical than taking the bus (e.g. snow holidays)
- people are well aware travelling by motorcoach is the cheapest way of travel these days
- travellers are accustomed to a certain degree of luxury they're seldomly willing to cede
- coaches are widely used for commuting
- in larger countries motorcoaches remain an important means of (cheap) transport

States

- a bus has four or more wheels and is self propelled
- green technology research impacts consumer products
- the internet
- cities morph into megacities and megaregions

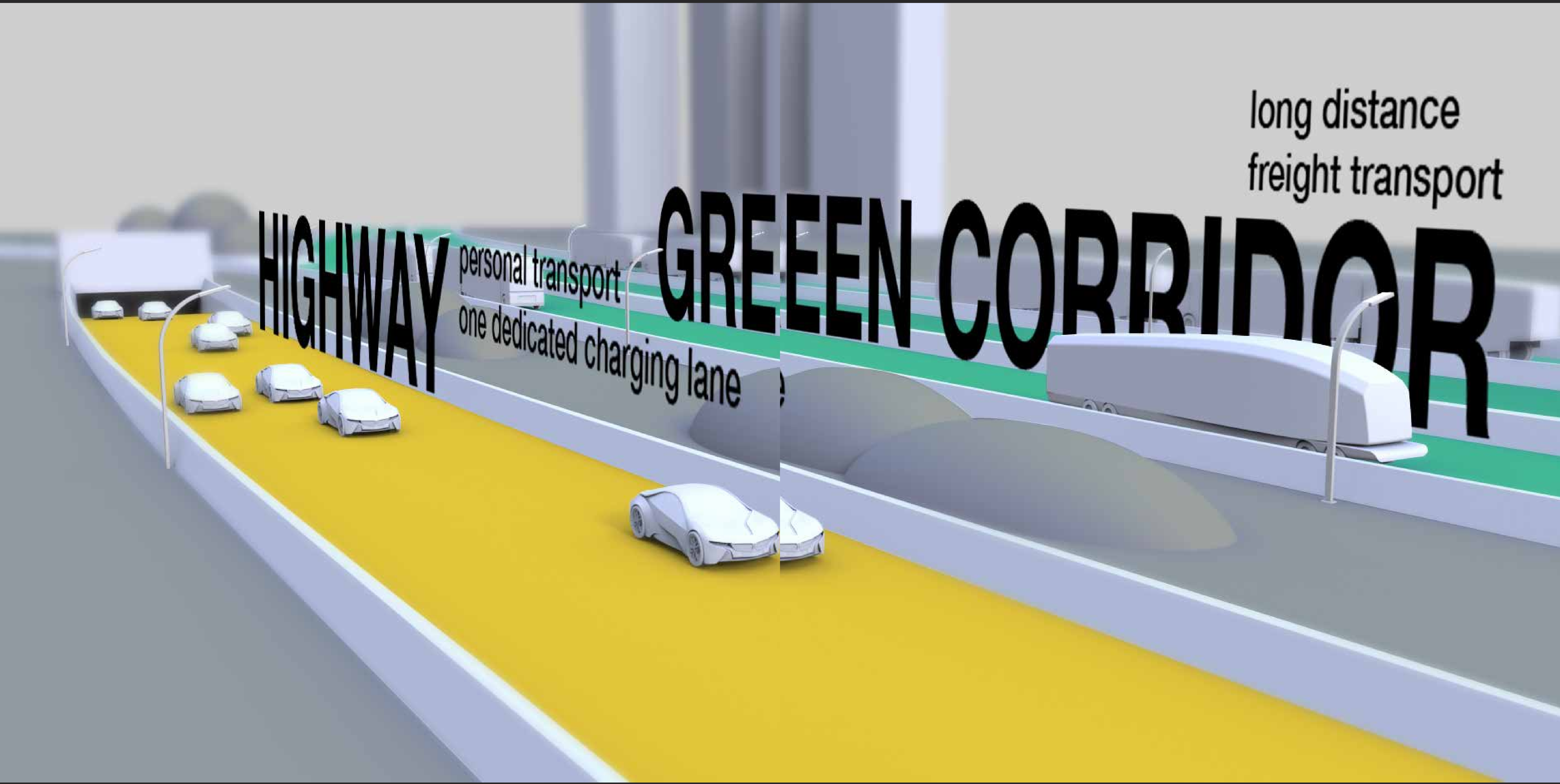
Developments

- traffic increases worldwide
- scarcity of raw materials, resources run out globally
- climate change, increase of GHG
- digitalization and automatization
- urbanization
- ageing population
- Green Corridors across Europe

Trends

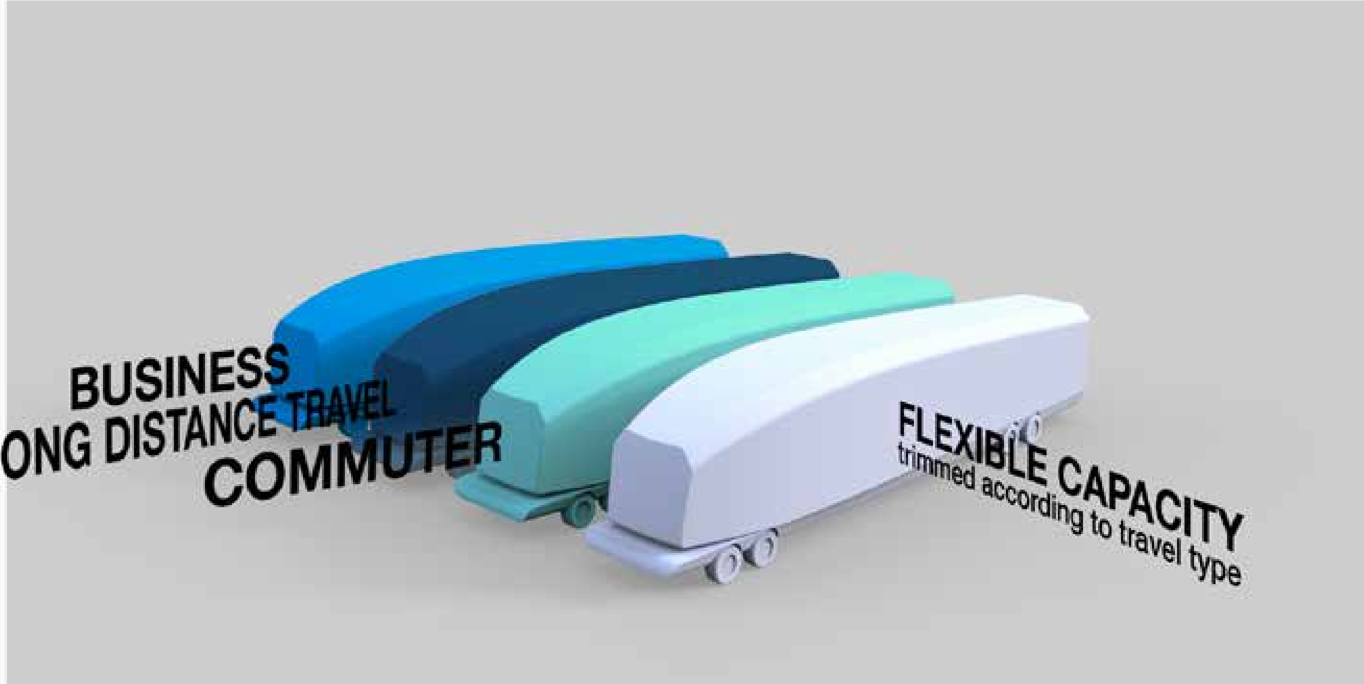
- V2V: intelligent, connected and safe traffic
- autonomous vehicles
- ageing population
- efficient use of space and energy
- nanomaterials completing multiple functions at once
- sustainability in product design
- green energy and a smart grid system
- sharing

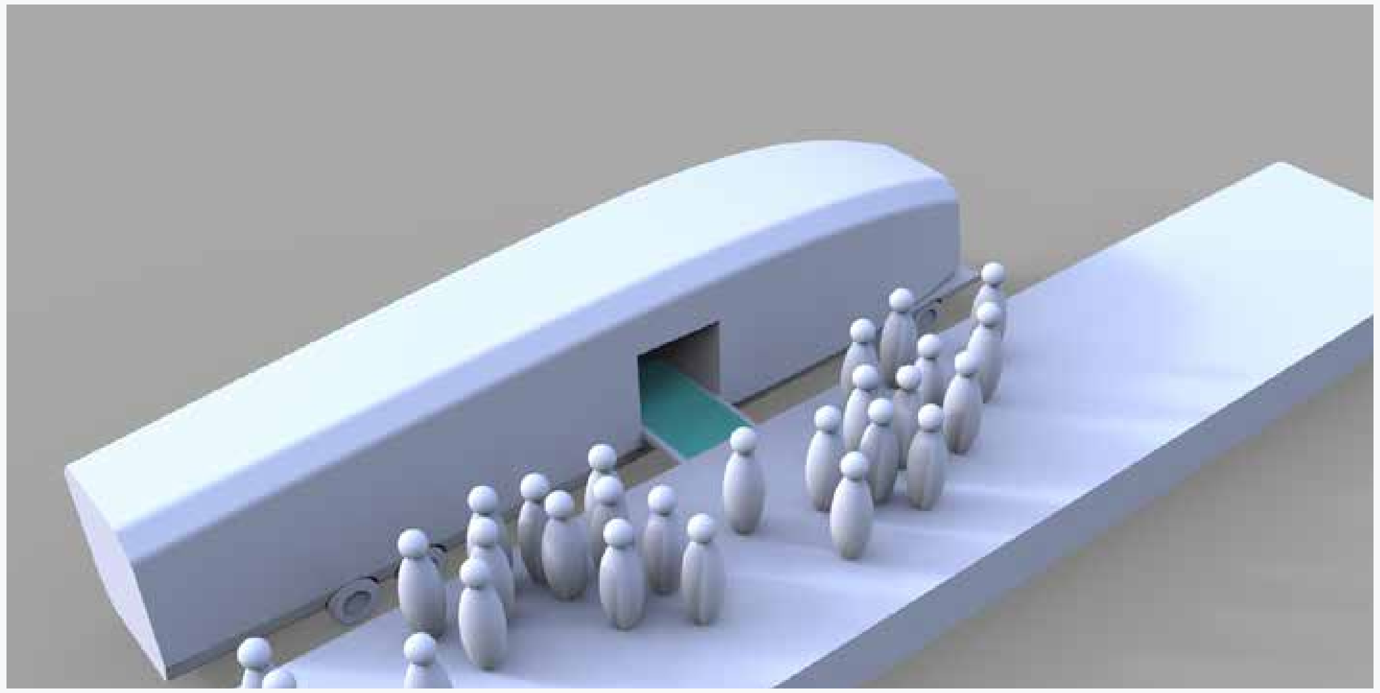
7.2.2 Scenario



A brief scenario will provide a visualisation of the context, and the main innovativities of the Next Generation LDC.

Fig.56-69: Next Generation LDC 2030 scenario imagery (Claus, 2014)



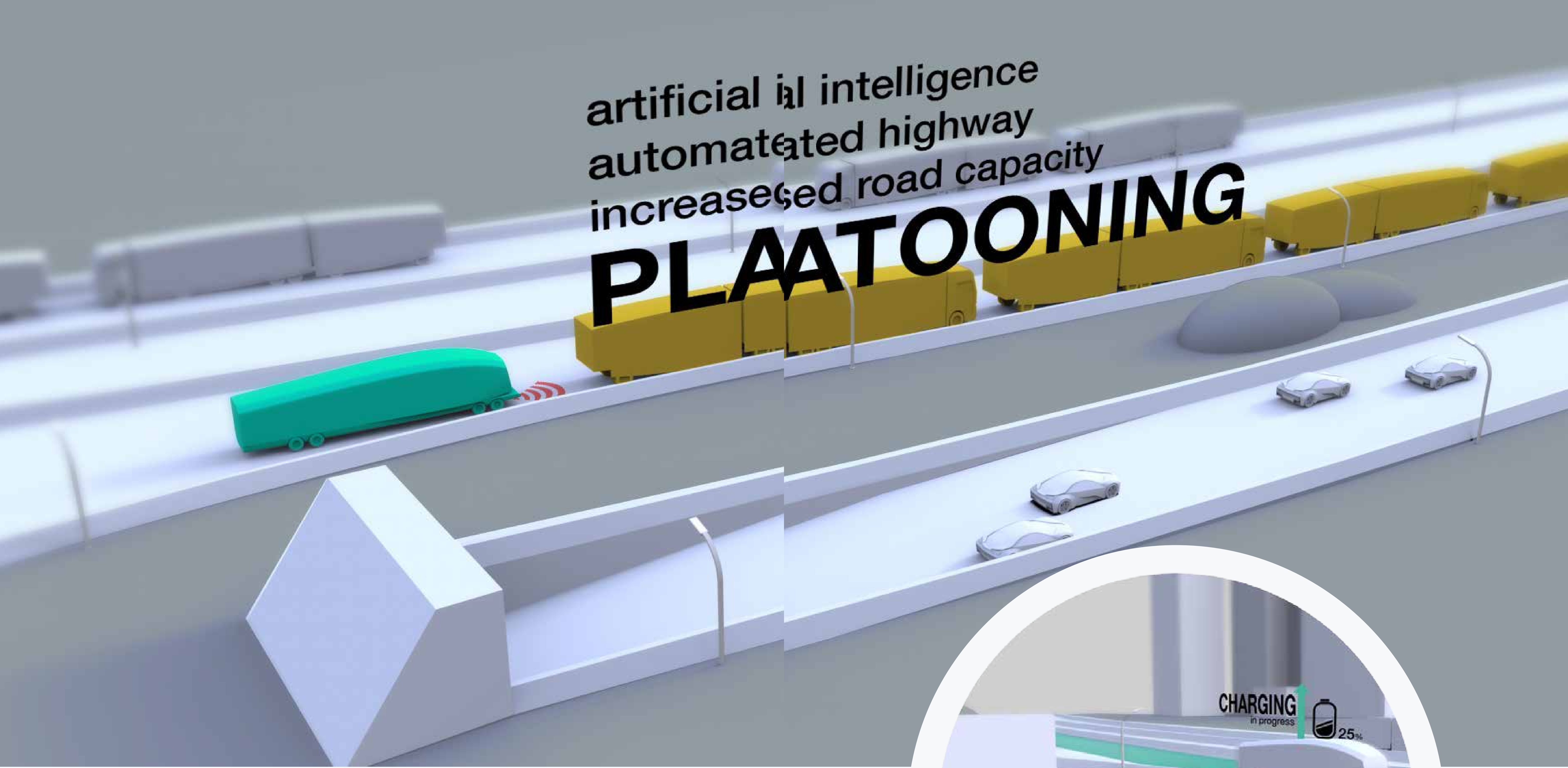


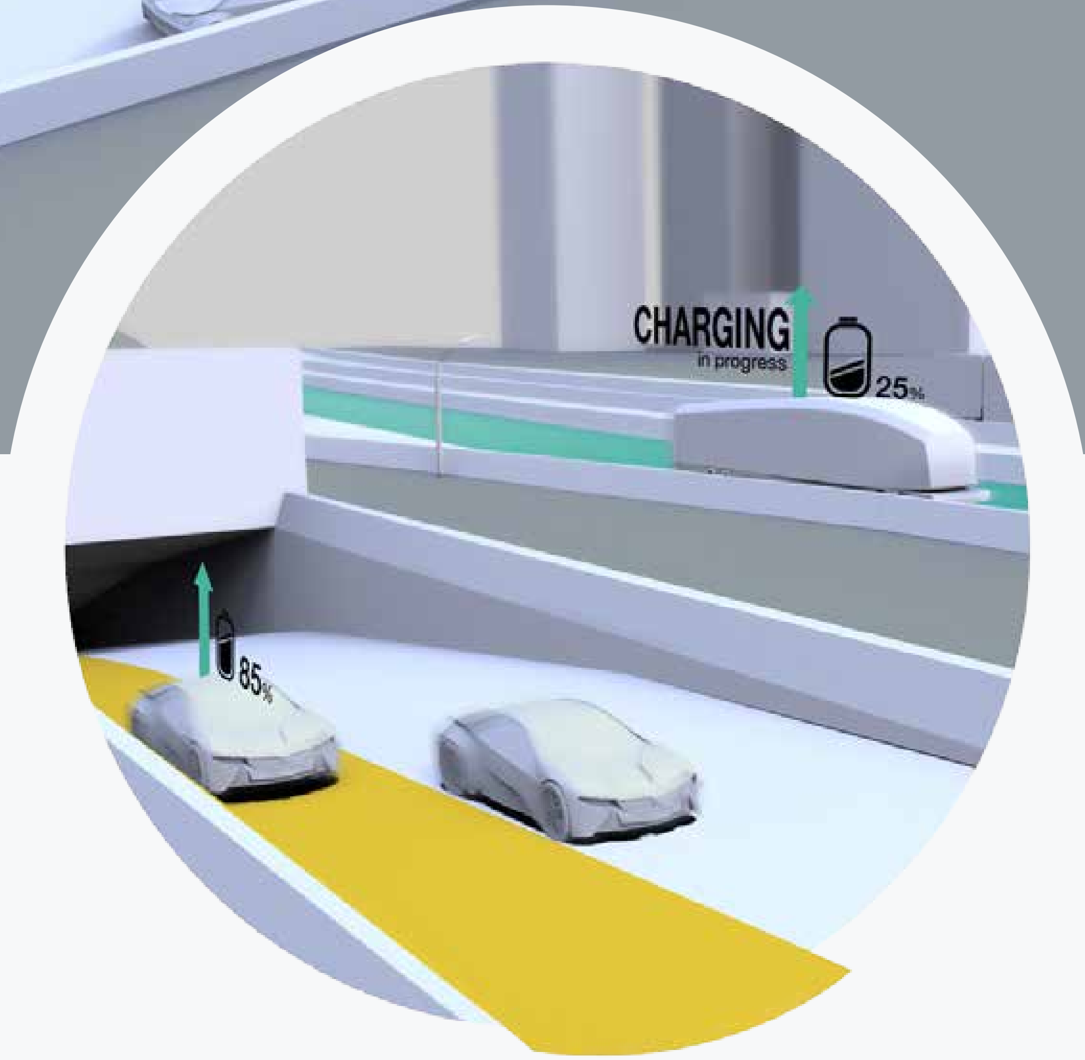
In this scenario, we follow a group of young adolescents on their way to a snowboarding trip. For this one, the Long Distance Travel trim is rented. *Upper left:* travel agencies or organizations choose between the three coach trims, in accordance to the desired travel type. *Upper right:* at the edge of the city centre, the group boards the coach from a platform. Terminals are constructed at traffic hub hotspots in cities, offering airport like infrastructure and service to travellers. Luggage is handled by personnel, storing the bags and suitcases in the designated area in the rear of the coach.

Just like boarding an airplane, the group can board stairlessly and without gaps from the platform, via the onboard ramp of the Adaptive Entrance, a standard innovation of the coach.

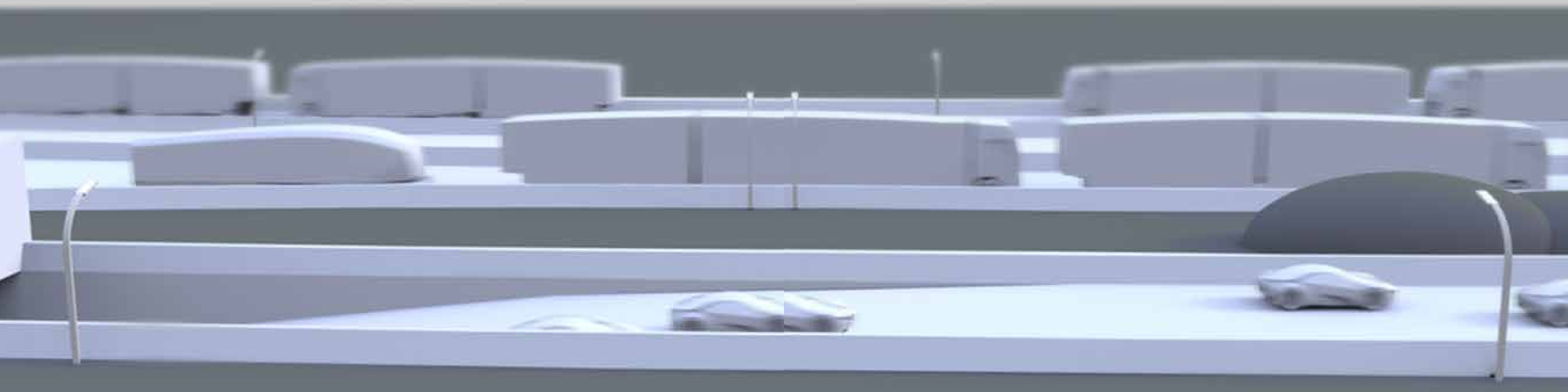
Inside, the seats morph to the assigned Traveller's Profile settings and antropometric preference. A snug fit is hereby guaranteed for everybody on board.

Spread image: The group heads to the Green Corridor, the long haul transportation hub for heavy goods transport and commercial transport. The entire trajectory is downloaded into the coach's system, signifying that the vehicle can anticipate power consumption, charging kilometres, exits, etc... The onboard computer relieves the driver by autonomously joining a platoon of trucks, blazing down the road...

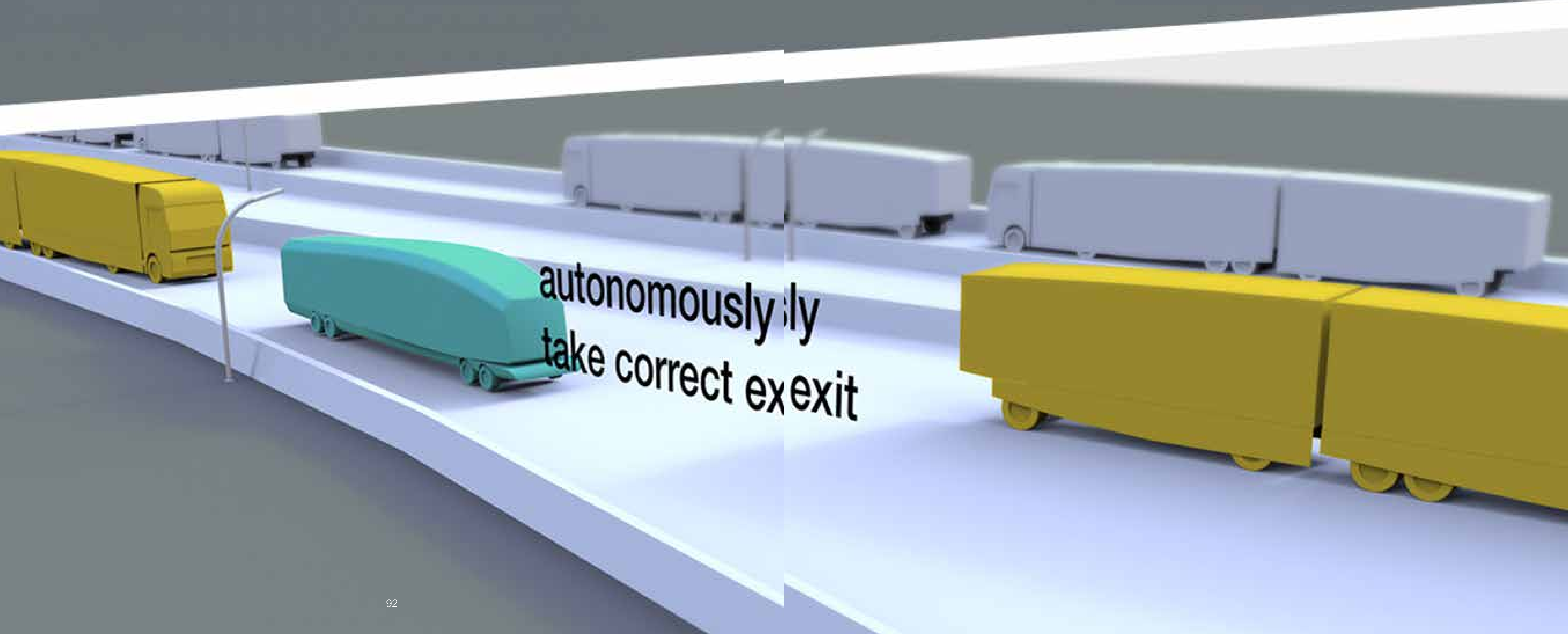




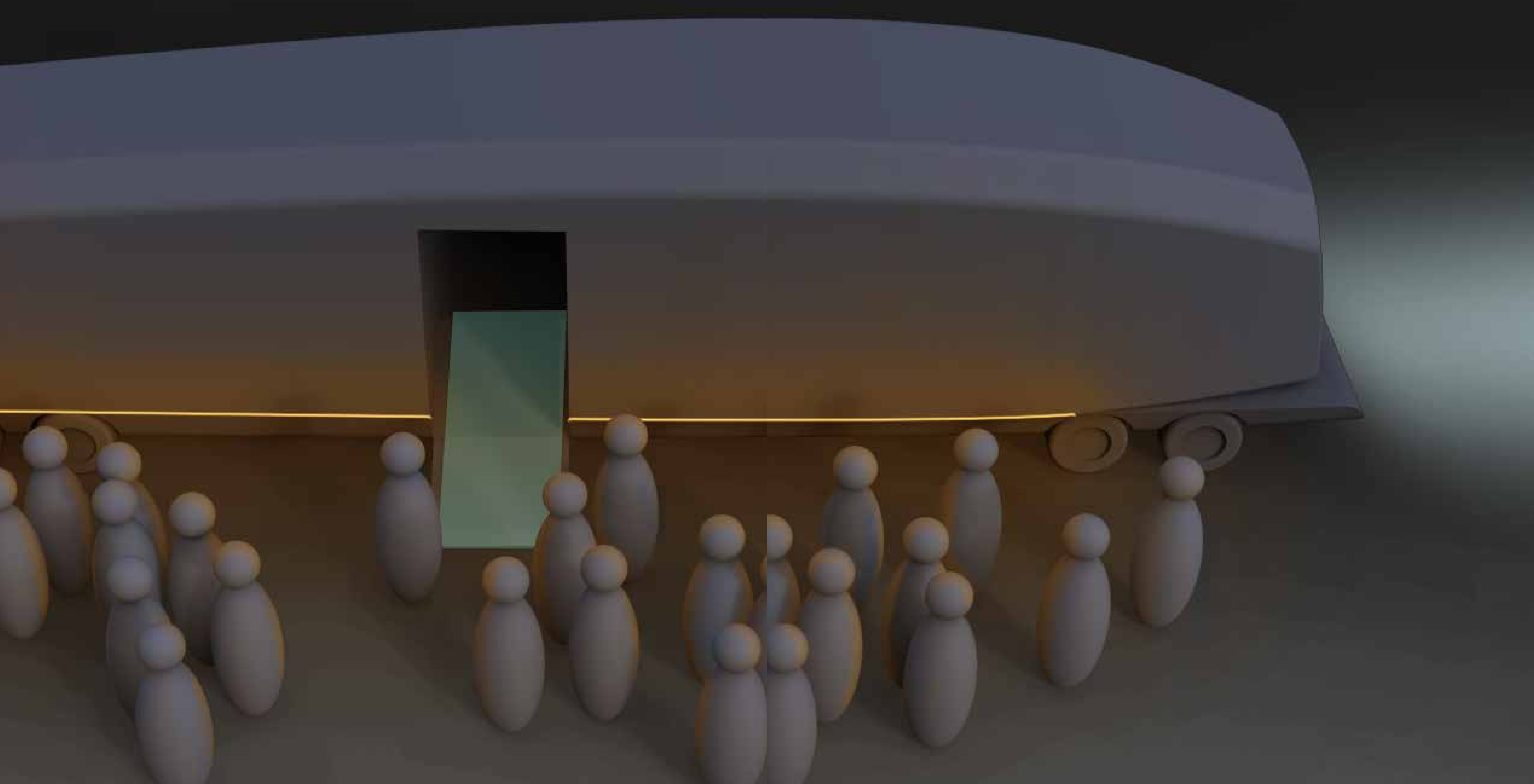
Upper image: while driving on the Green Corridor, the coach has the option to form a platoon with other vehicles on the stretch. Platooning increases the energy efficiency of a vehicle: by driving into the 'air hole' of a truck in front, the airflow over the bodywork of the bus changes positively towards a lower drag coefficient. Platooning also implies that the vehicles follow each other autonomously as they twist along the roads, accelerate or decelerate. The onboard computers continuously calculate the most efficient way to travel: when a platoon is moving too slowly, the bus can autonomously perform an overtaking maneuver. At this point, the driver can sit back and relax, even take his hands off the wheel. When accomodated for, snacks and drinks can be offered to the passengers, in a genuine aeroplane manner.
Insert: on predefined stretched, vehicles will be able to wirelessly charge while driving. Green Corridors can be seperately constructed infrastructure, on the most busy axes through Europe, or they can be dedicated charging lanes on regular highways.
Next page under: when reaching an exit, the driver is alerted 5 minutes in advance in order to be able to retake position behind the steering wheel. In the year 2030, autonomous vehicles will ride alongside semi autonomous or manual vehicles, which will make it required by law for a human driver to be behind the wheel on non-highway roads.



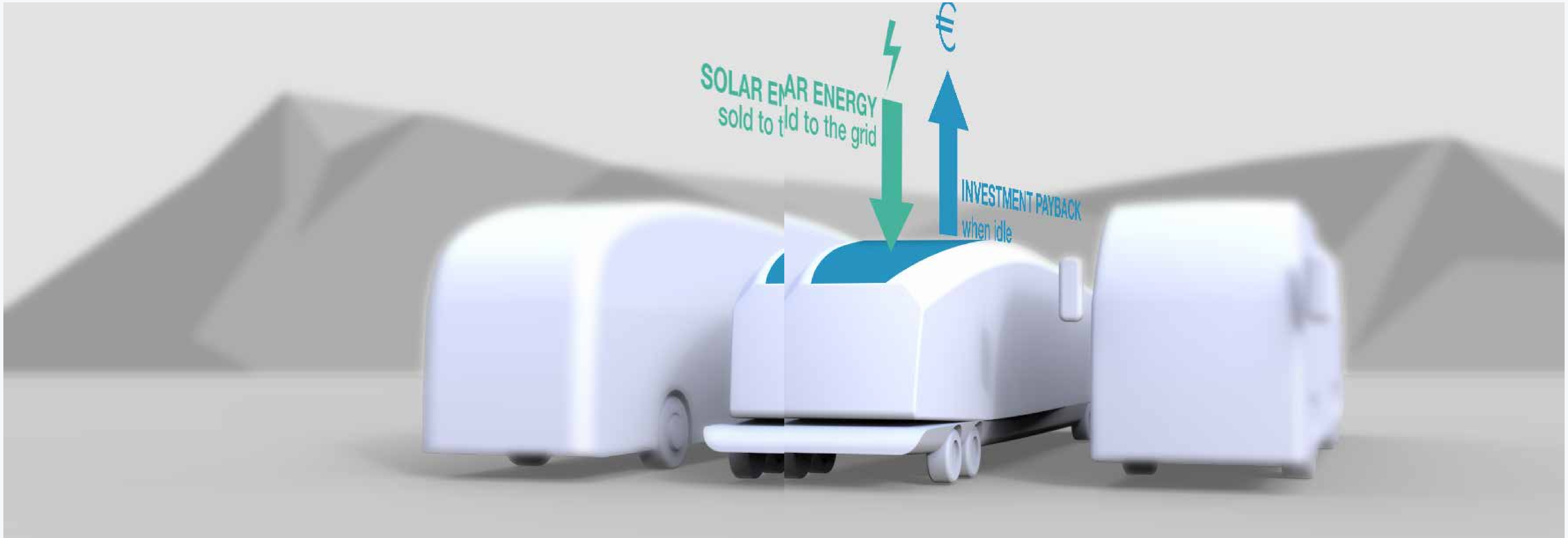
Miles and hours pass...



Late at night, the coach is reaching the traitorous mountain roads. The driver is feeling somewhat tired of the long day that has passed. At this point of the journey, the chances for catastrophic accidents raise considerably. Driver fatigue translates in slow reaction times and diminished attention levels. Luckily, the Jeeves system aids the driver and corrects his driving. This way, the vehicle and its passenger safely exit the bend that was entered too fast!



Once arrived at the destination, there is no boarding infrastructure present at the location. Thanks to the Adaptive Entrance, this proves to be no big deal. The passengers can deboard easily and wait for personnel to gather their luggage from the rear of the vehicle.



The next day and during the week which follows, coaches gather on the parking lot as groups go about their skiing and snowboarding business. The Next Generation LDC cleverly utilizes this idle time to refill its batteries through solar power or wirelessly sell electricity to the smart grid. When the solar panels on the roof are not sufficient to charge the batteries for the return journey to the hotel, electricity can be equally bought wirelessly.

At the end of the week, one individual has broken his leg doing stunts on his snowboard. He has his leg in a plaster and has to use a wheelchair to move around. With classic coaches, getting on board would be a lot of hassle. But not with the Next Generation LDC: its built-in Adaptive Entrance makes sure Tom can board with his wheelchair in a fast and easy manner.

7.2.3 Supportive trends

The concept for the Next generation LDC is the product of the findings from the NPP chapter, which is concluded with the definition of four Design Drivers (chapter 5.1). The setting was defined by the vision of the 2030 context, based on near future trends, and the 2030 interaction (7.2.3). In this chapter, six characterizing items that will enhance the concept's innovativity are shortly discussed.

Tailored service

- Data visualisation: communication between products enables corporations to discover patterns in user behaviour.
- Social media: people share personal information with companies and are accustomed to the idea of third parties using that information to provide a better service to the customer.
- Conscious technology: processor power increases and enables the development of smart systems that will adapt to their surroundings or desired personal use (Kurzweil, 2005).

Flexible capacity

- Micro architecture: lightweight and compact design solutions will enable personalizable spaces with room for personal fulfilment and social interaction.
- Inclusive design: the goal of inclusive design is to ensure that devices, products, environments, and experiences remain equally accessible to everyone, regardless of age, culture, or ability (BMW Guggenheim Lab, 2013).

Artificial Intelligence (AI)

- Safety: V2V will ensure a drop in traffic casualties.
- Green corridors: green transportation hubs across Europe will increase logistical efficiency and diminish its ecological footprint.
- Autonomous driving: systems for autonomous driving are developing towards fully automated systems (Continental AG, 2013).
- Traffic increase: urbanisation and the development of the middle class worldwide will lead to increased traffic and traffic issues, as cars become more accessible to the average man (Mitchell and Burns, 2010).
- Platooning: platooning creates bundles of vehicles, which increases road capacity and improves energy efficiency.

Inductive en route charging

- Extensive energy needs: demands for energy supply will rise significantly towards 2030-2050. More efficient use of available energy will become top priority, as well as the production of green energy, in view of climate change.
- Green energy: vehicles autonomously generate power from natural or energy efficient power sources, and are connected to a smart grid system when parked.
- Smart Grid: smart grid solutions are designed to fill in gaps in energy supply. The smart grid will make it possible to have an increase in EVs withouth having to build additional and mass polluting energy sources. Ultimately, the smart grid system is designed to flatten peak moments in energy demand by having EVs charge in off-peakhours.

Streamline

- A lot of energy consumption improvement can be sought in reducing the aerodynamic drag of vehicles. Working with nature instead of against will experience increased interest in design.

Multifunctional nanomaterials

- Reducing weight: nanomaterials and composite materials will enable a leap in weight reduction, as components will fulfill multiple functions.

7.2.4 Innovative features

The following elements will mark the most innovative functional elements for the Next Generation LDC. Each element complies within one of the specified Design Drivers, which each answers to a future trend and/or challenge. The challenges are direct NPP conclusions.

Challenge 1: increased traffic while improving efficiency and safety

Earlier, we established that traffic worldwide will increase due to societal and economic evolutions. City traffic will clog up unless alterations are made to the way vehicles and people move within cities. Expanding existing infrastructure is costly and does not guarantee a solution. Instead, focussing on designing clever solutions to improve the efficiency of traffic, will potentially prove to be more useful in the long-term. V2V systems and the introducing of platooning on city and intercity roads can increase road capacity without touching current road infrastructure on a large scale. Summarizing: both traffic efficiency and safety can benefit from implementing artificial intelligence that enable vehicles to communicate with each other. The Next Generation LDC will be designed to fit into this new era of mobility.

Challenge 2: inclusive design for accessibility and comfort

Fysical diversity poses a great challenge for public service designers. Design for all is gaining interest as it is becoming a benchmark in a world where it is no longer acceptable for minorities to be discriminated or to be hampered in their life fulfillment. It goes without saying that not only minorities benefit from inclusive design: a well fitting seat, for instance, is a joy for young and old.
Boarding a bus is, for disabled people, often an embarrassing experience. Wheelchairs are commonly lifted into the coach using a platform, a process of which the patient has no control whatsoever. Elderly people regularly struggle while boarding a touringcoach because of the steep and narrow steps. An ideal scenario would be one in which every person can board without any hiccups or irregularities. The concept will feature a smart and flexible entrance solution, which will adapt to different situations to make boarding an ever pleasant process.

Challenge 3: energy efficient use and prolonged range for EVs

Battery Electric Vehicles (BEV) are more energy efficient than ICE powered vehicles. This makes battery power the ultimate mobility solution. This comes, however, with an ultimate challenge: driving range and charging speed. The driving range will be secured by a solution that will simultaneously solve part of the charging speed problems: en-route charging on Green Corridors.

7.3 Conclusion

This chapter began with the deconstruction of the LDC as a concept. Using the Vision in Product design methodology by Hekkert and van Dijk (2011), the 2030 Next Generation LDC concept was further defined. Coach-user interaction and the 2030 context were exposed, which led to the definition of functional elements according to trends and visions that resulted from the NPP chapter.

8 The Next Generation platform

The Next Generation platform bundles all innovative functions of the LDC concept, combined with the core engineering - necessary for the functioning of the bus. Core engineering contains the drivetrain, suspension, electric motors, safety systems and structural elements. The platform enables to efficiently produce multiple versions of the same production model, be it longer or with a different trim, at higher production volumes than would otherwise be the case. Platforms are currently well established in the automotive industry (Muylaert, 2013).

The 2030 Next Generation LDC platform will feature the following innovativities:

1. Jeeves
Jeeves embodies the driving assistance systems, V2V hardware, on board systems managing, energy management systems, etc... It is the personification of the Next Generation LDC's artificial intelligence (AI). It is the controlling entity which assimilates all processes in the system.

2. Electrical architecture
The electrical architecture enables two power unit options: wireless en-route charging and fuel cell. The wireless power transfer (WPT) system ensures long distance range which is indispensable for long distance coaches. With battery technology and multifunctional polymer innovation not yet at a standstill, the need for rapid charging at any time will remain a necessity towards 2030. Depending on how the customer desires to deploy the coach, a second power unit is available in the form of fuel cell. The electrical architecture remains the same, only the power unit differs and is modularly installable in the platform.

3. Solar roof
Sub systems such as climate control, can be powered by primary energy sources, in order to maximise the driving range of the vehicle. When powered by the solar panels, the air conditioning will not subtract energy from the main battery packs, which will then enable to fully juice the electric motors that propel the coach. The second function of these panels, is a passive way for generating energy for selling purposes. The smart grid will enable people to resell energy, effectively paying back idle vehicle time.

4. In-wheel motors
Using battery electric propulsion creates opportunities to alter vehicle's architecture. Certain components change or can be located elsewhere, to create space in places where it would have been impossible before. A clear example are in-wheel electric motors: these compact electromotors can be mounted inside the rims of a vehicle, shifting the product architecture completely.

5. Flexible capacity interior and Adaptive Entrance
The flexible capacity interior will provide a way to maximise the capacity of the coach to the desired use and personal preferences of travellers. Seats will vary in price according to the chosen comfort mode and dimensions, which offers tour operators a cost efficient way of utilizing a fleet of vehicles. Travellers benefit as well: traveller profiles ensure maximum comfort at a fair extra cost.
The adaptive entrance is a flexible solution to make boarding easier regardless of the surrounding facilities or the lack thereof. It will consist of a smart platform that will be variable in height, length and angle, and will be able to transform itself into a wheelchair lift.

6. Lightweight chassis and aerodynamical bodywork
The chassis components will be optimized for strength, durability and weight, whereas the bodywork will be optimized for aerodynamical efficiency.

9 Jeeves

Jeeves is the AI on board computer which manages all systems and data flows within the vehicle. It communicates with other vehicles in the area, anticipates geographical surroundings, monitors the driver, etc... The majority of Jeeves' actions are silent: the driver is only notified with the most important and urgent information. Jeeves' is designed to make the life of the driver easier and more organised. The system is the result of the Design Driver 'Safety'.

A proper name was chosen in order to provide a sense of personification. It is important for the coach operator to put trust into the system, especially when command is handed over to the AI. Through popular culture, a lot of examples of name giving to computers can be found. One of the most famous AI entities is HAL9000, from the epic sciencefiction epos *2001: A Space Oddyssey*. It is rumoured that the acronym HAL comes from a single letter offset from IBM, the main sponsor for the movie. Another example is Jarvis, the loyal help of Marvel's *Iron Man*. In Jon Favreau's Iron Man movies, the Jarvis character is an AI monitoring thousands of variables in order to help protagonist Tony Stark. From these examples, it is clear that AI with a proper name exhales confidence and trust: a human bond. This reasoning brought the idea of providing the Next Generation LDC's super computer with a name.

The name 'Jeeves' was chosen as it is one of the most iconic and recognizable names for a gentlemen driver. Originally from *Jeeves & Wooster*, a British comedy-drama series which aired on British television from 1990 to 1993, the name was adopted because of the description of the character from the series: Jeeves was the valet of Bertie Wooster. A valet is someone who serves one man rather than a complete household or family (McMillan, 2014). This description led to the final decision to opt for that name.

Fig.70: HAL9000, still taken from 2001: A Space Oddyssey by Stanley Kubrick

Jeeves is, as was mentioned before, designed to make life easier. The implementation of said AI comes with a clear set of advantages for the coach as an eco system:

- managing: Jeeves quietly manages and processes large streams of data and filters the most relevant information to be shown to the coach operator.
- anticipation: the system is up-to-date with the planned trajectories and is able to anticipate steep road inclinations or other geographical hazards or traffic issues
- planning: Jeeves is constantly connected to a server, which contains information on planned trips, energy usage and charging/selling from/to the smart grid
- safety: Jeeves incorporates the V2V infrastructure which will add to a more durable and safe traffic flow

Society also benefits from AI integration in vehicles:

- road capacity: the concepts of V2V and platooning would enable more traffic on the same stretch of road. A capacity increase of around 200% is to be expected, without additional road infrastructure built (Tientrakool, 2011).
- traffic: traffic flow will be led more efficiently through V2V
- safety: 90% of traffic accidents are due to human error. Active driver assistance can diminish fatal car accidents to about 2% of a country's GDP (Muyllaert, 2013)
- environment: efficient traffic flow reduces energy consumption, and Jeeves monitors energy exchange between the coach and the smart grid, in order to flatten energy usage spikes in the grid, making global energy consumption more efficient.

Jeeves monitors all external and internal aspects of the Next Generation LDC at any time. This implies that in theory, the coach is able to steer itself through traffic. It is, however, unlikely that self driving vehicles will be allowed anywhere towards 2030. Official reports state that by 2025, Daimler and Ford expect autonomous vehicles on the market (Shepardson, 2014). In 2035, IHS Automotive report claims the largest part of self-driving vehicles will be operated completely independent from a human passenger's control (Tannert, 2014). Further, expert members of the Institute of Electrical and Electronics Engineers (IEEE) have predicted that up to 75% of all vehicles will be autonomous by 2040 (ieee.org, 2012). These numbers create an impression of how the autonomous driving market will develop towards 2030. The numbers do not mention heavy duty or passenger transport, but bearing in mind this sector introduces passenger car innovations with a few years of delay -but manages to respond ever more quickly to innovations- it is not unthinkable that the given percentages will not be far off for the heavy duty transport sector.

9.1 System requirements

Jeeves assists the driver and can perform certain tasks autonomously, such as platooning, parking or executing a life saving maneuver. This ability to make split second decisions is based on the fact that all sensor data is processed through the system's brain. The following diagram shows the information and data flow between the various systems of Jeeves. It is greatly inspired by a proposed diagram by HAVEit, a European Commission project for autonomous vehicles (HAVEit, 2011). Four clusters of systems can be identified: detection, human machine interface (HMI), decision making and execution. This chapter will discuss the top three clusters: HMI, detection and processing (grey frame). The execution part requires less attention, as car manufacturers or companies like Google already have done significant R&D for driverless vehicles and the needed components to reach the goal (Daimler, 2011).

Fig.71: Jeeves system layout (Claus, 2014)

9.1.1 HMI

The HMI connects the driver with Jeeves and the machine. The driver's input and his/her current state are constantly monitored by means of sensors and cameras. The HMI thus enables the driver to communicate with Jeeves: the computer is able to 'understand' the driver according to his/her input. Communication is a two way process, so the HMI provides feedback for the driver.

Driver input

The main driver input is analogous to the controls that have been around for decades: a throttle pedal, brake pedal and a steering wheel. Since EVs do not require a gear shifter as there are no gears, the function of the gear stick is somewhat simplified: the stick incorporates two functions, one makes the coach go forwards, while the other one makes the machine reverse.

Driver monitoring

Jeeves monitors the driver with a HD camera, which detects head and eye movement, heart rate and the attention level of the driver. The system also learns the different driving styles of each driver, which enables the computer to anticipate certain moves and intervene when needed.

Feedback

Different types of feedback can be provided to the driver: speech, display, sound, haptics... The type of feedback depends on the message that needs to be delivered. This is chosen according to ergonomic prescriptions.

Conclusion

A range of sensors enable Jeeves to understand the driver and comunicate with him/her through display, sound, speech or haptic feedback.

9.1.2 Detection

Understanding traffic is one of the most innovative functions of the Next Generation LDC. Using a wide range of sensors, the coach is able to determine its location, 'see' other vehicles or pedestrians, manage on board processes and communicate with traffic and infrastructure.

Location

The vehicle needs to know its location in order to succesfully navigate to the desired destination. The localisation needs to be as accurate as possible: Levinson et al. (2011) states a precision in the range of one decimetre would suffice. Location services can be provided through a combination between satellite GPS and cellular network triangulation.

Vision

Research provided insight in how AI vision and object recognition is acquired. One of the key elements in succesful vision and path/object recognition is the layering of sensors. In short, a short range radar is combined with a long and mid range radar. On top of this, front and rear mounted cameras observe the surroundings. In some cases, a 360° camera is mounted on autonomous vehicles. The system's layers are written down below. The further elaboration follows in the next chapter, where the technology behind Jeeves is discussed.

- short range (50m) radar and laser coverage on each side (158°): detection of objects or organisms near the vehicle
- long and mid range (100-200m) radar and laser coverage front and rear (158°): detection of size and movement of objects or organisms in the surroundings
- long range camera (200m) front (40°): detection of road signs, markings, etc...
- short range (50m) scan (360°): precise detection of objects or organisms
- long range scan (200m): front (40°): detection of traffic on highways

Fig.72: Sensor layering (Claus, 2014)

Micro organism

Jeeves monitors all processes within the coach (system temperature, system pressure, etc..), as well as speed and direction of the vehicle. These variables are calculated using the input of velocity and steering angle (odometry) and inertial sensors (accelerometer).

Communication

V2V and Vehicle to Infrastructure communication (V2X) enables Jeeves to anticipate traffic flow and movement. All road vehicles are interconnected with each other and with road infrastructure, which theoretically annihilates any change of accidents. Studies also show that communicating vehicles can increase road capacity (Tientrakool et al., 2012).

Conclusion

The input of various sensors enables Jeeves to anticipate, act and communicate with its peers. The Next Generation LDC can be seen as a micro organism within an interconnected system, which ultimately forms a meso organism: traffic.

9.1.3 Processing and acting

The merged data is sent to the main CPU, the heart and brain of Jeeves. An important part of Jeeves' tasks is to anticipate situations and make real-time decisions on the spot.

Anticipation

Through the input of all on board sensors and the V2V and V2X networks, Jeeves is able to predict traffic movement and anticipate on route hazards and traffic situations. Considering location, traffic situation and traffic analysis, an algorithm based navigation decision is made. The location of the vehicle is determined based on GPS and cellular data, in order to get a precise estimation of the whereabouts on a map. Traffic situations are, for instance, straight roads, crossroads, roundabouts, steep bends, etc... The analyzing of traffic is based on information from the radar, laser and camera sensors, and give data about the speed, direction, size and type of vehicle or organism.

Conclusion

The AI 'Jeeves' is able to understand traffic situations, anticipate and learn from past experiences. The algorithms hard wired into the system enable the vehicle to autonomously execute maneuvers.

9.1.4 Predictions on legislation

While Google had no immediate plans to commercially develop the system, the company hopes to develop a business which would market the system and the data behind it to automobile manufacturers. An attorney for the California Department of Motor Vehicles raised concerns that "The technology is ahead of the law in many areas," citing state laws that "all presume to have a human being operating the vehicle". According to The New York Times, policy makers and regulators have argued that new laws will be required if driverless vehicles are to become a reality because "the technology is now advancing so quickly that it is in danger of outstripping existing law, some of which dates back to the era of horse-drawn carriages". (Wikipedia)

Fig.73: 1956 ad about autonomous driving (N/A)

9.2 High tech

Driverless cars is something which has appealed to people and engineers for decades. The earliest record of driverless car concepts date back to 1925: Houdina Radio Control demonstrated the radio-controlled driverless car “linrrican Wonder” at New York City streets, where it travelled up Broadway and down Fifth Avenue through the thick of the traffic jams (The Milwaukee Sentinel, 1926). The image above depicts a typical 1950s visualization of how future transport could look like. Back in those days, the first concepts of electronic guiding devices, embedded in the road, appeared. These experiments continued in the 70s, with the Transport and Road Research Laboratory from the UK testing a driverless Citroën DS on magnetic cables in the road. The test was a success, and a cost benefit analysis proved that implementation on British roads would be repaid by the end of the century (Reynolds, 2001). However, the technology was never implemented anywhere.

These days, on the contrary, a lot of research and development on autonomous vehicles is going on, and predictions look promising. All major car brands seem to be joining in on the fun, betting heavily on the technology and its future. Mercedes-Benz, Audi, Nissan and BMW all expect to sell autonomous cars by the end of 2020 (Joseph, 2013; Preisinger, 2013; Eimer, 2013; Johnson, 2013; Shepardson, 2013). The technology itself enjoyed considerable media coverage since the DARPA challenges in 2004 - 2007 (Muyllaert, 2013). The best known autonomous prototypes are the Google Driverless car and Junior, a robotic Volkswagen Passat, conceived by Stanford University (2009). Although prototypes are very advanced and well on their way to total autonomy, the researchers continue to conclude it is still necessary for a safety driver to be behind the steering wheel during tests, as the robots have not yet succeeded to drive autonomously for hours without interventions needed to concur (Levinson et al., 2011). At Google, their driverless car uses maps for navigation. But, engineers need to drive a certain route a couple of times for the machine to correctly interpret the environment (Pinto, 2012).

Engineers are close to accomplishing full autonomy, but a few challenges still remain. One of these challenges is how to conceive a transition period in which driver only vehicles will intermingle with robotic vehicles. Anticipating the driving behaviour of said driver only vehicles remains a challenging feat for the programmers (Hoeger, 2012). The Next Generation LDC will, according to predictions made by major car brands, find itself in a period of transition, in which autonomous vehicles will emerge and V2V and V2X networks will gradually become operational.

This chapter will elaborate on the technology needed to accomplish the bespoken Jeeves system. The system will be discussed according to the same order used in chapter 9.1.

9.2.1 HMI

As discussed in chapter 9.1.1, the HMI enables the driver to interact with the machine. Interaction is hereby defined as a two-way process in which it is crucial for the machine to understand and ‘read’ the driver.

Driver input

The driver’s input remains largely the same as it has been over the years: steering movements are registered through a steering wheel, throttle and brake pedals account for the accelaration and deceleration input. Both the steering and pedals are drive-by-wire systems (DbW). Driving direction and/or mode is selected from an equally electronic lever (switch).
A number of advantages come from employing DbW systems: response times are significantly improved, as mechanical linkages are eliminated. On top of that, the elimination of these linkages introduce a considerable weight gain. Safety also benefits from DbW, as electrification enables computer controlled intervention to correct or overrule the driver in hazardous situations (Dittmer, 2001). Benefits for ergonomics will be discussed in the chapter ‘ergonomics’.

Fig.74: Xbox One Kinect sensors (source: Wired.com)

Driver monitoring

As stated in chapter 9.1.1, Jeeves monitors the driver with a HD camera, which detects head and eye movement, heart rate and the attention level of the driver. The system also learns the different driving styles of each driver, which enables the computer to anticipate certain moves and intervene when needed. To accomplish all this, Jeeves uses a 1080p camera and an infrared sensor, analogous to the latest Xbox One Kinect sensor setup. The system can detect gestures, emotions, heart rate and much more. The infrared sensor enables the system to function, even when dark.

One of the most impressive functions is the ability to detect heart rate without any additional physical sensors: only the optical 1080p sensor is needed. The technique is called Eulerian Video Modification and as the MIT engineers (Wu et al., 2012) explain: “Our goal is to reveal temporal variations in videos that are difficult or impossible to see with the naked eye and display them in an indicative manner. Our method, which we call Eulerian Video Magnification, takes a standard video sequence as input, and applies spatial decomposition, followed by temporal filtering to the frames. The resulting signal is then amplified to reveal hidden information. Using our method, we are able to visualize the flow of blood as it fills the face

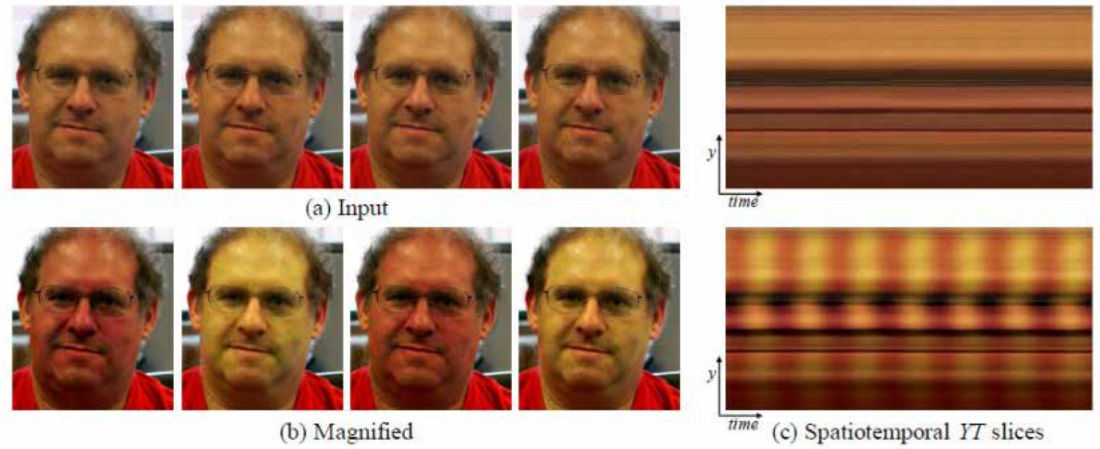


Fig.75: An example of using the Eulerian Video Magnification framework for visualizing the human pulse. (a) Four frames from the original video sequence. (b) The same four frames with the subject's pulse signal amplified. (c) A vertical scan line from the input (top) and output (bottom) videos plotted over time shows how our method amplifies the periodic colour variation. In the input sequence the signal is imperceptible, but in the magnified sequence the variation is clear.

and also to amplify and reveal small motions. Our technique can run in real time to show phenomena occurring at temporal frequencies selected by the user." The picture above illustrates the technique. When the frame's colours are magnified and put alongside each other, a clear frequency can be identified, uncovering a person's heart rate.

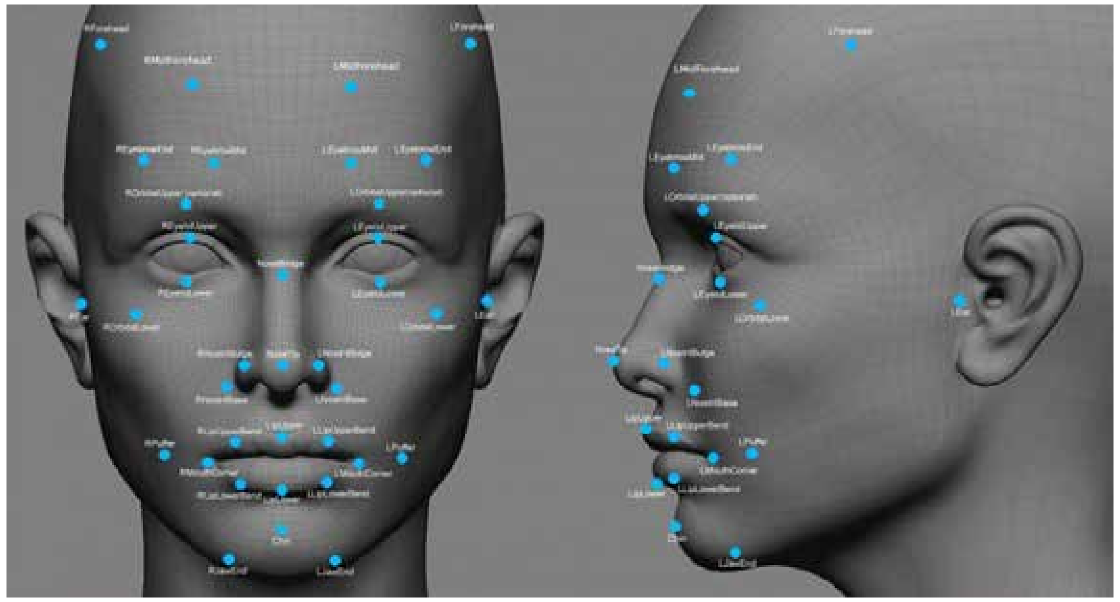


Fig.76: facial recognition and emotional mapping on Xbox Kinect. By means of virtual dots faces can be recognized and emotions analyzed. users can automatically log in to Xbox's servers by just sitting in front of their console.

The facial expressions and recognition software enables three functions: driver profile recognition, driver emotion monitoring and driver attention mapping. By placing virtual dots on a face and determining the depth of these points, the computer can identify different human beings. This enables drivers to automatically log in to the coach's systems. Unlisted or unknown drivers hence cannot operate the vehicle, as they will not be recognized by Jeeves. Driver emotion monitoring is useful for correcting the driver when he/she is, for example, aggravated. Driver attention mapping is accomplished by the tracking of the eyes, in conjunction with facial expression analysis.

Ergonomics

HAVEit (European Commission, 2011) identifies 5 levels of driving automation. It is probable that the Next Generation of automobiles will offer a range of driving modes corresponding with this proposal. However, towards 2030, a period of transition may be at hand: driver only mode will most likely disappear. V2V and V2X will ensure safety for all vehicles.

- Driver only: the driver has controls, Jeeves only manages crucial on board systems
- Driver Assisted: the driver has controls, Jeeves will intervene when accidents can occur
- Semi-Automated: the driver has controls, Jeeves maintains and regulates speed (cruise control). The driver can override at any time
- Highly Automated: Jeeves controls most of the vehicle, the driver can override
- Fully Automated: Jeeves has full control of the vehicle, manual override only via killswitch

Fig.77: Levels of driver automation (HAVEit, 2011)

Design guidelines, useful for the implementation of Jeeves' driver assistance functionality, are defined by the Intelligent Transport Systems workgroup of the United Nations. The rules define the minimum requirements for a HMI to allow the driver to understand and judge driving situations, and effectively use the control system (IHRA-ITS, 2011). The 12 design principles are:

- System actions should be easy to override at any time under normal driving situations and when collisions are avoidable.
- When a collision is determined to be imminent, the system can take actions intended to avoid and/or mitigate crash severity.
- For systems that control the vehicle under normal driving situations, the driver should have a means to transition ON / OFF manually and to keep the system in the OFF state.
- For systems that control the vehicle under critical driving situations, the initial set state of the system should be ON.
- Drivers should be provided with clear feedback, informing them when the system is actively controlling the vehicle's speed and/ or path.
- Drivers should be informed of the conditions when system operation is malfunctioning or when there is a failure.
- Drivers should be informed if/when system operation is not guaranteed.
- In cases where systems automatically control the longitudinal and lateral behaviour of the vehicle, and the driver's task is to monitor system operations, arrangements should be considered to support drivers continued monitoring of the vehicle, road and traffic situation.
- If symbols are used, a standard, universal symbol should be used if available.
- System activation should be displayed to other road users.
- ...

The before mentioned 1080p camera, installed to monitor the driver, will also function as a means to communicate with Jeeves. The camera can distinguish a couple of hand gestures to browse through interface menus or to have Jeeves execute certain tasks. A couple of hand gestures from Xbox is shown below.

Fig.78: Xbox One Kinect hand gestures, Microsoft (2013)

9.2.2 Detection

The coach needs to be able to understand traffic and anticipate maneuvers. To accomplish this, a couple of sensors are needed. In this chapter, location, vision and communication will be discussed. Micro organism will not be further elaborated on, as system sensors are current technology and are implemented on almost all vehicle systems these days.

Location

A number of approaches for self driving vehicles are being developed by companies and universities worldwide.
The first method is called 'the global navigation approach' (Muyllaert, 2013). This method for autonomous driving is based on accurate, predefined maps of the environment. This method is mostly being developed by Google, based on their Maps service.
A second method is called 'reactive navigation'. Reactive navigation can be seen as the opposite of the global navigation approach: these robots only rely on the sensor input , from which it generates an image of the surroundings.
Thirdly, there is a method called 'guided navigation'. With this approach, the vehicle is able to locate itself by analyzing existing landmarks, such as crossroads.
Analogies between these three systems exist: all need a good map and estimate of their location to function properly. Literature also confirms that the three systems can be used together, mixed into a fourth, holistic approach (Luettel et al., 2012).

By 2030, 3D maps will be available for most of the cities worldwide, with a decent precision. Google Maps and Navteq True provide a look into the future of global 3D maps, with a few large cities already accessible on the web. A rough 3D map is created from Velodyne LIDAR and camera input (CNET, 2012). However, these maps are somewhat rough these days, it is to be expected that the roughness will be improved by 2030.

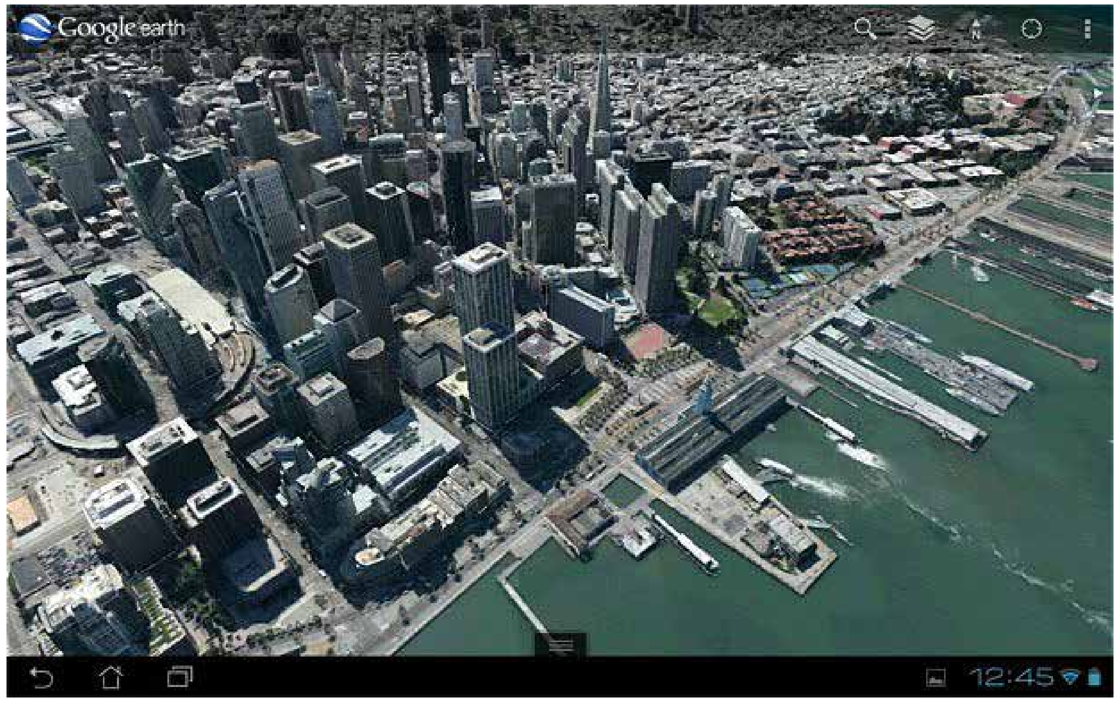


Fig.79: Google Earth on an Android device (2012)

Satellite navigation is paramount for succesful vehicle navigation. Current GPS signals are too inaccurate to secure autonomous driving: the best GPS receivers today have a horizontal accuracy of 3 metres or better (Grimes, 2008), where an accuracy in the range of decimetres is required for autonomous vehicle guidance. A solution could come from using reference beakons on earth. This is called 'Real Time Kinematics' (Robesafe, 2012). Current day RTK only cover small areas, which would implicate building a lot of stations. The development of Wide Area RTK (900m) would fix this problem. WARTK accuracy is at decimetre level (Hernandes-Pajaras et al., 2010).

Vision

In chapter 9.1.2, a layered system was proposed. This is also the way current autonomous vehicles obtain their ability to analyse and thereby 'see' the environment. The system's range covers the surroundings from 5 to 200 meters. To get to highly accurate vision, a load of sensors is needed: LIDAR (Light Detection And Ranging), RADAR (Radio Detection And Ranging), laser scanners and ultrasonic sensors.

LIDAR sensors are rapidly spinning lasers that use low-energy laser beams to scan the environment. Like with RADAR, the rays bounce off objects and provide the system with an accurate 360° image, which can let it judge distances, other objects and the road itself (Atiyeh, 2014). LIDAR generates a 3D point cloud of the environment. All experimental self driving machines use Velodyne HDL-64E LIDARs, which cost approximately 65.000 euros (Pinto, 2012). The system is fairly large in dimensions, which makes it hard to imagine it being mounted on top of a commercial vehicle. However, Ford and MIT have cooperated and designed a small LIDAR solution consisting of four small rotating LIDAR HDL-32E modules, the little brother of the larger and more complex HDL-64E. It is a remarkable example of how fast technology can develop: MIT and Ford's solution is nearly ten times smaller than the Velodyne LIDAR.

Fig.80 and fig.81: Velodyne HDL-64E and HDL-32E systems mounted on the roof of driverless cars. Right is the Ford and MIT's compact solution.

RADAR transmits pulses of radio waves, which bounce off objects in its path. Some of the wave'ts energy is then reflected to the vehicle's sensors, which enables the system to determine the range, altitude, direction and speed of both moving and fixed objects. A RADAR can detect multiple objects at once (Autonomousstuff, 2012). RADAR is a technology which has been around for a considerable amount of time, and has been utilized in a wide range of applications. The technology is thus well known to man, which has, along with progress of technology, enabled for the sensors to shrink in size and volume. The compactness and long range (up to 300m) of these sensors make it a valuable asset to the system's Vision department. In combination with a camera, RADAR is able to detect and identify objects such as bicyclists, deer, etc... (The Telegraph, 2013).

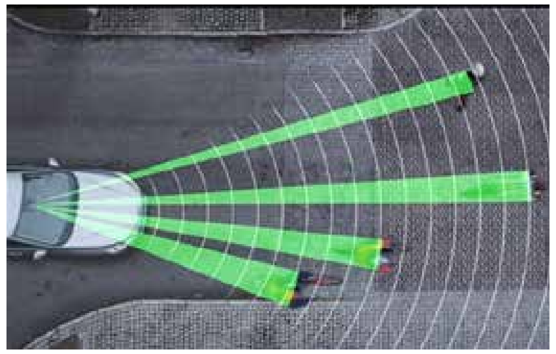


Fig.82 and fig.83: Camera assisted RADAR (left, source: Volvo) and point cloud image from LIDAR (source: CNET, 2012)

Laser scanners effectively function in the same way as a LIDAR does: they generate a point cloud within a vision angle. Where LIDAR generated a 360° 3D point cloud of the environment, laser scanners need to be pointed at an object to be able to generate a point cloud from it. For instance, the Ibeo Lux sensor employs eight lasers to generate a narrow point cloud (Ibeo, 2011). The size of current laser scanners for the automotive industry falls within the range of the Velodyne HDL-32E.

Stereo cameras are a type of camera with two lenses. This stereo vision enables the system to calculate the 3D position of image points. Muyllaert (2013): "The method of Optical Flow enables tracking of image points over several images in a sequence to measure speed. As a result, objects can be recognized, including their relative position and directional velocity. (...) Stereo cameras work for a visible range of about 50 metres". Stereo cameras work best with a laser and/or RADAR system alongside. In certain conditions (bad visibility) the cameras need supportive data to generate an image of the surroundings.

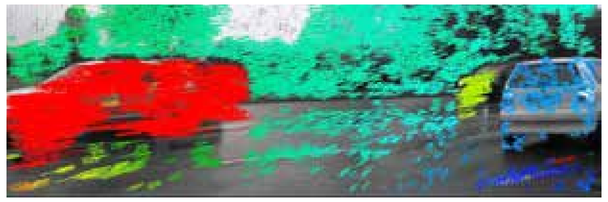


Fig.84: (Left) Audi's laserscanner, which fits in a human hand (source: Audi)
Fig.85 and fig.86: (Top right) A windshield-mounted stereo camera in a Mercedes-Benz S-Class (source: Mercedes) and 'Optical Flow' (Bottom right): the perception of motion by stereo cameras (source: 6D-Vision, 2013)

Communication

Complementary to the battery of sensors on the vehicle, Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2X) ensure improved traffic flow and safety. V2V embodies a wireless network that enables vehicles to effectively communicate with each other. Messages between vehicles include data about speed, location, direction of travel, braking and loss of stability. The network used to accomplish this, is often referred to as a WiFi network, as one of the possible frequencies is equal to that on which WiFi networks are relying: 5.9 GHz. The network used for V2V is based on 'dedicated short-range communications' (DSRC). DSRC is a standard recognized by both the Federal Communications Commission (FCC) and the International Organization for Standardization (ISO). The accuracy of this network protocol is more accurate than the likes of WiFi, with a range of up to 300 meters (Howard, 2014). There is, however, "some concern that opening up the 5.9 GHz frequency band to other wireless users could cause harmful interference and affect the integrity of the V2V safety communications" (Lavrinc, 2014). This is why the Association of Global Automakers are working closely together with the WiFi industry in order to secure that the spectrum can be safely shared.

Howard (2014): "V2V would be a mesh network, meaning every node (car, smart traffic signal, etc.) could send, capture and retransmit signals. Five to ten hops on the network would gather traffic conditions a mile ahead. That's enough time for even the most distracted driver to take his foot off the gas."

On the first cars, V2V warnings might come to the driver as an alert. Later, vehicles will be able to correct the driver autonomously, avoiding obstacles and intervening in maneuvers.
Traffic signals or other stationary devices are called V2X, or Vehicle-to-Infrastructure. V2X basically does the same as V2V, but enables communication between vehicles and fixed infrastructure.

The costs of a system like V2V and V2X would initially go down for around 175 dollars per car and could go down quickly (Center for Automotive Research, 2012). Towards 2030 and further, it will be common for new cars to come with standard V2V and V2X communication hardware, interwoven with internet connectivity ("the internet-of-cars").

The development of vehicle communication systems will enable car builders to produce smarter and lighter vehicles, as crumble zones, steel reinforcements and safety features such as airbags will be a thing of the past. All major car brands - including Audi, Volkswagen, BMW, Ford, General Motors, Honda and Toyota - are already heavily researching V2V technology (Lavrinc, 2014). It is to be expected that around 2030, a period of transition will be at hand: newer vehicles will run V2V communication hardware, while older vehicles will not. Aftermarket upgrades will become available for instalment on used vehicles, but unless said systems will become obligatory by law, the situation will occur that a number of vehicles runs without a communications device nor detection apparel. Unless all cars will feature these devices, it is possible the law will dictate drivers must be in control of the car at all times (meaning: behind the steering wheel) when not driving on highways.

9.2.3 Processing and acting

Understanding traffic requires complex algorithms and calculations from all the sensor data combined. Input from the V2V and V2X networks, the sensor data from the driver monitoring and driver input need to be processed so that the computer would make correct decisions and ultimately drive the vehicle or alert the driver appropriately.

Anticipation

Human judgement is, to date, still unmatched by any intelligent system or organism. Decision making on a level equal to that of the human brain requires an AI which is programmed to learn from past experiences.

Full autonomous driving is today being experimented by the likes of Google, Toyota, Stanford University... Although steady progress is made, conclusions still confirm there is a long way to go until safe full autonomous driving is obtained. As previously stated, the year 2030 will be an era of transition, from manual to Semi-Automated Drive and beyond.
City traffic accounts for the most difficult part of traffic situations. Because of this transitional period, the Next generation LDC will, for the time being, only be able to drive autonomously on highways. Anticipating highway traffic is a lot more straightforward than complex city traffic. This means that the programming and algorithms for the required maneuvers are less intricate than all-round autonomous vehicles would need to operate. In fact, a lot of these maneuvers can already be executed by modern day roadcars: detecting a vehicle, slowing down behind a vehicle and retain distance behind a vehicle in front. Researchers from Stanford University are already working on - and succeeding in a proper functioning of the next generation of basic maneuvers such as overtaking. The image below illustrates the algorithm for such overtaking maneuvers, used in the Junior robotic vehicle from Stanford University (Montmerlo et al., 2013). The algorithm calculates whether the most efficient route is to stick behind a slow car in front or to perform an overtaking maneuver.
Because all sensors for all-round autonomous driving are installed on the Next Generation LDC, it will be possible to upgrade the sensors and software when legislation allows for fully automated driving on regular roads.

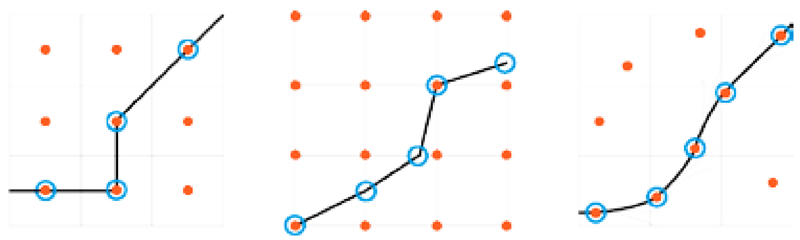


Fig.87: Graphical comparison of search algorithms. Left: A associates costs with centers of cells and only visits states that correspond to grid-cell centers. Center: Field D* (Ferguson and Stentz, 2005) associates costs with cell corners and allows arbitrary linear paths from cell to cell. Right: Hybrid A* associates a continuous state with each cell and the score of the cell is the cost of its associated continuous state.*

Acting

Radar: Jeeves' radar sensors detect vehicles ahead and the system automatically slows the coach down, to match the speed of the reference vehicle in front. The system can come to a complete standstill when necessary. In traffic jams, the vehicle will keep distance to the vehicle ahead and maintain the same speed. In V2V connected platoons, the coach moves as one with the rest of the connected vehicles.

V2V: when driving behind a vehicle in Highly Automated Mode, Jeeves will maintain the speed of the vehicle ahead and will keep a fixed distance between the two vehicles. Through the V2V network, the two vehicles can connect and platoon, according to the route these vehicles will travel.

Overtaking: Jeeves will determine whether platooning or overtaking a slower moving vehicle ahead is the most efficient route. If overtaking is the way to go, Jeeves will perform an overtaking maneuver when possible, guided by its on board sensors.

Exit Green Corridor: platoons, highways and Green Corridors can be autonomously left by the on board computer. The driver will be notified by means of sound feedback that the system will be switched back to Driver Assisted Mode.

Driver correcting: in Driver Assisted Mode, Jeeves corrects the driver when necessary. This ensures a zero crash tolerance of the vehicle.

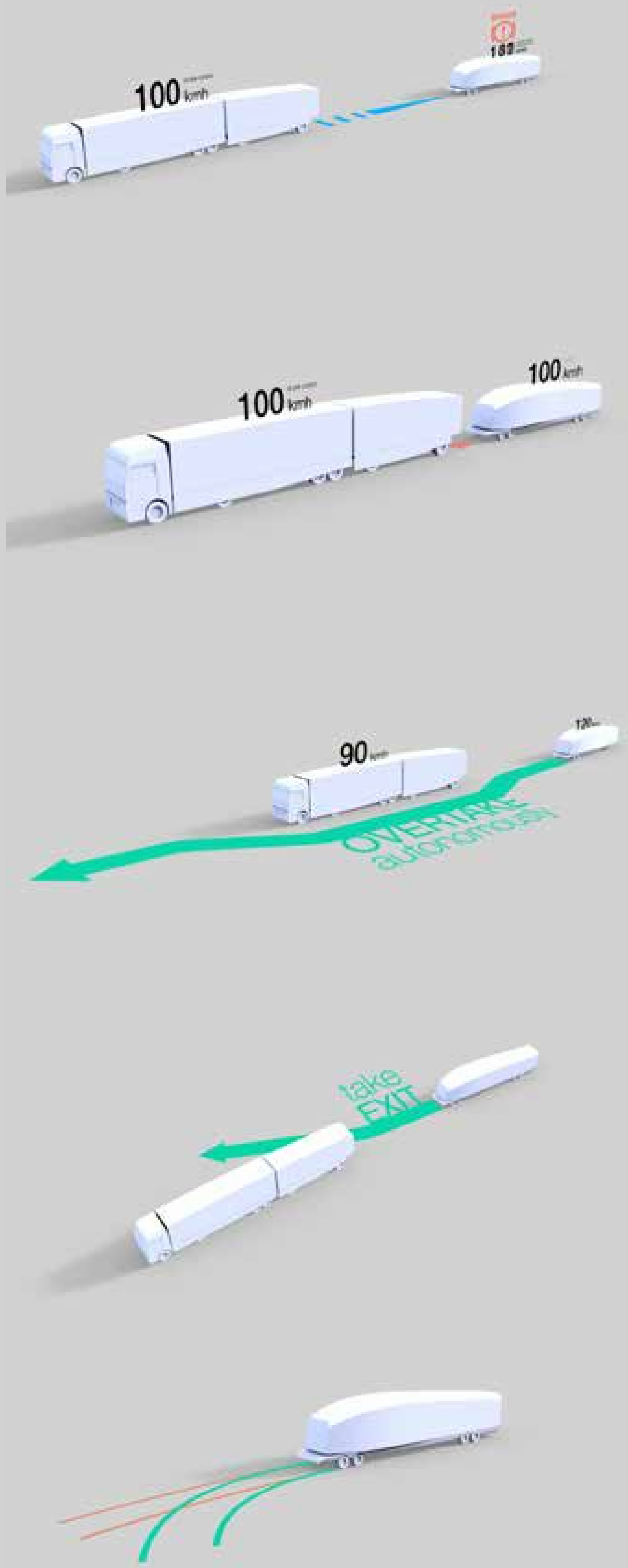


Fig.88: Jeeves' autonomous manoevers (Claus, 2014)

9.3 Jeeves system design

Analyzing current day self driving vehicles from leading companies and institutions such as Google and Stanford University, led to the definition of an Artificial Intelligence (AI) capable of assisting and correcting the driver. The system is also capable of driving the vehicle fully autonomously on highways and Green Corridors, performing basic maneuvers without human intervention. A system architecture, based on the scheme presented in chapter 9.1, is depicted below.

9.3.1 Architecture

Jeeves' system architecture was broadly discussed in this chapter. Chapter 9.1 defined the system requirements for an AI with driving capabilities. The initial overview diagram, inspired by a proposal by HAVEit, a European Commission project for autonomous vehicles (HAVEit, 2011), can now be complemented with individual components. The selection of components are the result of the technological overview on the previous pages in this chapter. As with the initial overview diagram, the system architecture is divided into four clusters: HMI, Detection, Processing and Execution.

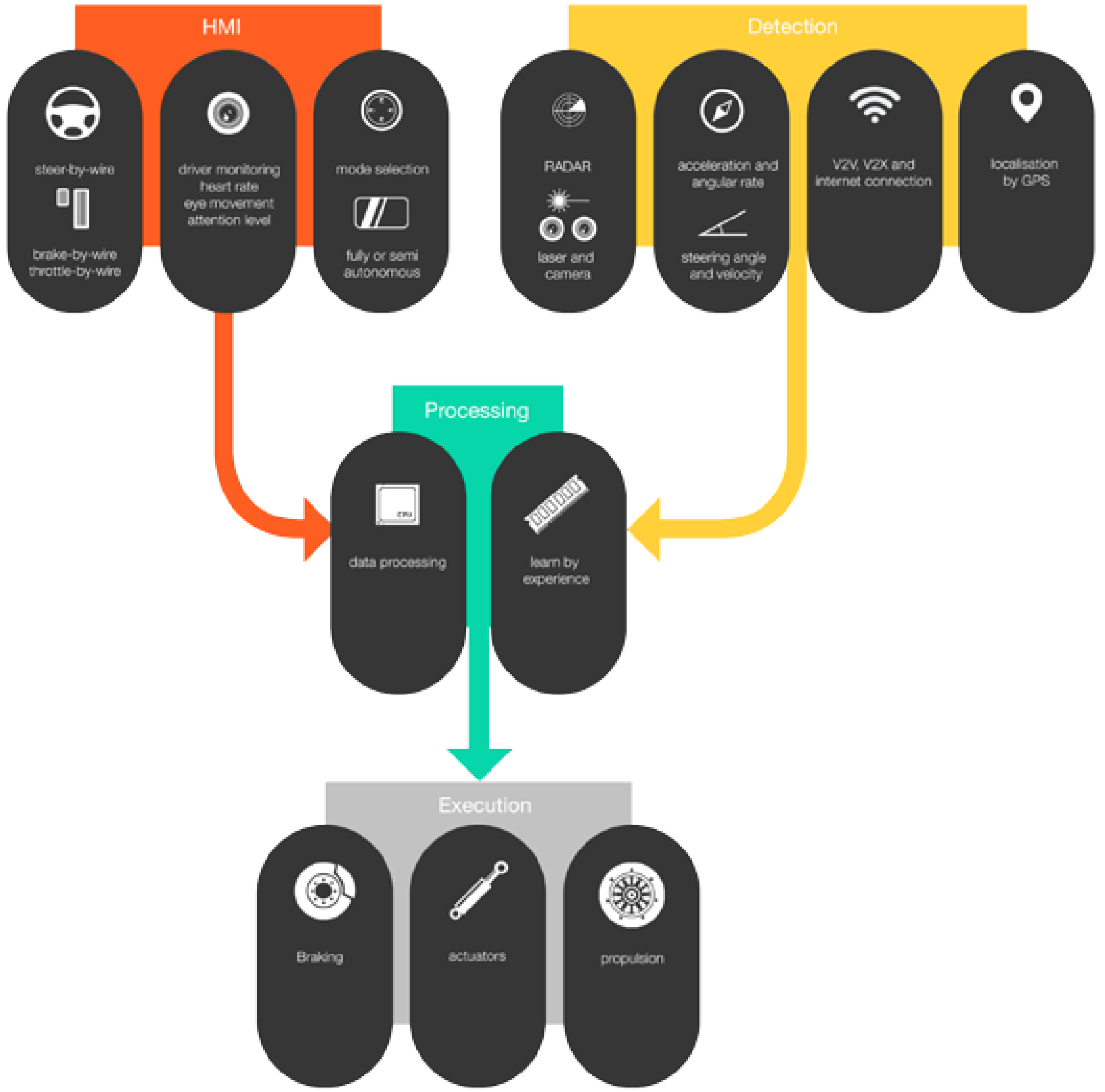


Fig.89: Jeeves' system architecture, devided into four clusters

9.4 Conclusions on Jeeves

In this chapter, a system design for the on board Artificial Intelligence (AI) was developed. In general, the system functions as an extra pair of eyes for the driver, a manager and an assistent. The protocol can drive autonomously on highways and Green Corridors and is able to correct the driver to avoid accidents from happening.

The system requirements were specified for the detection, HMI and processing and acting.

10 Wireless En-Route Charging

The Wireless En-Route Charging (WERC) system is the first of two powertrain options available for the Next Generation LDC concept. WERC is a Wireless Power Transfer (WPT) system which enables the Next Generation LDC to charge batteries while driving. It is the result from the Design Driver 'Zero Emission'. The NPP research indicated that Plug-in Hybrid vehicles (PHEV) and fuel cell are predicted to be the main power sources for vehicles. Fuel cells will, by 2030, have an approximate market share of 25% (ERTRAC, 2012). Yet experts are sceptical about fuel cell driven heavy duty trucks (HDT) and people carriers, as a lot of the storage space will have to be sacrificed for the hydrogen fuel tanks. Instead, the construction of power grids along roads seems to find a large amount of acclaim with rulemakers and car constructors. Introducing Green Corridors along all major axes would provide Europe with a 'green' and efficient transportation hub. In this context, efficiency means "high operational performance, effective use of resources, limited impact on the surroundings and the environment." Ditching the ICE and replacing it with an electrical architecture also provides HDTs and buses with an increased commercial payload (Hernandez, 2012). A number of en-route charging methods are in the running for global implementation: as cited from the NPP phase, chapter 5.1.1: "contact charging". An abundance of experience is available from trolley buses and trams around the globe: sliding contacts have been used on a massive scale. Siemens is testing a 'trolley system' for truck application. This might as well become an option for implementation in Europes Green Corridor axes. Another system, tested by Volvo for trucks and already implemented on trams in Bordeaux, is a slider contact system located in the road surface. For this project, however, the preferenced method for en-route charging is WPT. Advantages are numerous: no manual handling or plugs are needed, there are no open contacts, there will be no surface corrosion, no mechanical wear of contact surfaces, etc... Electronic modules can also be retrofitted into existing vehicle architecture. A robust design makes for very limited maintenance, with components that are easy to access, thanks to a modular architecture. The most beautiful aspect of WPT, however, is its ability to invisibly integrate in the environment (Hernandez, 2012).

Experiments with WPT have been conducted and an efficiency of 80% has been achieved, with reasonable air gaps between the inductive coils (ERTRAC, 2012). Wireless electric driving has already proven to be very cost effective in public transport

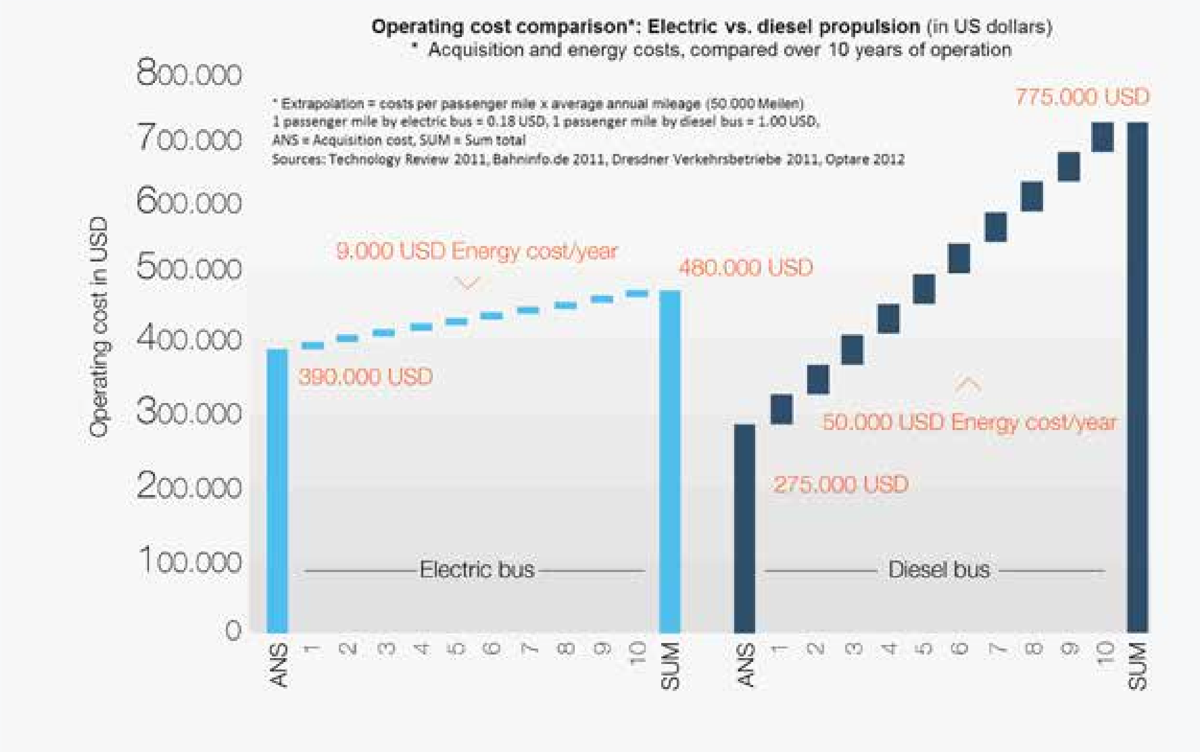


Fig.90: operating cost comparison between electric and diesel powered buses (source: Conductix-Wampfler GmbH)

projects in, for instance, Brunswick, Bruges, Mannheim, Nanjing and Berlin (Walker, 2013). Electric buses cost more than diesel powered buses, but "with the cost of electric power costing only $9,000 a year compared to $50,000 a year for diesel, Conductix-Wampfler estimates a payback period of less than four years" (Ingram, 2012). Numerous renowned companies and OEMs are investing heavily in R&D concerning WPT: Siemens (Moving with energy into a mobile future), Bombardier (Easy Urban Mobility) and even Rolls Royce/HaloIPT (So simple, even your chauffeur can use it).

A couple of advantages come from the WERC system: the time it takes to charge, is now time to be used for driving. This enables fast and efficient transport, considerably reducing downtime from recharging the coach's batteries. The vehicle's range is significantly extended while reducing the amount of battery volume. Less batteries equals lower costs, as batteries will continue to be quite costly due to their high tech nature.
Fitting coils under road infrastructure can be a retrofit or be installed on new roads or implemented when roadsurfaces are renewed. The cost of the system is fairly low, as the coils needed for such a system are made out of plain metal (Schiller, 2012). A WPT system could also mean a first step into the introduction and development for WPT parking spots, which connects vehicles with the smart grid, effectively functioning as a buffer for peak moments in energy demand.

This chapter will elaborate on the system architecture of a WPT system. The system uses V2X for communication with wireless grid infrastructure. Smart grid applications require development towards communication, authentification, metering and billing, standardisation, infrastructure, fraud prevention and privacy (Perik, 2011). This project will mainly focus on the on board components of a WPT system.

10.1 WERC system requirements

Institutions such as Stanford University and companies like Volvo and Flanders' Drive are currently exploring and testing the possibilities of wireless charging for EVs.

10.1.1 Power consumption

Current heavy duty trucks (HDT) and coaches are not quite optimized for aerodynamic efficiency, causing them to consume more energy than would be the case when streamlined and with optimized aero efficiency. A case study by MAN proved that drag coefficients of HDTs can be reduced to a number within the range of road cars, when specific attention is paid

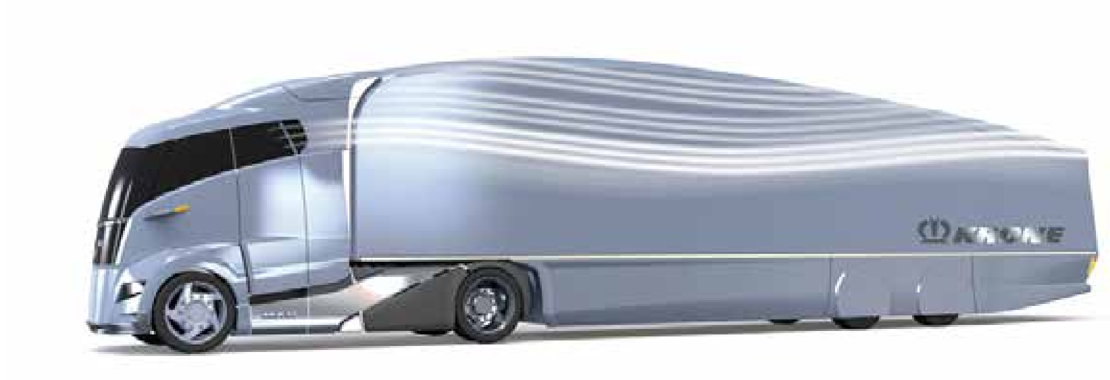


Fig.91: MAN ConceptS with KRONE AeroLiner (2010), demonstrating how clever design can drastically reduce power consumption for HDTs

to aerodynamics. The MAN ConceptS and KRONE AeroLiner feature a unique design which resembles the shape of a Humpback Whale. MAN claims fuel consumption and CO_2 emissions are lowered by 25% by optimizing airflow over the vehicle (Zercustoms, 2010).

According to literature, a current day motorcoach uses approximately between 100 and 140 kW at cruising speeds. A paper concerning the development of a lightweight touring coach for VDL Bus & Coach by Winkelmolen (2013) mentions a power consumption of around 98.5 kW for a lightweight coach at cruising speed. Assumed that there is a 25% improvement in efficiency by using high tech materials for construction and an aerodynamic design for the outer shell of the Next Generation LDC, the 2030 proposal should be able to cruise at around 75 kW.

10.1.2 WERC performance

The WPT system should cover the power consumption while driving on Green Corridor charging lanes. Road inclination and headwinds worsen power consumption significantly, but these worst case scenarios are not taken into account as it is fairly difficult to set an upper limit for WPT system performance in 2030. It is however notable that the more performant a WPT system, the more costly and heavy it becomes.

10.2 WPT systems

A number of WPT systems is available for discussion: electromagnetic induction, laser beam power transfer, microwave power transfer and resonant magnetic coupling (Muyllaert, 2013). Given the state of the art and research done by companies such as Bombardier, Flanders' Drive and WiTricity, only electromagnetic induction and resonant magnetic coupling are relevant for discussion within the Next Generation LDC project.

10.2.1 Electromagnetic induction vs. resonant magnetic coupling

Electromagnetic induction

Normal transformers are non-resonant coupled inductors and work on the principle of a primary coil, generating a magnetic field, and a secondary coil which is opposite to the field of the primary coil so that the power passing through the secondary coil is as close as possible to that of the primary coil. The field of the primary thus needs to be covered by the field of the secondary. This results in very short range and therefore demands a magnetic core. Non-resonant induction is highly inefficient over greater distances, as it wastes a large amount of energy in resistive losses of the primary coil.

Resonant magnetic coupling

Employing resonance drastically improves efficiency over larger distances. With resonant coupling, each coil is capacitively loaded in order to form a tuned circuit. If the primary and secondary coils are resonant at a common frequency, it turns out that significant power may be transmitted between the coils over a range of a few times the coil diameters at reasonable efficiency (Steinmetz, 1914). Resonant inductive coupling or electrodynamic induction is the near field wireless transmission of electrical energy between two coils that are tuned to resonate at the same frequency. This system is often referred to as a resonant or resonance transformer.
Resonant transfer works by making a coil ring with an oscillating current. This generates an oscillating magnetic field. Because the primary coil is highly resonant, energy placed in the coil disappears relatively slowly over many cycles. Although, if a

second coil is nearby, this coil can pick up most of the energy before it is lost, even at a considerable distance. The fields used in this system are non-radiative, near field, as all hardware is kept well within the 1/4 wavelength distance they radiate little energy from the transmitter to infinity.

Wireless highway charging

Both Stanford University and Flanders' Drive believe that, in the near future, metal coils will be embedded into the road, to wirelessly transmit large amounts of current between roadways and vehicles (Perik, 2013 a; Murray, 2012). This seemingly simple idea, which has been around for some time (9.2 High tech), could prove a viable answer for 'range anxiety' and extensive battery packs.
The system works with both concrete and asphalt road surfaces, but tolerances hint at using prefabricated modules. Positioning tolerance for the WPT to perform desirably is a mere 40 cm. The coils can be placed into the road surface at an interval, meaning reduced labour intensity for roadbuilders (Perik, 2013 b). It is as yet unknown how many coils would be needed or how far they would need to be spaced from each other, as Sven Beiker, executive director of the Center for Automotive Research at Stanford (CARS) explains: "It could be 10ft or 20ft or 50ft," Beiker said. "More research will tell us what the exact number is."
A WPT system would not only function as a range extender for EVs, it would also allow for remote control of vehicles. The coils in the road surface could carry a control signal which would effectively become a 'virtual rail' for vehicles to follow. Much

Fig.92: intense road works in a WPT project on a test track (2013, source: Flanders' Drive)
Fig.93: reduced roadworks in a next generation WPT module project (2013, source: Flanders' Drive)

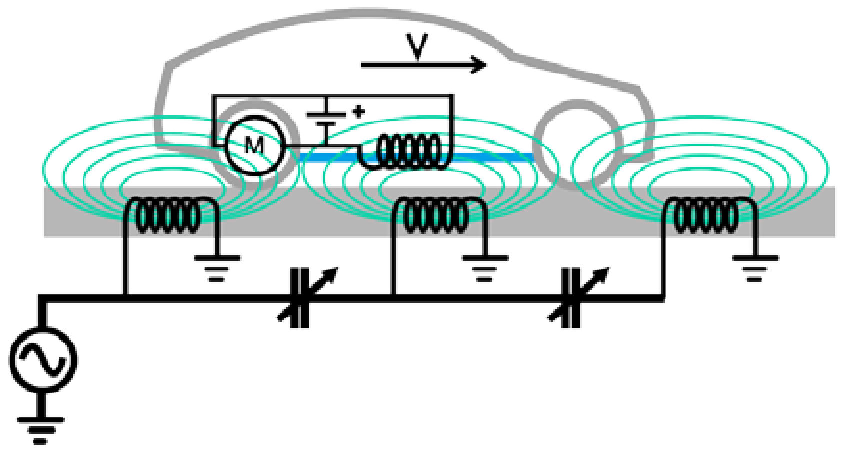


Fig.94: schematic overview of how resonant magnetic coils could provide wireless electricity for an EV while cruising down the road (Claus, 2014)

as in the 70s, with the Transport and Road Research Laboratory from the UK testing a driverless Citroën DS on magnetic cables in the road, the WPT highways would become automated roads. The control system could at the same time activate charging processes, when sensors detect an EV over the inductive field.

10.2.2 Stationary WPT vs. dynamic WPT

Perik (2013 a): “The only difference between static and dynamic charging systems is a set of additional requirements related to maximum allowable speed and topology.
As for the topology, dynamic charging can be done using a series of static charging stations, either back-to-back or placed with intervals. With a back-to-back installation there are no efficiency losses provided the control electronics are placed correctly, resulting in a homogenous field when traversing the dynamic charging trajectory. When placed in intervals, there will be efficiency losses as the system will have to ramp up itself up to its maximum charging capacity.” According to Flanders’ Drive research, static and dynamic charging are technically feasable and comparable to each other in terms of efficiency.

10.2.3 Fixed position WPT system vs. lowering WPT system

A fixed position WPT system is basically an inductive coil mounted under the floor panel of a vehicle. The position of the coil is thus ‘fixed’, a couple of centimetres above the surface. In order to protect occupants, the floor of the vehicle must be fitted with an Electro Magnetic Field (EMF) shielding steel plate. Using this simple fix against the EMF, Flanders’ Drive accomplished EM results within acceptable values (Perik a, 2013). Although, the shielding deflects the EMF, so that the EMF extends from under the vehicle. This produces dangerous zones around the perimeter of the coil. Perik (2013): “Obviously, living objects should not come within electromagnetic fields exceeding the maximum threshold values (...). Other objects, particularly electrically conductive objects, should not come within electromagnetic fields as they will heat up. Simulations and experiments show that a mere 500 to 1000 mW of power dissipated in a metal object such as a coin, a metalized pharmaceutical wrapper, a paper clip or a golden ring can raise the object’s temperature to above 80° C. This may lead to hazardous situations such as fire or tissue burns when touching/picking up metallic objects.”
This hazardous problem can be partially rectified by ‘magnetic design’: shaping the shielding plating around the coil so that the EMF remains within the desired boundaries. During Flanders’ Drive testing, promising prototype evolution was shown concerning the EMF extending from under a vehicle.
Another solution is the adoption of a lowering WPT system. This system can lower its coil to make contact with the ground. This way, the EMF is drastically reduced, creating a safe surrounding around the vehicle when at a standstill (e.g. boarding). A lowering device for the pickup may prove to be “a possible short-term solution for controlling the EMF during static charging” (Perik, 2013). The lowering WPT system can be used in both stationary and dynamic scenarios, which makes it an interesting component for the Next Generation LDC.

Fig.95: setup used for WPT testing by Flanders’ Drive (2013, source: Flanders’ Drive)
Fig.96: Bombardier PRIMOVE lowering WPT system (source: Primove)

10.3 Safety

Magnetic resonant coupling is already being implemented in numerous applications, which is to say that the technology enables safe wireless power transfer. A spin off company from MIT called WiTricity already offers magnetic resonant coupling modules on the public market.

10.3.1 EM field

As with normal electromagnetic induction, resonant magnetic induction creates a magnetic field surrounding the coils. Safety guidelines for EM exposure of the general public are prescribed by the International Commision on Non-Ionizing Radiation Protection (ICNIRP, 1998). As seen on the illustrations on the previous page, the EM extends from under a vehicle to the sides. This zone is dangerous for objects or organisms as they can heat up and cause burns or fire. Muylaert (2013): “For frequencies above 100 kHz, basic restrictions are provided in terms of heating: the Specific Absorption Rate (SAR) to the body.” Research has proven that, in a worst case scenario, where a human being is located 10 mm from the coils, the acceptable power is limited to 280W (Christ et al., 2012). Existing wireless chargers have a built-in detection system that kills the system when an object or organism is detected within the EMF.
Flanders’ Drive testing established that EMF radiation levels in a bus or coach with a floor mounted WPT system remained within the limits with “a shielding thickness of 3 mm, which results in a shielding effectiveness of 95% for most types of alloys considered” (Perik, 2013 a) at 20kHz.

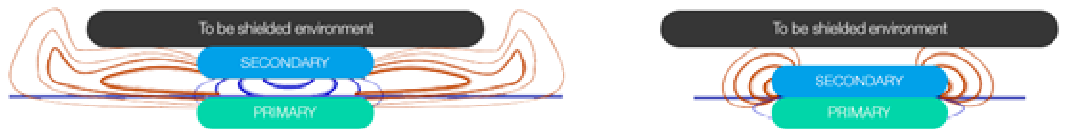


Fig.97: comparison between EMFs produced by fixed position WPT system (left) and lowering WPT system (right) (source: Flanders’ Drive)

10.3.2 System standardisation

Magnetic resonance coupling only functions at a certain frequency. This enables standardisation of the system. With this, decisions can be made concerning the frequency range as to minimize interference with other components or communication devices. All occupied bands are registred with the Industrial Scientific Medical (ISM), so that any new frequency won’t interfere. It remains, however, difficult to predict how standards will develop in the following years towards 2030 and further. Standardised limits and measuring methods for EMF strength are still in need of development. International standards for wireless charging of EVs are expected to be released by 2015 (SAE, 2010; BWF, 2012; DKE, 2013).

10.4 anticipated WPT system specifications

The numbers specified below are expectations towards 2030, derived from state of the art data provided by Flanders' Drive (Perik, 2013 a) and Bombardier PRIMOVE 200 specifications (Walker, 2013).

- Type: lowering hybrid resonant magnetic coupling module
- Power transfer: between 80 and 150 kW, wirelessly
- Energy efficiency: >90%
- Grid connection: AC 400V or DC 750V
- Distance transmitter – road surface: <15 cm
- Dimensions: 2000 x 900 x 100 mm
- Pickup unit weight: approx. 300 kg
- Rectifier/amplifier cooling: water/glycol
- Receiver in fixed position meets International Commission on Non-Ionizing Radiation (ICNIRP) standards

10.5 WPT system design

In this chapter, the components for the WPT system are discussed. Estimations on size are made according to current state of the art technology.

10.5.1 System architecture

A one way WPT for receiving power consists of five components: a coil, rectifier, converter/inverter, battery or supercapacitor and a controller unit. A WPT for transmitting energy swaps the rectifier for an RF Amplifier. The WPT system on the coach combines both system types, in order to meet the specified demands for buying/selling energy from/to the smart grid. The wayside architecture is a similar system, located in the road surface.

The image on the right presents a basic scheme of the on board WPT system. Both coils on the scheme below are part of a pick up module. Both operate at the same time, sharing the load and doubling the amount of kWs that can be pumped into the system. The combined output power is thus the sum of the output power from each pickup unit (coil).

Flanders' Drive (Perik, 2013): "The wayside infrastructure is directly connected to a mid-level supply of 10 kV, transformed and rectified towards 750 VDC. To be able to support dynamic charging, multiple inductive segments were applied, each segment requiring a vehicle detection system. Both segments and vehicle detection are controlled by a proprietary controller."

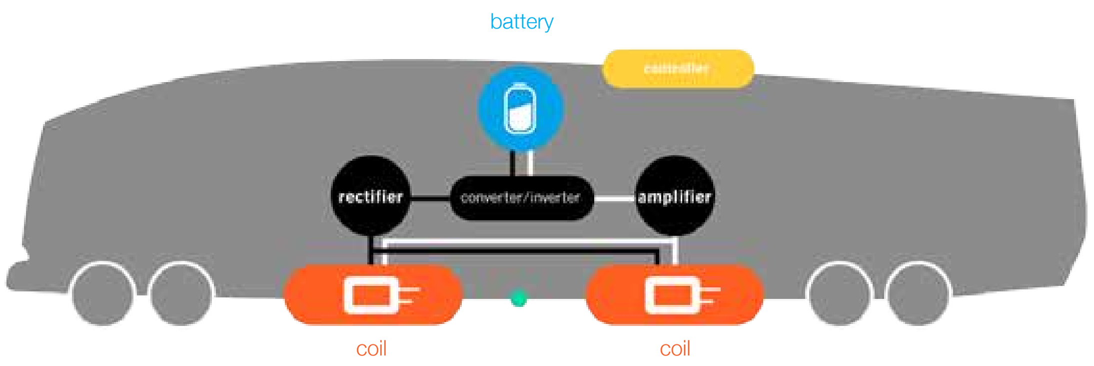


Fig.98: schematic dual way WPT system overview. Black lines show power flow when receiving power, white lines show power flow for energy transmission (Claus, 2014)

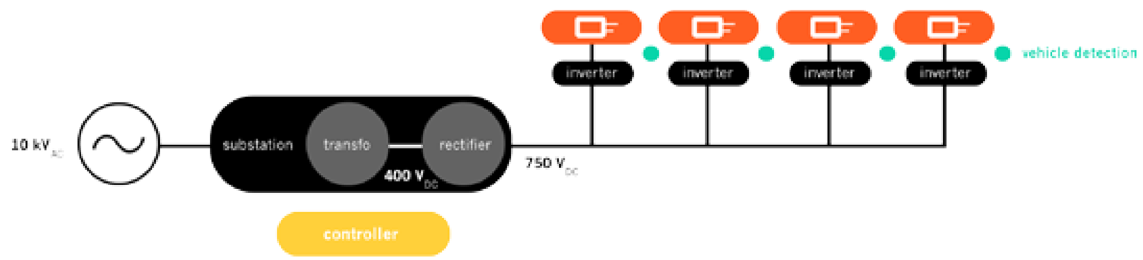


Fig.99: schematic one way WPT wayside system overview. (source: Flanders' Drive, adaptation: Claus, 2014)
A dual way system architecture adds a converter to each inverter module and an amplifier to the substation.

10.5.2 Components

As this project aims for a holistic approach and due to the short timespan, the individual WPT components will not be individually discussed, apart from a brief explanation on the subjects.

Rectifier

For the AC power, transmitted through the coils, to be stored in the battery, it needs to be converted to DC power. This principle is already being used in commercial EVs today. The converting of AC to DC causes considerable heat dissipation, which requires the system to have some sort of integrated liquid cooling device.

Converter/inverter

Magnetic resonant coupling operates on AC, where batteries operate on DC. The inverter transforms DC to AC, so that the coach is able to transmit energy from its batteries to the smart grid. Converters are often integrated with an inverter, which steps up the voltage that is required for a high power WPT system (Muyllaert, 2013).

Muyllaert (2013): Efficient, high power inverters are already in use in existing EVs. For example, a 120kW inverter by Magna E-Car (2012) has a reported peak efficiency of over 94%. Efficient, high power converters are already used in existing fastcharging systems. A 30kW converter by IPC Systems (2013) has an average efficiency of 96%."

RF amplifier

An RF amplifier or Radio Frequency Amplifier is used to enable resonant magnetic coupling. This principle employs resonating coils to accomplish electromagnetic induction over distances up to 20 cm. An RF amplifier amplifies high-frequency signals in the kHz range. Current WPT systems include resonant inverters (Ahn et al., 2011), but the use of RF amplifiers is currently being implemented in 3.3 kW WPT systems (WiTricity, 2012).

Coil

The coils are the most important parts for the WPT system as they enable the wireless power transfer. These coils come in modules, from a variety of manufacturers. For coils which will be deployed for resonant magnetic coupling, the material quality is of great importance as it defines efficiency.

Fig.100: drop down module for 2x 60kW (4 pickups) (source: Conductix-Wampfler GmbH)

10.5.3 Battery pack

Instead of defining motor power (W) or battery capacity, a desirable driving range (km) will be provided. From the Design Specifications, we note that an autonomous driving range of 200 kilometers for the WPT system is considered desirable. The thought behind this number is that 200 kilometers of autonomous range gives the vehicle an average opportunity to drive between stretches of motorway without WPT infrastructure. The inauguration of the Smart Grid in 2030 will see a rise in wireless charging opportunities between and within cities as well. The idea behind the battery system is analogous to how electrical city buses are being used today: at certain stops, the batteries are partly charged. This way, they do not need to be fully charged all the time, while still retaining a virtually unlimited driving range. Motor power and battery capacity for the year 2030 are hard to predict, as it is uncertain how fast technology will continue to leap forward.
Overall battery costs are expected to drop with 30 to 50% by 2020 (Deloitte, 2011; McKinsey & Company, 2011; Roland Berger Strategy Consultants, 2009).

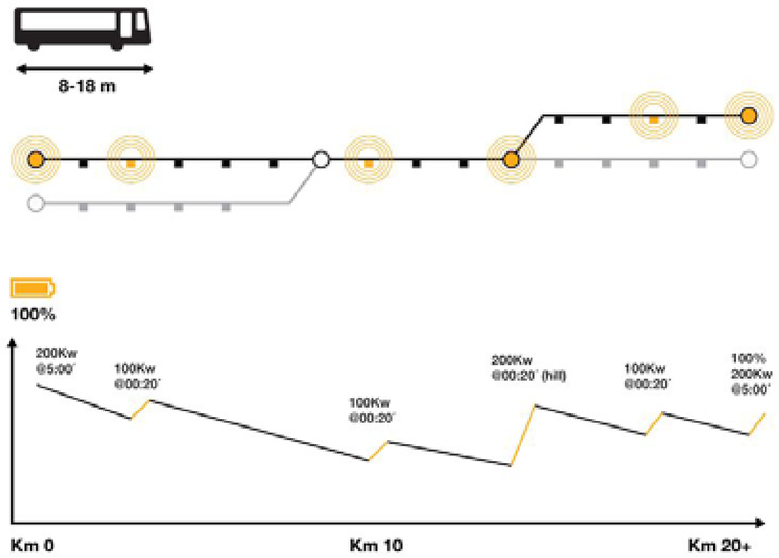


Fig.101: wireless charging with a drop down module for 2x 60kW (4 pickups) (source: Conductix-Wampfler GmbH)

10.6 Conclusions

In this chapter, a wireless power transfer (WPT) system was discussed, enabling the En-Route Wireless Charging (WERC). The thechnology behind this feature, resonant magnetic coupling, was discussed and a system architecture proposed.

11 Fuel cell

The electrical architecture of the Next Generation LDC enables to provide buyers with some drivetrain options. The first solution, WERC, was described in the previous chapter. In this chapter, the second solution, a fuel cell, will be shortly discussed. The fuel cell is also a result from the Design Driver 'Zero Emission'. Altough experts believe fuel cell driven HDTs and people carriers to be unfeasible due to the feared loss of available commercial space, the fuel cell is yet expected to hold a 25% market share by 2030 (ERTRAC, 2012). From a designer's point of view however, the loss of commercial vehicle space, due to the hydrogen tanks, should not to be an insurmountable issue: cleverly arranging components and increasing component volumes should ultimately lead to commercially feasible product proposals.

The main advantage of implementing a hydrogen fuel cell into a vehicle is that it basically provides the vehicle with its own power house. Apart from necessary adaptations to gas station infrastructure, little other road infrastructure has be taken into account for alteration if vehicles are to run on hydrogen.

Fuel cell technology is the less 'green' power source compaired to the WERC system. The process of generating hydrogen through electrolysis is fairly energy consuming, even more so considering the fact that after production, the potential energy does not immediately come out of the socket, ready for use. Instead, it has to be distributed and then processed in some sort of engine to produce useable energy. However, hydrogen fuel cell technology is considered a 'green power source of the future', as pollutants are virtualy absent in its emissions. This is, of course, in accordance with global sustainability goals and public health guidelines (National Fuel Cell Research Center, 2011).

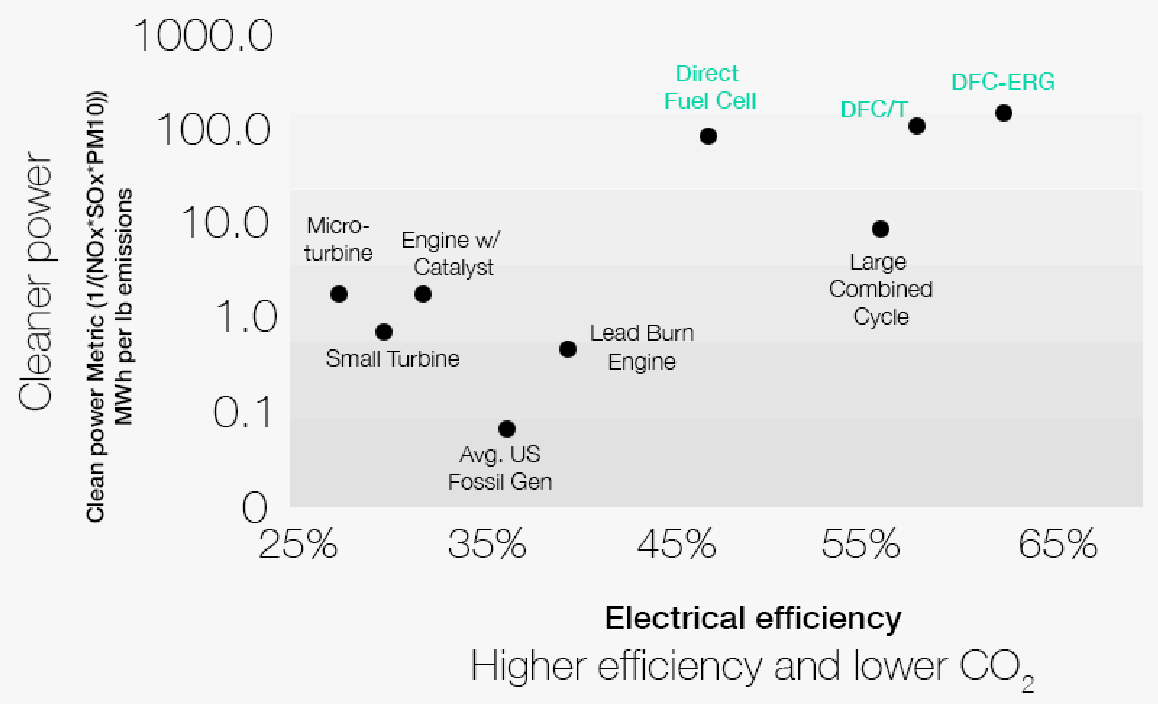


Fig.102: fuel cell solutions compared to its rivals (source: (National Fuel Cell Research Center, 2011)

Several automotive companies are heavily researching fuel cell energy and are trialling fuel cell buses. The most famous companies in the fuel cell for automotive business are Daimler AG, cooperating with Ballard Power Systems. Their F-Cell system technology has been well underway since 1994 and their first fuel cell powered concept car, the NECAR 1, featured a fuel cell system which filled the entire cargo space. At the time, it was one of the most compact fuel cell systems ever made. Eighteen years later, in 2012, Daimler AG presented the Mercedes-Benz B-Class F-CELL. This car sported a fuel cell, heavily reduced in size, and hydrogen tanks that were stored safely in a sandwich structure in the floor (Daimler AG, 2014). This is yet another example of how fast technology progresses, reducing components in size with each iteration.

Since 2005, a couple of London's public buses are powered with a Daimler AG F-Cell, the project is still ongoing and succesful. VDL Bus & Coach as well have their fuel cell technology in place, with the recent Phileas trambus. VDL Bus & Coach (2011): "The energy storage in the Phileases is realised through use of a combination of supercapacitors and a battery system. A vehicle powered by hydrogen may be labelled a 'zero emission' vehicle – there are no harmful emissions, after all, because the exhaust consists of nothing but pure water. An additional environmentally-friendly aspect of the new generation of fuel cell systems is the greatly reduced energy consumption. Moreover, they hardly produce any noise." The Phileas is the living example that fuel cell technology is well suited for commercial passenger transport: the vehicle can carry up to 105 passengers, with an average of four persons per square meter (VDL Bus & Coach, 2011).

Fig.103: 1994 Daimler AG NECAR1 vs. 2012 Daimler AG Mercedes-Benz B-Class F-CELL

Fig. 104: VDL Bus & Coach Phileas

11.1 Fuel cell system requirements

The requirements for the fuel cell system are analogous to those of the WERC system discussed in the previous chapter. Some of the figures are recapitulated in this chapter.

11.1.1 Power consumption

Chapter 10.1.1 revealed that current day motorcoach uses approximately between 100 and 140 kW at cruising speeds. A paper concerning the development of a lightweight touring coach for VDL Bus & Coach by Winkelmolen (2013) mentions a power consumption of around 98.5 kW for a lightweight coach at cruising speed. Assumed that there is a 25% improvement in efficiency by using high tech materials for construction and an aerodynamic design for the outer shell of the Next Generation LDC, the 2030 proposal should be able to cruise at around 75 kW.

11.1.2 Fuel cell performance

For the fuel cell, it is desirable for it to have a power output equal to that of the maximum power transfer of the WERC system: 150 kW. According to data from Ballard Power Systems (2011), current fuel cells used in buses produce between 75 and 150 kW. It is to be expected that future fuel cells will be capable of producing even more kiloWatts. For now, 150 kW seems a reasonable medium value to retain. It is probable that the Next Generation LDC will be available with a variety of fuel cell systems, with a range of kWs to choose from.

11.2 PEMFC

Khurmi at al. (2013): “A fuel cell is a device that converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent”. Different types of fuel cells exist, where the polymer exchange membrane fuel cell (PEMFC) is the most promising technology, commonly known for its automotive applications. The main advantage with this kind of fuel cell is the relatively low operating temperature (between 60 to 80 degrees Celsius), which enables the device to generate electricity fairly quickly, as warm up does not take long. PEMFC is, in general, uses one of the simplest reactions of any fuel cell (Strickland et al., 2000).

A PEMFC consists of four important elements: the anode, cathode, electrolyte and a catalyst. As Strickland et al. (2000) point out: “The anode, the negative post of the fuel cell, has several jobs. It conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit. It has channels etched into it that disperse the hydrogen gas equally over the surface of the catalyst. The cathode, the positive post of the fuel cell, has channels etched into it that distribute the oxygen to the surface of the catalyst. It also conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water. The electrolyte is the proton exchange membrane. This specially treated material, which looks something like ordinary kitchen plastic wrap, only conducts positively charged ions. The membrane blocks electrons. For a PEMFC, the membrane must be hydrated in order to function and remain stable. The catalyst is a special material that facilitates the reaction of oxygen and hydrogen. It is usually made of platinum nanoparticles very thinly coated onto carbon paper or cloth. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen. The platinum-coated side of the catalyst faces the PEM.”

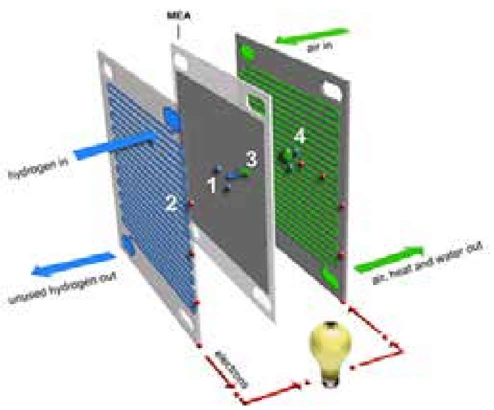


Fig.105: schematic overview of a polymer exchange membrane fuel cell (*PEMFC) (source: alternative-energy-news.info)*
Fig. 106: Ballard FCvelocity – HD6 fuel cell system (source: Ballard Power Systems Inc.)

11.3 Anticipated fuel cell system specifications

Numbers specified below are expectations towards 2030, derived from state of the art data provided by Ballard Power Systems Inc. (2011).
- Type: EMPFC
- Power output: >150 kW
- Energy efficiency: >80%
- Voltage: 730V
- Dimensions (including controller box): 1530 x 871 x 495 mm
- Fuel: gaseous hydrogen
- Oxidant: air
- Weight: approx. 350 kg
- Cooling: water/glycol
- Operating temperature: 63°C

11.4 Fuel cell system design

As with the WERC system, the fuel cell system is presented in a graphic below. The simple system consists of hydrogen tanks, which deliver hydrogen to the fuel cell. In the fuel cell, hydrogen is mixed with air, generating electricity. This is then stored in a battery pack. A cooling system for the fuel cell is obligatory.

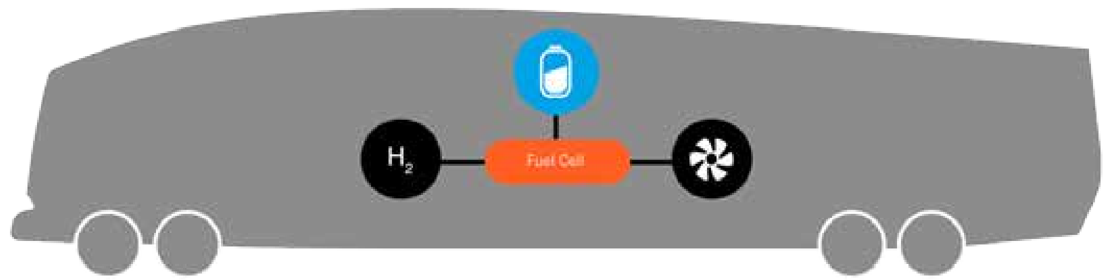


Fig.107: schematic fuel cell system overview. Black lines show power flow (Claus, 2014)

11.5 Battery pack

The main difference for the battery pack, compared to the WERC system, is that the fuel cell is able to constantly deliver electricity. Because of this, the need for a large battery pack is diminished, while fear over range is not at issue.

11.6 Conclusions on fuel cell

The second powertrain option for the Next Generation is a polymer exchange membrane fuel cell (PEMFC), a system which has been developed for over 20 years, and is still being developed for future use. The power output is comparable to that of the WERC powertrain described in the previous chapter.

12 Solar roof

The solar roof is, together with the WERC system, a result from the Design Driver 'Zero Emission'. 2030 will hypothetically be a transitional period in which future concepts about mobility and energy begin to take shape and be implemented in local pilot projects accross Europe. The Next Generation LDC concept is developed with this technology race in mind: the vehicle is "next generation", meaning it is fully equipped to meet future requirements.
The solar roof performs a dual purpose: on the one hand, it autonomously generates energy from a primary resource, to power on board systems. On the other hand, the solar cells function as a mobile 'green' energy source.

The idea is that vehicles and buildings will increasingly be equipped with solar panels or fuel cells. These energy sources continuously generate 'green' electricity. Vehicles will become mobile powerhouses. Thus, they transform unused areas such as parking spots into a valuable source for renewable energy. During peak moments in energy demand, EVs in particular can be employed to level off the energy demand curve: EV excess power can be transmitted to the smart grid, assisting existing power plants in their power supply. During off-peak hours in the night, EVs can be charged to be at full capacity for operation the next day. For example: during a tourist excursion, buses are often parked for hours. This idle time can now be productively utilized. As this is positive news for society, it is good news as well for the travel agencies owning the vehicle: the coach pays back itself, only by sitting in a parking spot.

Implementing a solar roof to a large roof surface that would otherwise be without function other than shelter from the weather elements, also provides extended range for the vehicle. Subsystems such as climate control can be powered from the solar cell's energy, providing an extended autonomous range when travelling off Green Corridors.

Smart grid applications require development towards communication, authenticication, metering and billing, standardisation, infrastructure, fraud prevention and privacy (Perik, 2011). This project will mainly focus on the on board components for the solar roof. The subject will be discussed in a more concise matter, as the solar roof is a less critical component in comparison with for instance Jeeves or the WPT system.

12.1 Solar roof system requirements

In this chapter, it is shortly investigated whether it is expected to be possible for the climate control to be powered completely by the solar cells. Internal VDL Bus & Coach research documents concerning solar panels were consulted for this chapter.

12.1.1 Climate control power consumption

Internal communication and documents from VDL Bus & Coach, provided by M. Franssen, mentions a power consumption of 32.7 kWh per day for a climate control system on a city bus with similar dimensions as the Next Generation LDC concept. The research mentions an estimated worst case scenario, in which the interior temperature had to be brought back to the desired temperature within one minute. The research revealed that it is more economical to have the climate control operate at full capacity directly after closing the coach's doors, and having it maintain the air temperature during a commercial trip. By doing this, the power consumption of the - unspecified - climate control module drops to 22.2 kWh per day.

12.1.2 Solar roof performance and efficiency

Current solar panels have efficiencies of up to 40%. This number however remains theoretical: commercial practice learns that efficiencies of around 15-19% are more common (Solar3D, 2014).
New technologies emerge as companies strive to improve efficiency and power output of solar panels. For instance, a company named Solar3D (2014) offers a new solution with a special wide angle feature on the surface which captures more light in the morning and evening hours, or in winter when the sun is not directly overhead. Solar3D (2014): "Our 3D solar cell is calculated to have an internal efficiency of 25.47%, more than any existing silicon solar cell, and is designed to take advantage of low cost manufacturing processes." By estimation of Solar3D (2014), their three dimentional cell "can produce 200% of the power output of conventional solar cells". By accomplishing this, the investment payback period will be shortened by approximately 40%. The 3D technology is based on a silicon solar cell, building on the already vastly developed silicon infrastructure and manufacturing processes of the growing solar industry.
Another example of technology progress exists, as scientists at the U.S. Department of Energy's Argonne National Laboratory and the University of Texas at Austin have constructed a new, inexpensive material with abilities to capture and convert solar energy from the bluer part of the spectrum (Sagoff, 2014).
University of Texas Professor Brian Korgel (2014): "The holy grail of our research is not necessarily to boost efficiencies as high as they can theoretically go, but rather to combine increases in efficiency to the kind of large-scale roll-to-roll printing or processing technologies that will help us drive down costs."

However, silicon-based solar panels remain very expensive. Research from VDL Bus & Coach (Franssen, 2013) mentions CIGS (thin film cells) solar cells, with which the roof surface of the coach can be covered. Industrially produced, efficiencies of 16% are being achieved. The target for the future is 20%, but not much more. For solar cells, the average energy output per day per m^2 in the Netherlands is 2.7 kWh/m^2. The available average power is thus: 0,2*15*0,85*0,6*2,7 = 4.1 kWh/day (with an area surface of 15 m^2, according to Franssen, 2013).

12.1.3 Conclusions on the solar roof

Although the solar roof is a relatively small component in the system architecture, it remains vital for the functioning of the Next Generation LDC in its 2030 context: EVs will gradually become mobile powerplants, connected to the smart grid, assisting existing power plants in their power supply during peak-hours.

Efficiencies will continue to improve, as was briefly discussed in this chapter. Practical efficiency results of up to 30-35% will become a reality towards 2030. New materials and a broadened spectrum capturing will dictate the development of the next generation solar cells.

13 In-wheel motors

The Next Generation LDC is an EV. This finds its origin in the specifications from the Design Driver 'Zero Emission'. A number of propulsion methods for EVs is available for commercial implementation, such as electric motors with gearbox, without gearbox, with and without transmission and finally in-wheel motors. This chapter will briefly elaborate on in-wheel motors and the benefit that comes with it.

First off, integrating drivetrain components into the wheels opens up possibilities for rearranging the vehicle's architecture: removing the ICE from the back creates an open space available for extra commercial load. It also enables to alter the architecture and lower the passenger floor by several inches, effectively creating a low floor coach (LFC). Fitting retrograde upgrades for e.g. increasing power is also easier to accomplish with in-wheel motors: simply swapping wheels does the trick.

As Jeeves and the WERC system were more critical parts to the concept, the in-wheel motors will only be discussed briefly. Some background concerning performance and technology will be provided.

13.1 Performance

For the performance of the Next Generation LDC, facts and figures from Ziehl-Abegg (previously e-Traction) served as a basis. The engine solution for large buses (fig. 107) currently tops at figures around 7500 Nm of peak torque. This engine spec is currently being used in VDL's Citea Electric city buses, making for a combined torque figure of 15000 Nm. The Citea SLF Low Floor is a 12 m coach for regular city services. The lightweight constructed bus boasts an ability to be arranged for the most ideal and optimal combination of electric drives. These drives can be selected for every deployment area, without consequences for accessibility, interior layout or comfort.
An inspiration of how electric drive and in-wheel motors in particular can change the way a bus is perceived comes from the Ellisup concept bus from IVECO in corporation with Michelin. Iveco (2013): "ELLISUP is equipped with an electric motor developed by Michelin which is housed within four of the eight small wheels. The motor uses an innovative combination of batteries and super-capacitors which act as devices for the storage of energy, characterized by high power density and great durability. The small wheel size enables a new architecture which is a total departure from that of a traditional bus. The interior space has been increased and rendered more liveable, optimizing the flow of passengers at bus stops (boarding and exiting). The design also allows for larger windows that grant passengers panoramic views."

Fig.108: VDL Citea Electric (source: VDL Bus & Coach)
Fig.109: IVECO Ellisup concept coach (source: IVECO.com)

13.2 In-wheel system

The Next Generation LDC's engines will be embedded in the wheels. Mounting the engine into the wheels for creating extra passenger space is not a new idea in automotive circles. For decades, however, the technology proved to be not ready just yet. The complexity of in-wheel motors led to forgetting a brilliant idea. Today, with the arrival of hybrid electric and fully electric vehicles, the development of electric engines has become a hot topic again. Today, a number of companies produce in-wheel motors, with the application becoming available for buses as well. A Dutch company named e-Traction has developed motors for in-wheel application, that are currently being used in hybrid electric city buses (Gav, 2014).

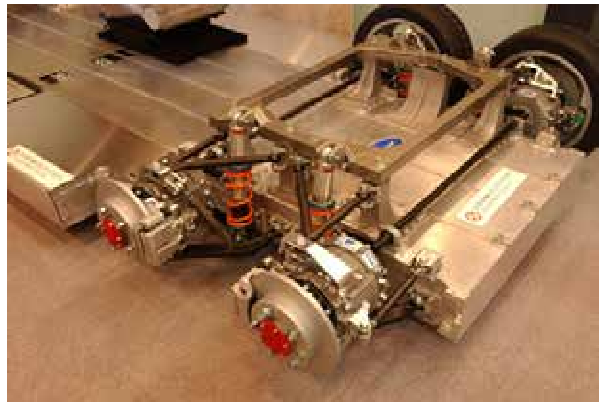


Fig.110: a chassis with in-wheel motors mounted on the wheel suspension (source: eunice-project.eu)
Fig.111: e-Traction's TheWheel SM440 and SM500 in-wheel motors

e-Traction's in-wheel motors regenerate electricity from slowing down, and are built to function as the wheel rim itself. The larger bus module (engine most to the right) is currently designed to fit in the rear wheels and are thus relatively sizeable: the engine fits in 22,5" rims and standard OEM 455/45 R 22.5 super-single tire solutions, the depth is around 555 mm. On the left, a production road car unit is shown, which has a less dramatic width compared to the diamter of the motor. It is to be expected, that in-wheel motor units for buses will become increasignly small yet becomeing more powerful towards 2030.

Questions have been raised towards the increase of the unsprung mass and how it will influence driving dynamics. According to specialists, a classic chassis design and a well tuned suspension are key to a well behaving vehicle (Lotus Engineering, 2011). Michelin as well has done considerable research about in-wheel motors, and they addressed the unsprung mass problem as explained by Vijayentiran (2008): "For the suspension, an electric motor controls an actuator connected to a damping system with varying levels of firmness. This unique system features extremely fast response time—just 3/1000ths of a second and all pitching and rolling motions are automatically corrected."

13.2.3 Conclusions on in-wheel motors

In-wheel motors enable engineers and designers to rethink the architecture of vehicles. The technology is being implemented in city buses today, which signifies a great step in the development of the system. Valuable data will come from the mileage ran by the buses in the projects. This will help manufacturers to come up with and develop better, smaller and lighter in-wheel motors towards 2030 and further. This chapter gave insight into the basics of these developments, illustrated by information from e-Traction and Michelin.

14 Flexible interior and Adaptive Entrance

This chapter will briefly elaborate on how a flexible interior solution will be perceived, and how it will influence the cost effectiveness of the vehicle. Put short: the flexible interior is a direct result from the Design Drivers 'Efficiency' and 'Accessibility'. It aims to provide a solution to problems defined in the NPP chapter: the over or under capacity in which most modern coaches operate. The second part of this chapter concerns the Adaptive Entrance, a result of the interior philosophy of not having steps nor stairs in areas accessible for passengers, as specified in the Design Driver 'Accessibility'. For the Adaptive Entrance, the following description was defined in the Specifications: "Flexible ramp system integrated in entrance, providing stairless accessibility at any given location (platform/no platform, curb/no curb)". A solution to this description is proposed in this chapter, along with some background on regular lift/platform systems for coaches.

The benefits of having a flexible interior and Adaptive Entrance is twofold: tour operators benefit from having a flexible interior solution in which passengers can choose the amount of comfort and space they are willing to pay for. This equals a minimal adjustment for the coach owner, with a greater rate of return. The Adaptive Entrance enables effortless boarding in any given circumstance, regardless of age and physical condition of passengers.

The largest part of the subject 'flexible interior' will be touched in Part 3: Product Design. Dimensioning and packaging will be ideated on in a later stage as well. In this chapter, a solution for variable seats will be introduced and the system design for the Adaptive Entrance will be presented.

14.1 Variable seats

During a panel discussion concerning "Life on board the Next Generation LDC", it was mentioned earlier that the idea of a 'traveller's profile' found great acclaim in the group. This profile would contain personal traveller's preferences, physical dimensions and other personal characteristics. This would enable touring operators to provide a tailored onboard service to each customer. Some extra services would be charged extra for, but the traveller will always be able to select any desired option from his or her traveller's profile. A solution for this is proposed in this chapter.

14.1.1 Morph

Having the opportunity to have a flexible amount of seats and space has been an issue in the people transporting sector for decades. Having a plane or bus operate with too many empty seats is as frustrating as having too few available seats. British design consultancy Seymourpowell has come up with an ingenious solution, that might resolve more than only the capacity paradigm. Originally intended for airlines, the concept had potential for implementation in coaches. Seymourpowell (2013): "We have designed a concept economy seat for airline travel that has been inspired by difference, new materials and flexibility. Called Morph, the seat has been designed to offer passengers choice over the amount of space they pay for and to provide a better fit for more people." The concept addresses the fact that standard airline - and indeed coach line - seats have been designed to "ergonomically fit everyone, by averaging the sizes of the largest and smallest percentiles to a point where it fits relatively few people properly" (Seymourpowell, 2013). Morph is a standard seating solution that is designed to adapt to the individual needs of each passenger. The seating concept uses an innovative and lightweight architecture which combines maximum adaptability with a minimum of components.
Seymourpowell (2013): "The concept seat works by replacing traditional foam pads with a fabric that is stretched across the width of three seats, around a frame and over formers. One piece of fabric is used for the seat back and one is used for

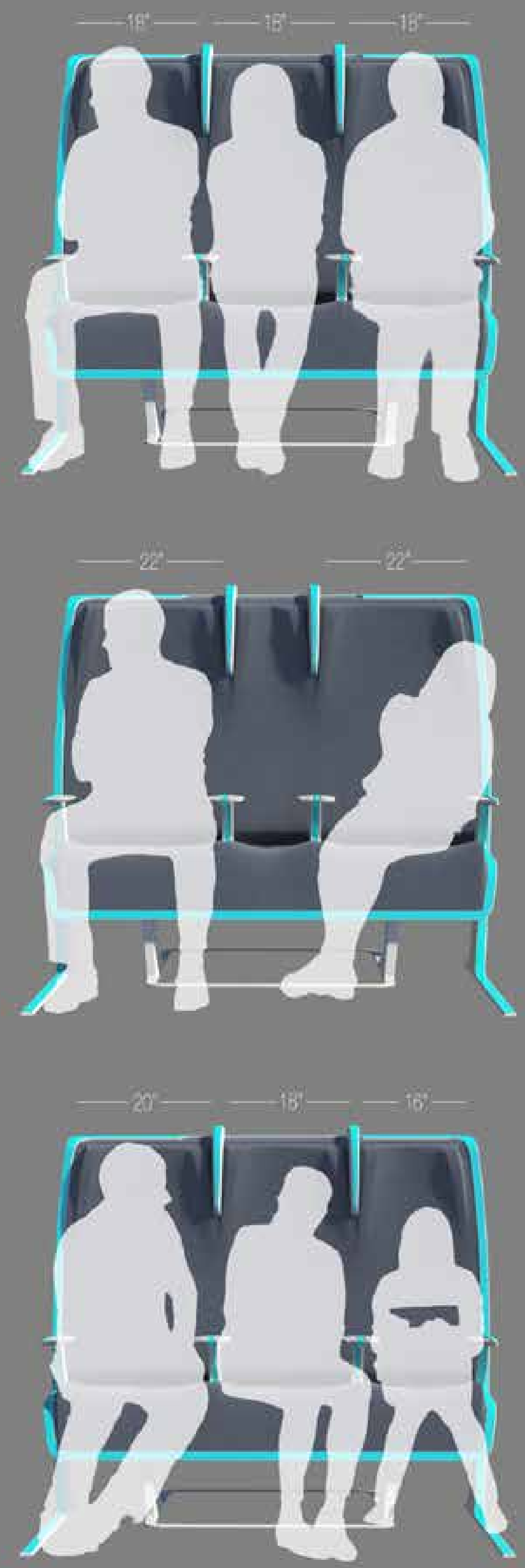


Fig.112: Seymourpowell's Morph (source: Seymourpowell)

Fig.113: Morph's internal framework, with a clear view of the movable formers (source: Seymourpowell, 2013)

the seat base. The fabric is clamped down by the armrests and the upper dividers to form three individual hammock seats. By moving the formers and pushing them through the fabric we can control the recline and a large range of ergonomic adjustments, morphing the fabric to provide a tailored fit and greater comfort." By employing the concept of hammock seats, further weight reduction can be accomplished because of the missing foam pads. The image on the facing page illustrates the simple beauty of the concept: a child can have a customly fitted seat next to its parents, who then have an increased available space for their own. Passengers pay according to their used space and comfort, blurring the lines between comfort classes (Flaherty, 2013). The concept enables a local increase in comfort wit facing a minimized reduction in capacity.

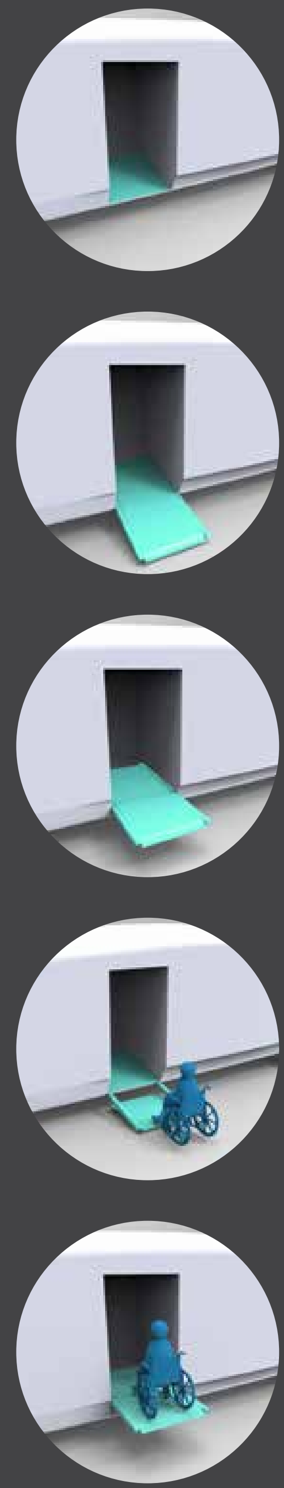
On the image above, a presentation of Morph's inner framework is shown. The space between the frame and movable formers remains open and is not filled with foam. The rails on whoch the formers can move laterally are also visible (around the orange highlighted components). The armrests can be flipped open to provide a larger surface.
The concept can be easily converted into a two-seater configuration. The amount of possible seating possibilities would decrease, but the main advantage - the ability to locally increase comfort and capacity - remains.

14.1.2 Economic advantage

A bus, plane or train is at its most efficient when operating at full capacity. The more cargo, or in the case of buses, people a vehicle can carry, the less expensive it is to run. In the NPP chapter we established that running at half capacity is a common world problem in both regular and occasional services. Undercapacity can be partly solved with the Morph concept seats: when a coach trip is not fully booked, travellers can be offered more comfort for a little extra fee. The traveller then has a choice whether to accept the offer or not. For fully booked trips, the opposite can be achieved: the last seats, which will probably be the least comfortable as the majority of already booked places will have been adjusted to passenger's profile, can be offered at reduction prices. This way, full capacity can be achieved whilst some seats bring up more money than would be the case with fixed layout seats.

14.2 Adaptive Entrance

The NPP chapter was concluded with a wish to have an accessible coach. It was described as follows: "Large doors with smart ramps will provide easy acces to the LDC. People will be able to move faster in and out of the vehicle, as there are no stairs nor steps. The smart ramp will be able to adapt the entrance of the vehicle according to its surroundings. The system will be a flexible means to board the coach, regardless of any physical limitations of passengers." In this chapter, a solution for such flexible entrance is proposed and shortly discussed.



The Adaptive entrance ramp system neatly fits into the interior of the coach. The angle of the top ramp can be adjusted to level with the reference plane of the passenger floor.

Underneath the top ramp, a secondary ramp is mounted on two telescopic arms. This enables the assembly to extend and form a ferry bridge from the ground level to the passenger floor of the vehicle.

The complete assembly can tilt up or downwards, to adjust to occasional curbs or boarding platforms.

The secondary ramp is connected to the telescopic arms with hinges, enabling to adjust the angle of the panel to align with the ground surface. A wheelchair can then be rolled onto the panel.

The primary and secondary platform can alter their angle individually and align with each other to enable a wheelchair to be lifted into the coach.

Fig.114: Adaptive Entrance (Claus, 2014)

15 The 2030 platform

The 2030 platform bundles all innovative functions of the LDC concept, combined with the core engineering - necessary for the functioning of the bus. Core engineering contains the drivetrain, suspension, electric motors, safety systems and structural elements. The platforms enables to efficiently produce multiple versions of the same production model, be it longer or with a different trim, at higher production volumes than would otherwise be the case.

15.1 An electrical architecture

The electrical architecture enables two power unit options: WPT and fuel cell. The wireless power transfer system ensures the long distance range which is indispensable for long distance coaches. With battery technology and multifunctional polymer innovation not yet at a standstill, the need for rapid charging at any time will remain a necessity towards 2030. Depending on how the customer desires to deploy the coach, a second power unit is available in the form of fuel cell. The electrical architecture remains the same, only the power unit differs and is modularly installable.

15.2 Clever solutions

The driver has a personal assistent: Jeeves. The system embodies all driving assistance systems, V2V hardware, on board systems managing, energy management systems, etc... It is the personification of the Next Generation LDC's artificial intelligence (AI). It is the controlling entity which assimilates all processes in the system.

Sub systems such as climate control are partly powered by solar energy from the solar roof, in order to maximise the driving range of the vehicle. When powered by the solar panels, the air conditioning will not subtract energy from the main battery packs, which will then enable to fully juice the electric motors that propel the coach. The second function of the panels, is a passive way for generating energy for selling purposes. The smart grid will enable people to resell energy, effectively paying back idle vehicle time.

Using battery electric propulsion creates opportunities to alter vehicle's architecture. Certain components change or can be located elsewhere, to create space in places where it would have been impossible before. In-wheel electric motors can be mounted inside the rims, creating space for other components.

The flexible capacity interior provides a way to maximise the capacity of the coach to the desired use and personal preferences of travellers. Seats will vary in price according to the chosen comfort mode and dimensions, which offers tour operators a cost efficient way of utilizing a fleet of vehicles. Travellers benefit as well: traveller profiles ensure maximum comfort at a fair extra cost.

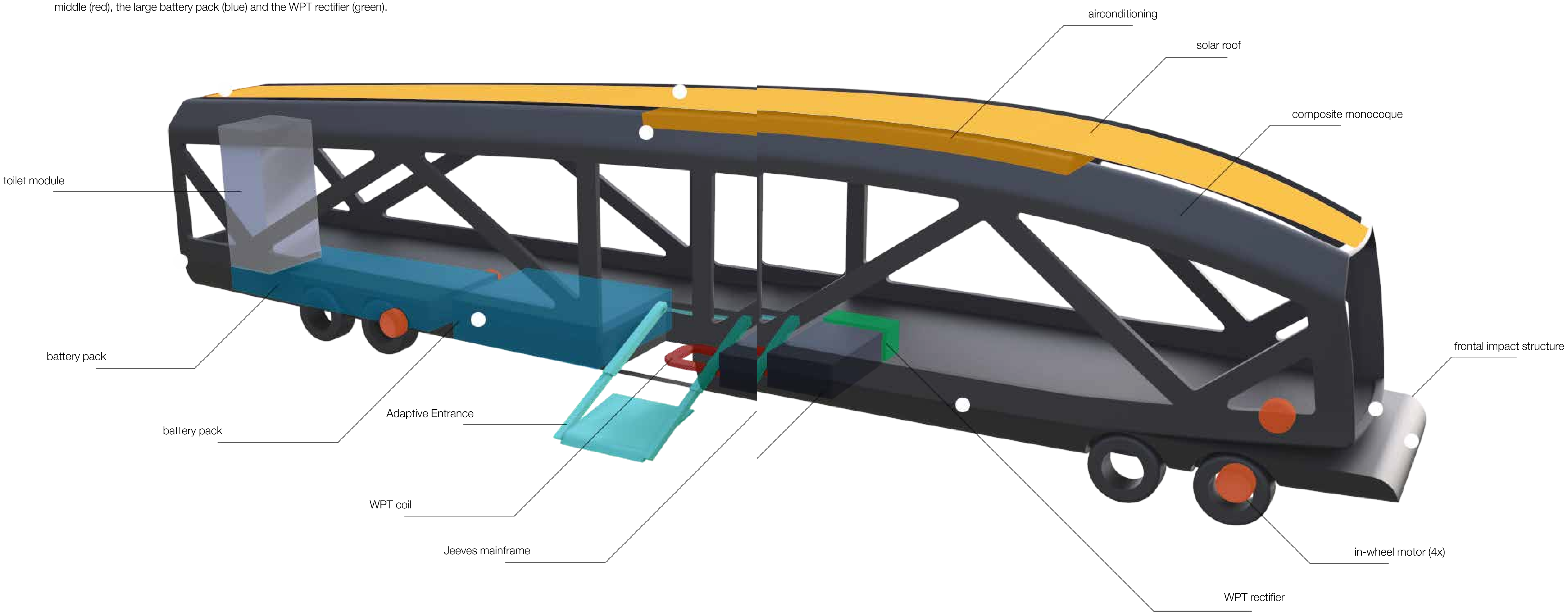
The adaptive entrance is a flexible solution to make boarding easier regardless of the surrounding facilities or the lack thereof. It consists of a smart platform that is variable in height, length and angle, and is able to transform itself into a wheelchair lift.

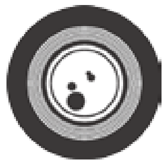
The chassis components are optimized for strength, durability and weight, making for a lightweight and multifunctional monocoque chassis.

15.3 Next Generation platform with WPT

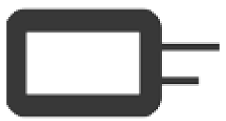
On this page, a basic schematic of the 2030 platform with WPT drivetrain is shown. The white dots indicate locations in which sensors for autonomous or guided driving are located. Characterizing for the WPT powertrain is the WPT coil in the middle (red), the large battery pack (blue) and the WPT rectifier (green).

Fig.115: platform with WPT overview (Claus, 2014)

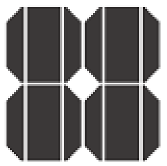




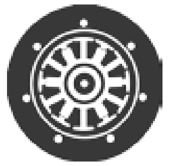
Jeeves' sensors are spread accross the chassis of the vehicle (white dots). In the front area: RADAR, laser and stereo camera. On the sides: RADAR and laser sensors, plus LIDAR. At the rear end, additional RADAR, laser and a camera is mounted.



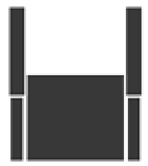
The coils for the WPT system are located under the floor of the coach, at the center (green). A lowering hybrid resonant magnetic coupling module is opted, in order to assure safe charging even when passengers are boarding from the Adaptive Entrance.



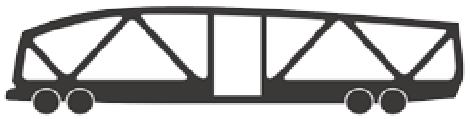
The roof is covered with a solar cell film (dark blue), over an area of up to 16 m^2. This area provides valuable backup power for the climate control system to run from. It enables the vehicle to decrease it's power consumption.



The in-wheel motors (red) are located in the front wheels (2) and in the rear wheels (2). These four engines are more than capable of propelling the vehicle at a quick pace. The architecture enables for a tighter package and all wheel steering.



The Adaptive Entrance (cyan) enables passengers to board stairlessly from and to the coach, regardless of the presence of roadside architecture such as platforms or a sidewalk.

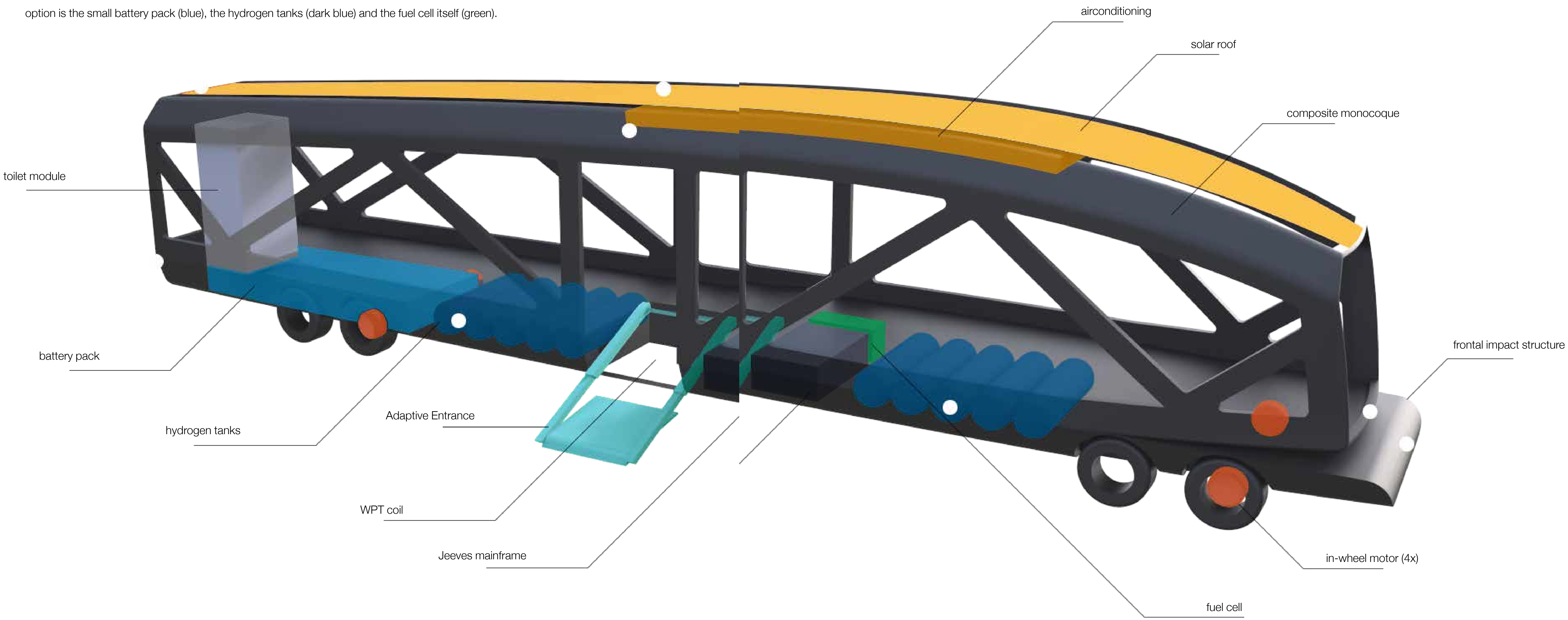


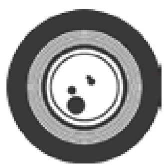
The monocoque chassis (seethrough) is made from carbon fibre and is built from modules. The chassis hereby is stiffer and lighter than conventional chassis. Incorporating batteries into the chassis is a possibility.

15.3 Next Generation platform with fuel cell

As on the previous page, a basic schematic of the 2030 platform with fuel cell drivetrain is presented below. The white dots indicate locations in which sensors for autonomous or guided driving are located. The main characteristics for this drivetrain option is the small battery pack (blue), the hydrogen tanks (dark blue) and the fuel cell itself (green).

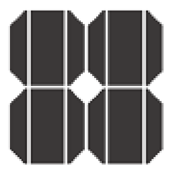
Fig.116: platform with fuel cell overview (Claus, 2014)



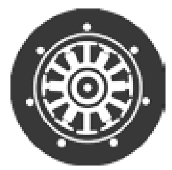


Jeeves' sensors are spread accross the chassis of the vehicle (white dots). In the front area: RADAR, laser and stereo camera. On the sides: RADAR and laser sensors, plus LIDAR. At the rear end, additional RADAR, laser and a camera is mounted.

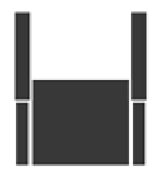
The fuel cell system (blue and green) is in fact a relatively small and light solution. The power output is comparable to the WPT system, which enables the coach to travel long distances without having to refuel.



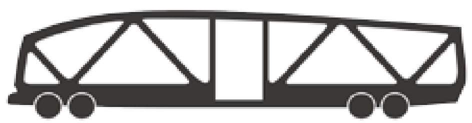
The roof is covered with a solar cell film (dark blue), over an area of up to 16 m². This area provides valuable backup power for the climate control system to run from. It enables the vehicle to decrease it's power consumption.



The in-wheel motors (red) are located in the front wheels (2) and in the rear wheels (2). These four engines are more than capable of propelling the vehicle at a quick pace. The architecture enables for a tighter package and all wheel steering.



The Adaptive Entrance (cyan) enables passengers to board stairlessly from and to the coach, regardless of the presence of roadside architecture such as platforms or a sidewalk.



The monocoque chassis (seethrough) is made from carbon fibre and is built from modules. The chassis hereby is stiffer and lighter than conventional chassis. Incorporating batteries into the chassis is a possibility.

Product Design

The third phase of this project, Product Design, is the pinnacle of the designing process. It aims to generate an attractive, dynamic and sexy exterior which combines all the System Design solutions proposed in the previous phase. Product design enables all development issues to be bundled seamlessly, into a beautifully designed and engineered product. For this particular project, the aim will be to develop a concept car to showcase the innovative features.

16 Vehicle packaging

In the previous chapter, the Next Generation Platform was defined: a bundling of all innovative functions of the LDC concept, combined with the core engineering - necessary for the functioning of the bus. The following steps within the scope of this thesis are the development of an exterior and interior design proposal, which implements the innovative features of the Next Generation Platform in a solid product. Before the exterior and interior can be designed, the vehicle packaging has to be examined and ultimately defined.

For the Next Generation LDC, the seating arrangement is the most important factor of the packaging proposal. It defines the number of available seat rows, the amount of space for both passengers and other critical components, needed for the functioning of the vehicle.

Because of the limited available time for this thesis, a packaging proposal will be developed only for the holiday trim. The proposal will largely dictate the exterior design in terms of dimensions. For the final design, a separate design vision is defined in the following chapter. The aim for this design vision is to transform the concept into a showcase vehicle: a full blown concept car.

16.1 Interior requirements

During the NPP and System Design chapters, a couple of requirements concerning the interior of the coach were defined.

16.1.1 Flexible seating capability

The Design Driver 'Efficiency' stated the holiday trim to have 46 variable seats, comparable to the Morph concept, provided with long haul comfort. The seats can each individually adjust to travellers' anthropometry and it is possible for travellers to book additional seating space at a premium. The maximum seating capacity will thus be 46, driver excluded. This is 6 seats short in comparison to the smallest size 2014 VDL Futura FMD2-122. The reason for reducing the amount of seats was found in the NPP chapter: further reducing weight and the fact that coaches often operate at half capacity made for the decision to lower the capacity by 6 seats.

16.1.2 Adaptive Entrance, stairless interior and low floor coach

The Adaptive Entrance, as introduced in chapter 13.2, is featured in every Next Generation LDC trim. Furthermore, the interior and gangways in particular are without any form of stairs or steps. This as a measure to improve overall interior accessability. The cargo bay is situated at the rear of the vehicle, enabling the passenger deck to lower significantly compared to modern day coaches.

16.1.3 Aerodynamical exterior

The interior arrangement will be strongly dictated by the aerodynamic droplet shaped exterior.

16.2 Packaging proposal

For the final packaging proposal, the 95th percentile of Dutch men and the 95th percentile of British boys were used as reference for dimensions. This was firstly laid out in SolidWorks sketches and afterwards, presentation images of the final arrangement were generated. When working on the interior arrangement, it became apparent that because of the Adaptive Entrance, only a classical 2+2 configuration was realistic. The Adaptive Entrance needs a specific location and height above the ground plane, as the slope of the ramp is paramount if the system is to fulfill its promise of great accessibility. These requirements cause the passenger deck to have a slight inclination in the middle of the vehicle. As the Design Driver 'Accessibility' stated that the vehicle will not have stairs nor steps, the difference in height is covered by a curved ground surface. The Adaptive Entrance adds a third functionality to its job description: during a trip, it is a transformed into a wheelchair spot.
Turning to the schematics below: the minimum dimensions of the passenger space was determined (green area). The front wheels are moved forwards to increase the amount of space under the passenger deck. This grey area contains batteries (in the case of the WTP variant) or hydrogen tanks (in the case of the fuel cell variant). The dark blue area at the front is a front impact zone, obligatory by law in 2030.

(95th percentile)	DUTCH M.	12YR BOY
SITTING HEIGHT (8)	995	830
BUTTOCK-KNEE (13)	665	555
BUTTOCK-POPLITEAL (14)	570	455
KNEE HEIGHT (15)	610	530
POPLITEAL HEIGHT (16)	495	430
SHOULDER BREATH (17)	520	395
HEAD LENGTH (26)	210	360
FOOT LENGTH (30)	295	255

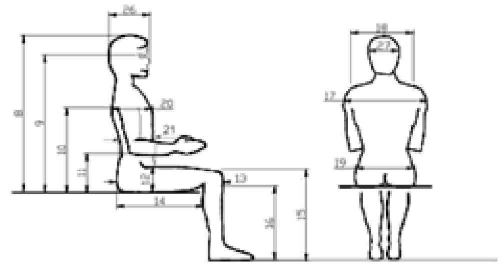


Fig.117: antropometric data used for the interior arrangement (Pheasant and Haslegrave, 2006)

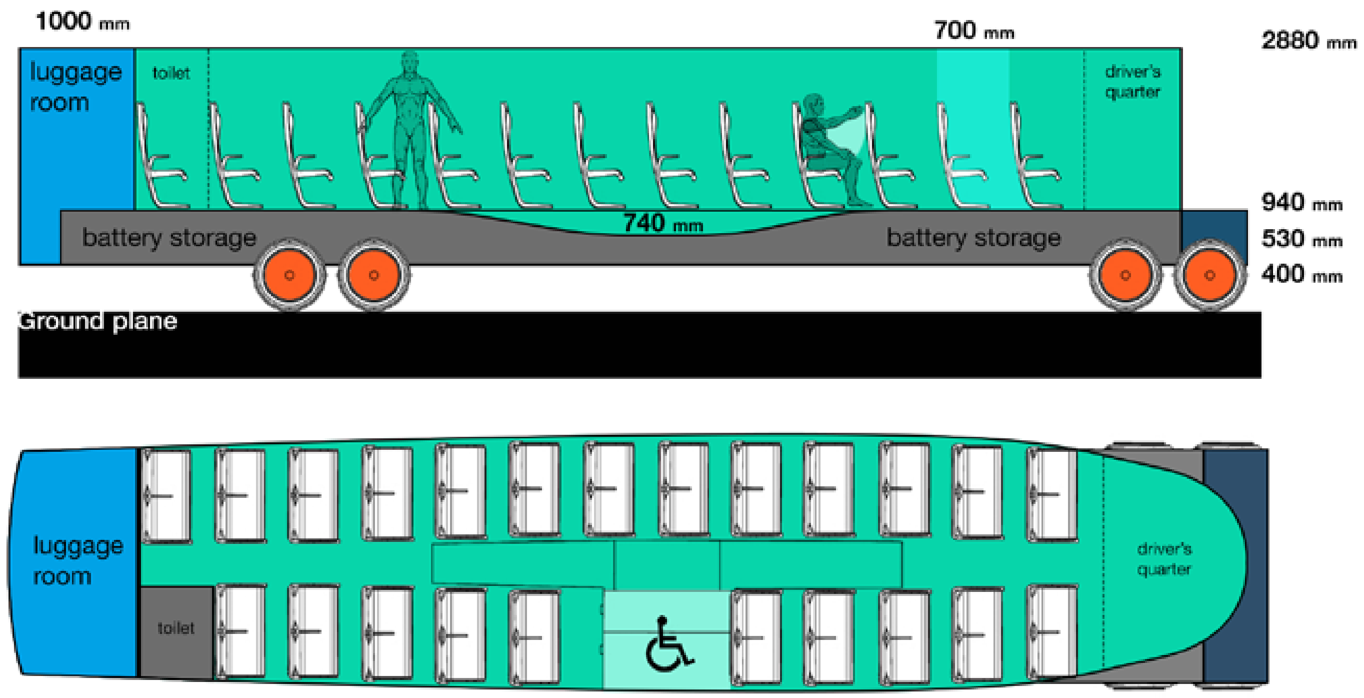


Fig.118: Next Generation LDC packaging proposal (Claus, 2014)

17 Exterior design

The exterior design of the Next Generation LDC is the sole aspect of this project which has been developed and tweaked for the longest amount of time. Since the start of the second phase, System Design, the design has been meticulously crafted and continuously revised, in order to provide an almost tangible result at the end of the project. One of the key goals since the beginning of this thesis was the look and design of the coach. A revised architecture creates opportunities to envision a type of coach which has yet to be invented. A coach that inspires, that propels an entire sector into a new era in which power efficiency and increased luxury act as symbionts rather than opposites. This chapter provides insight into the design philosophy and process, which is ultimately translated into a coach 'concept car': a look into the future, made as realistic as possible, but futuristic enough not to impede on the dreamers.

17.1 Design philosophy

The design philosophy emenates from a personal wish on the one hand, and the industrial promotor's design vision on their coaches and buses on the other hand.

The author's wish was to envision a coach with an allure that brings back the grandeur of the Golden Age of motorcoach travel, represented by the transcendent GM PD-4501 Scenicruiser (picture below). The Scenicruiser was, and still is, an icon of the American way of life: it was exclusively built for the Greyhound Corporation, which made it an all time classic. It embodied the timeframe in which it operated as no other: air suspension, comfortble seats, a complete washroom and a high-level observation deck. The stance and allure of this design, based on a design originated by Raymond Loewy, still stands as a benchmark for style and class in motorcoach travel.

VDL Bus & Coach prioritise in endowing their products with a well designed look: "Advanced mobility concepts deserve an advanced design. Even standing still, the designs have a dynamic look. Stylish details and a first-rate finish provide the finishing touch to the unique design" (VDL Bus & Coach, 2014). This vision proved a grateful addition to the author's perception of how the design of the Next Generation LDC should be perceived.

The combined design philosphy thus reads: "a unique, advanced and dynamic design which stands out from current day box-shaped motorcoaches, and which puts the motorcoach as such back in its rightful position as being the pinnacle of on-land travel." This emotional description will be completed with design elements derived from the previous two chapters: whale-like aerodynamics, the Adaptive Entrance, crash impact zones and Jeeves' sensors.

17.2 Moodboard and initial concept sketches

On the following pages, the designing process is shown by means of a moodboard, sketches and explanatory text. As designing is an organic and emotional process, this text will elaborate on why certain decisions and design directions were made.

From the beginning, it was decided to experiment with two concepts: a futuristic approach and a more conservative variant. For each concept, an initial image was generated, which would capture the desired atmosphere and stance of the vehicle. These images would then serve as inspiration for further formal exploration.

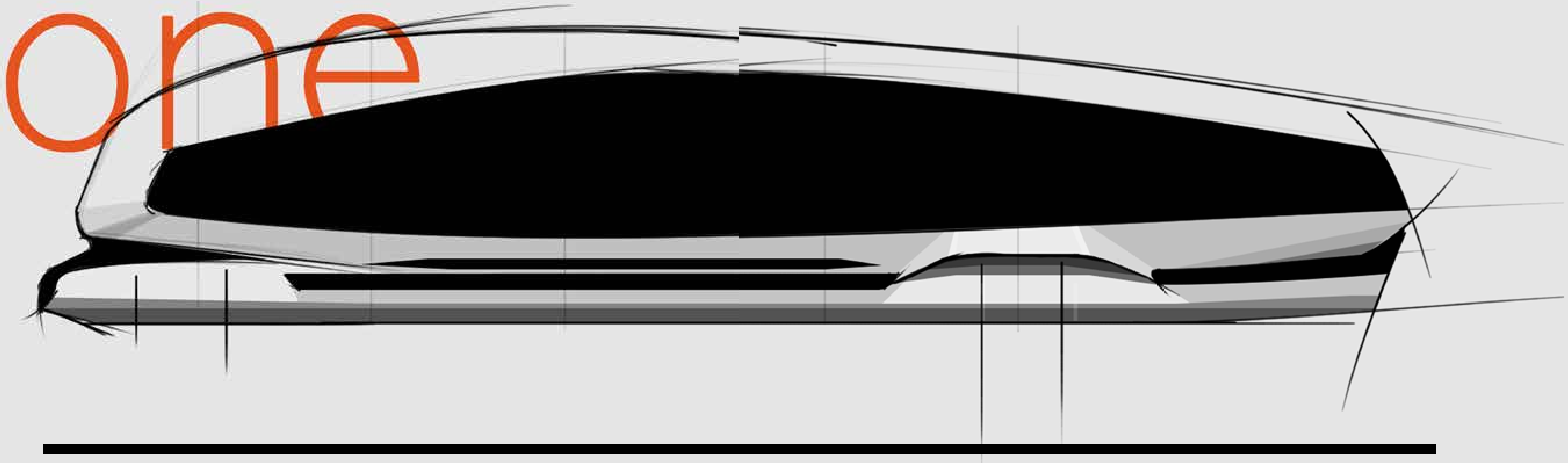
Fig. 119: GM PD-4501 Scenicruiser (Wikimedia.com)

Fig.120: Mack Truck Concept Model by Jay Brett, via Behance

Fig.121: Ford Urban Mobility by Tianye Wang, via Behance

Fig.122: Herman Miller's Mirra 2

Fig.123: Renault Frendzy Concept by Deyan Denkov



17.2.2 Initial sketches

The first concept sketch (above) captures the image of an extremely streamlined, organic yet structured body. The aim was to create a play with lighter and darker surfaces, with each curve of each surface redefining the overall perception of the main volume. The classical anatomy of a motorcoach is consciously abandoned in favour of a more dynamic, split-bodied approach: through light and surface treatment, the illusion of a modular architecture is awoken. The second concept sketch (below) is the more conservative approach on how a dynamic design solution could present itself. The typical single-body look is spiced up with striking split lines, fracturing the volume's surfaces in order to provide it with an almost roadcar-like sophistication and elegance.

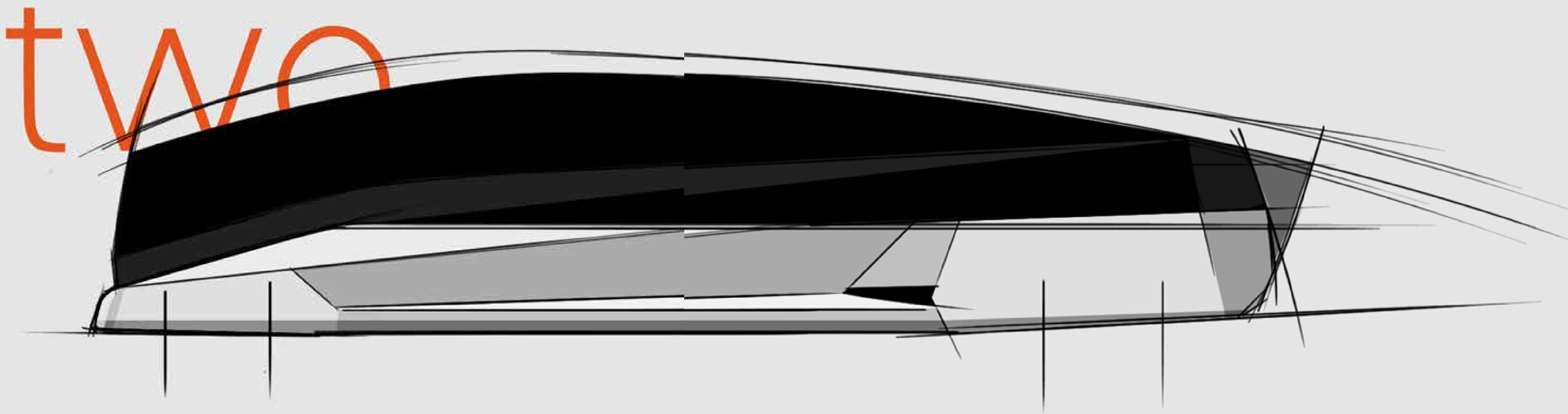
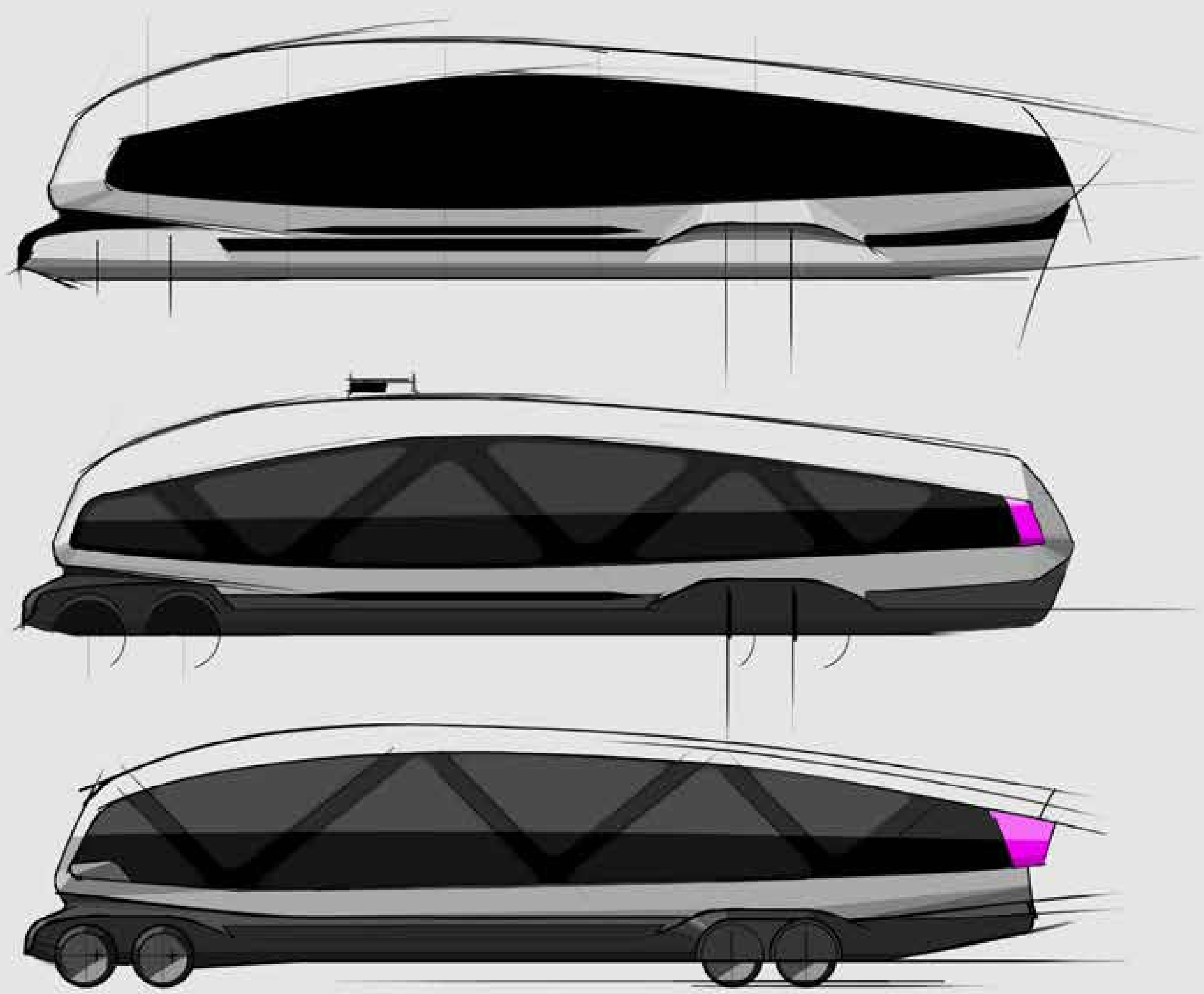


Fig.124: initial design sketches (Claus, 2014)

Fig.125: concept one sketches (Claus, 2014)

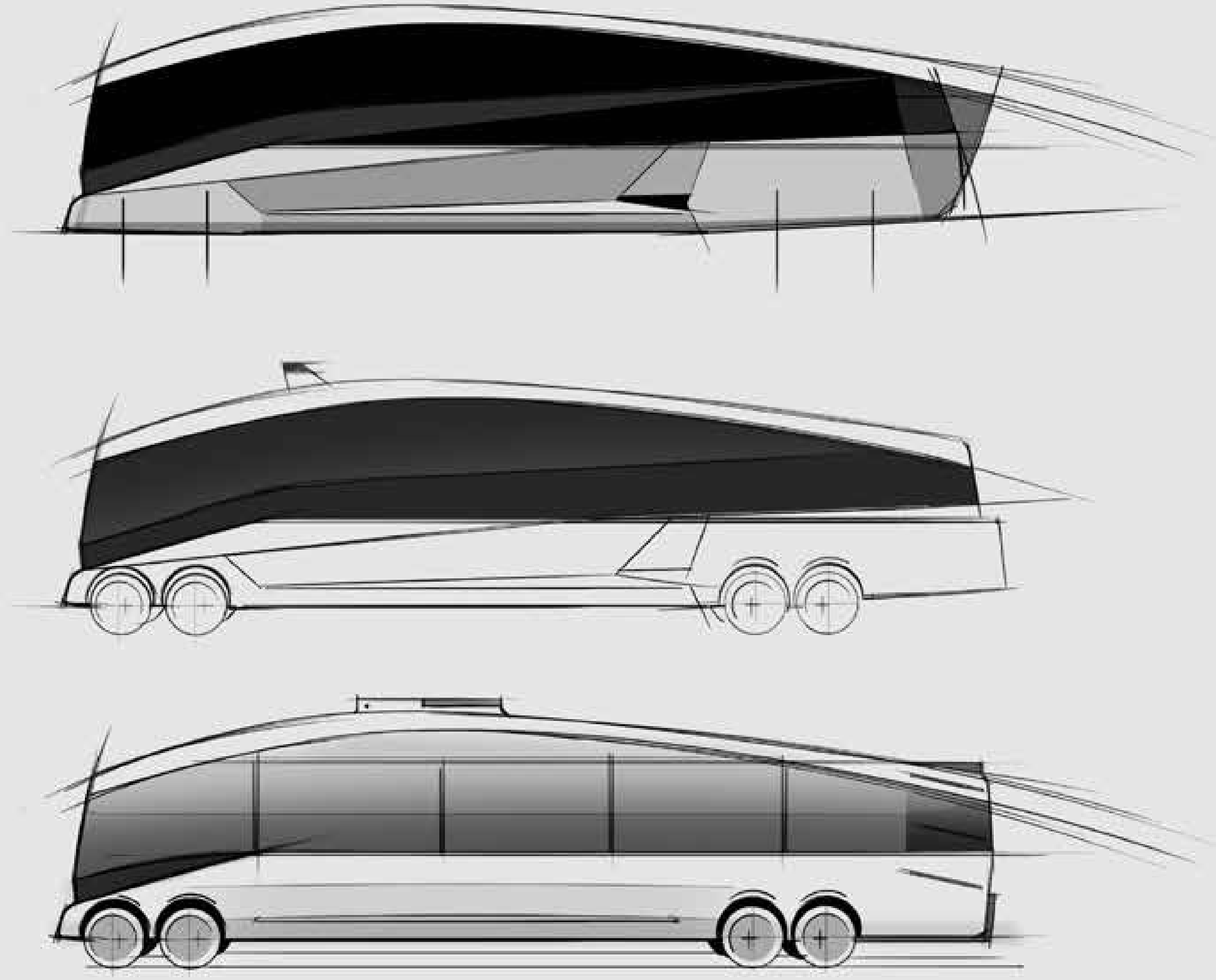


17.3 Exploring concept one

Each of the two concepts was individually evaluated by means of additional sketches atop of the concept sketches, shown on the previous pages. These additional sketches examine how the styling of the concept could potentially evolve during the process, going from a concept sketch to a finalized product.

Author's thoughts: "As I imagined the future's coach to be as dynamic and as far away as possible from the box-shaped buses we know today, I had to define a limit for myself. This limit would guide me through the designing process and would set a target for how futuristic or realistic the final result of this thesis would be. For the first concept, the overall shape, windows and the split-body exterior were the main characteristics that had to be preserved if the identity of the concept were to be conserved. The top sketch is the inital sketch as seen on the previous two pages. The middle sketch shows a more defined version of the concept. In this drawing, I started to play with the idea of a chassis with a V-shaped structure, which is visible through the large side windows. The idea of shaping internal parts so that they become aesthetic enough to be visible, appeals a lot to me. We also see the evaluation of my sketch lines through the maturing of the concepts: on the cover for the rear wheels, the two vertical openings are an interpretation from the initial wheel position vertical lines, as seen on the top sketch.
The bottom sketch is the most realistic one of the three, however still provided with artistic liberty.
A final version for this thesis would focus on a presentation as seen in the middle sketch, with elements from both the two other sketches incorporated."

Fig.126: concept two sketches (Claus, 2014)



17.3 Exploring concept two

In line with the previous chapter: the second concept is evaluated in order to extract possible development directions.

Author's thoughts: "Although, in the design philosophy, I expressed the wish of distancing the Next generation LDC's design to be as far away from current day coaches as possible, I felt it was appropriate to experiment with a more conservative approach to the matter. The second concept is built around breaking up surfaces in order to generate a more intricate, dynamic look. The initial sketch was, to my opinion, too dense and chaotic. The proportions too were not as balanced as is the case with concept one. Further exploration led to the generation of the middle sketch, which is a first iteration on how this particular body would work with wheels underneath. I still hated the proportions of the vehicle at this point. The third and last sketch is a hyper realistic drawing of how the Next Generation LDC would look like without fantasy. Dull as it may look, it illustrates that aerodynamical changes can be implemented on buses in the near future, without radically changing too much on the original design if wanted. The sketch could be a candidate for a master thesis, but given my own objectives and design philosophy, I decided to not go down this path. From these three sketches, the middle sketch would be the guiding point."

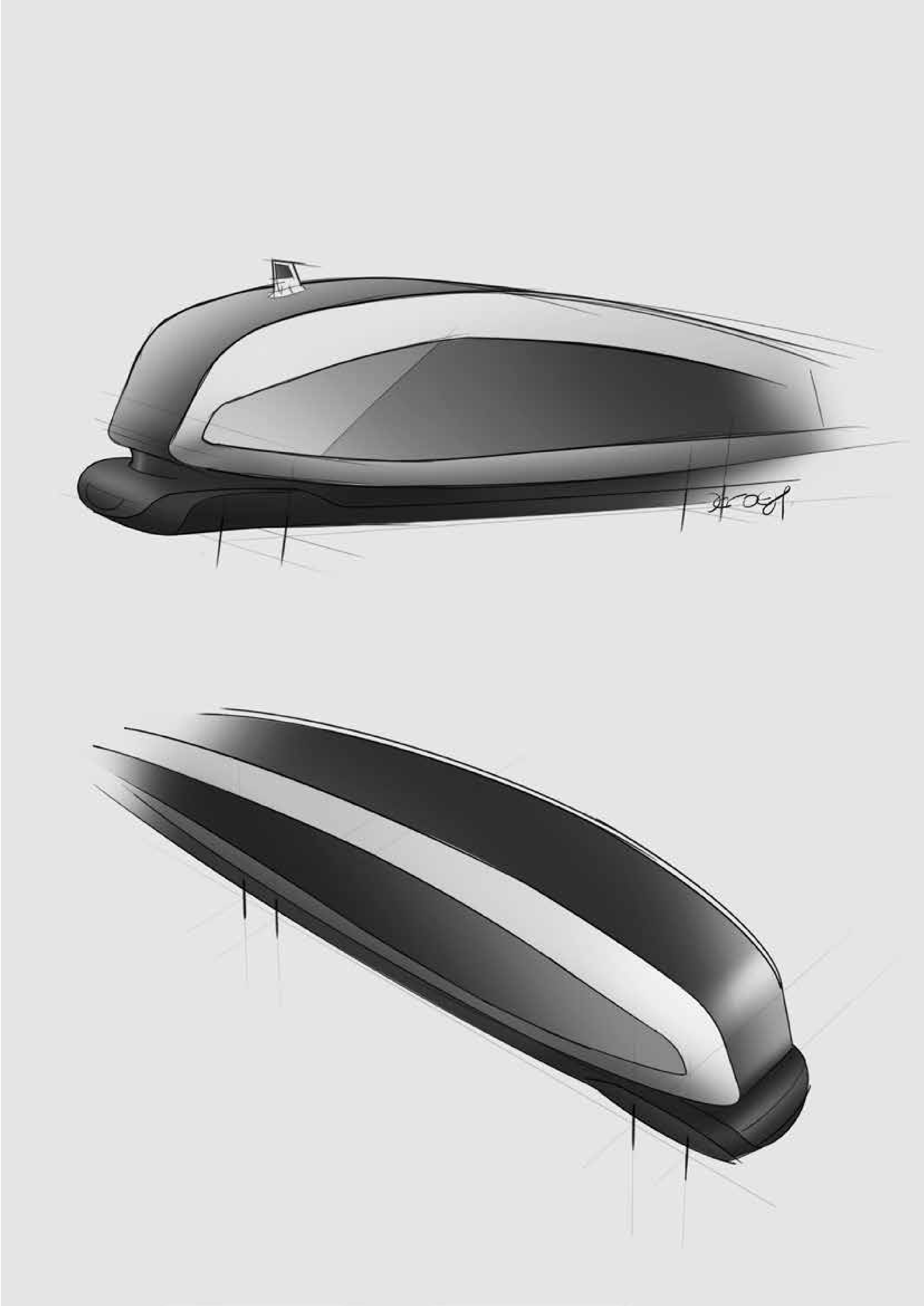


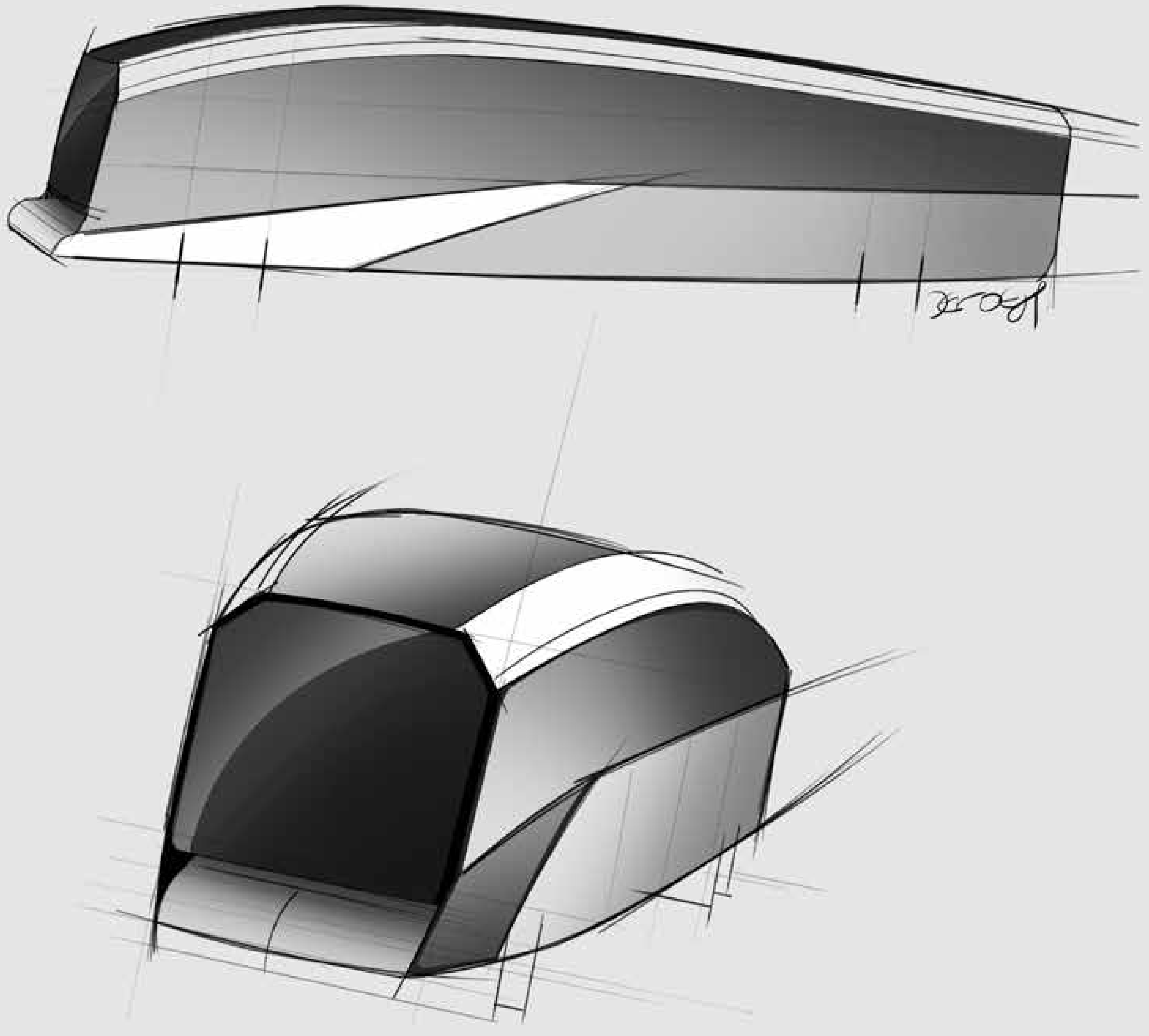
Fig.127: concept one sketches, second iteration (Claus, 2014)

17.4 Iterating concept one

Each concept was iterated and tweaked, clean overview sketches were made.

Author's thoughts: "Concept one was a very challenging one to master. It took me a good couple of hours to get the lines and surfaces right. Combining an almost whale shaped body with some sort of natural elegance proved to be a hefty task. It was a case of providing every single line with a curvature in every direction. Managing these curvatures so that the vehicle would look OK from every angle was the result of meticulously crafting the sculpture. The idea for the front end of the vehicle was to visually provide a difference with the upper and under side of the bodywork. The two connect to each other in a fabric-like way, as if a piece of canvas is tightly wrapped between the two. This provides a soft counterpart for the distinguished upper part of the bodywork. These soft curves not only smoothen the overall appearance, making it more 'friendly' to look at, but hint at a very streamline efficient skin."

Fig.128: concept two sketches, second iteration (Claus, 2014)



17.5 Iterating concept two

In line with the previous chapter: iterations on the second concept were made.

Author's thoughts: "Unsatisfied with the quality of the second concept in the early stages, I felt it was time to step up my game. These two sketches were among the best that resulted from an intensive sketching night. They beautifully captured the atmosphere and design language I wanted for this concept. A classic, yet stylish and sleek approach characterizes this second concept. The idea was to have a lot of stretched glass surfaces, which are connected, but do not really align properly, creating an interesting play with light and shadow.
This concept, because of the conservative approach, can easily be imagined in the production phase."

17.6 The final proposal

Concluding on which of the two concepts to choose for further development was a tough decision. Eventually, the design philosophy briefing (chapter 16.1) proved to be the decisive factor. The objective was to make a legendary era of motor coaching revive with a unique, mind bending bus proposal. Concept one had the characteristics to fully comply with that design philosophy, but was inherently very complex. Concept two was the most sleek and classic proposal, and proved to be too conservative to be developed in the end. It remains, however, a valuable insight on how future coaches can be built with the new aerodynamic rooftop and frontal impact zone.

Author's thoughts: "In the end, I made an atypical decision: complexity won over simplicity. Concept one was the most challenging proposal. I like to push myself in finding a unique product. Working for hours and hours straight in order to find the perfect dimensions, curves and surfaces is what I like to put myself through. Being well aware that the complexity and overall appearance of concept one might not be well received by the general public, I set to take hold of the challenge."

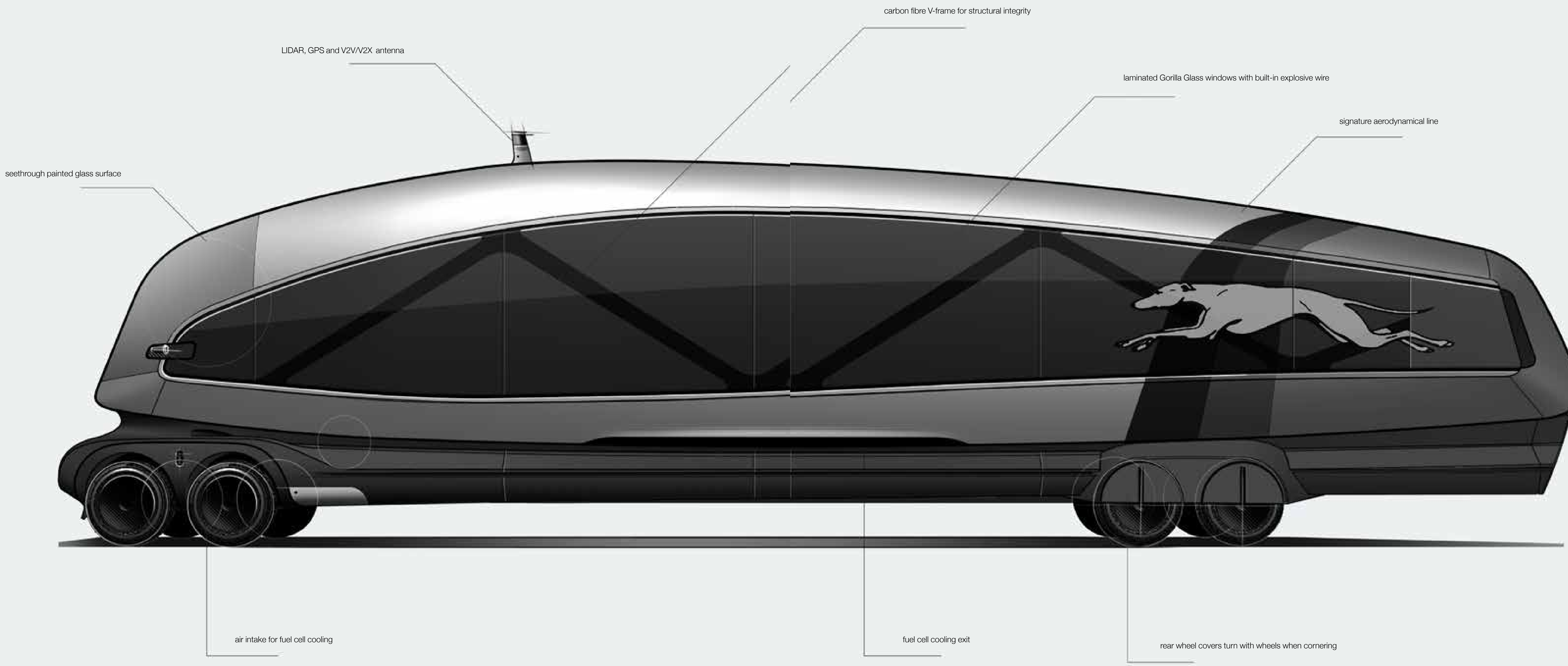


Fig.129: final concept drawing with fictitious Greyhound Lines, Inc. decals (Claus, 2014)

17.7 Exterior refinement

After determining the overall look of the exterior, the correct choice of details is as important a job as defining the first lines of a product. In this chapter the front and rear end are discovered.

17.7.1 Defining a face

Daniel Simon (2007): "Every vehicle needs a face to be acceptable to our eyes". The face largely defines the stance of a vehicle. A vehicle can look friendly, surprised, confident, angry, attacking, pretty much every emotion one can imagine is possible. The emotion coming from a car has a prominent role in the acceptance of a vehicle.

Author's thoughts: "For the Next Generation LDC, I wanted a face which expressed a sense of confidence and mystique. My first experiments mostly resulted in angry faces (B and C), whereas later, things evolved to more friendly and neutral faces (A, D and E). It was up until the very last weeks into the SolidWorks modelling phase that a face with an acceptable stance emerged (F). In the final proposal, the headlamps are hidden in a splitline between to panels, rendering them invisible when the vehicle is parked. The daytime running LEDs will have largely the same shape as the full beam lights, so the main face is contained in every situation. To me, the subtle yet arrogant stance was a fine addition to the concept."

Fig.130: different 'face' proposals (Claus, 2014)

17.7.2 The rear end

Identical to the process applied with the front end, the rear end light design was explored by means of simple rear view sketches of the vehicle. Each time, different light features are proposed onto the the rear view. The rear end defines the vehicle to a lesser extent than the front, but remains nonetheless a key characteristic in defining the overall stance of a vehicle.

Author's thoughts: "For the rear end, I wanted to continue the stance that was defined for the front end: a mystique lighting feature that is unmistakably part of the overall bodywork sculpture, but with an interesting twist to it. First iterations (B, D) resulted in lighting proposals analogous to some of the sketches from the early design phases. C and E did not pack enough punch to be considerable. A and F were most fit to the design philosophy for the stance of the coach."

Fig.131: different rear end proposals (Claus, 2014)

18 Design verification

During the designing process, the interior space volume, aerodynamics and the turning circle are shortly evaluated and verified. This verification links back to all previous chapters and makes sure the design remains on track to qualify for all the goals set from the beginning.

18.1 Interior space volume

The vehicle packaging concept discussed in chapter 15.2 defined a minimum passenger space volume. After the exterior design was complete, it needed checking whether the final design can accomodate the fixed number of 46 seats, the Adaptive Entrance, a toilet and the luggage room. The vehicle package was quickly drawn in 3D, after which it was inserted into the 3D model of the finalized concept. The seats as well were fitted into the model, according to the arrangement defined in chapter 15.2.

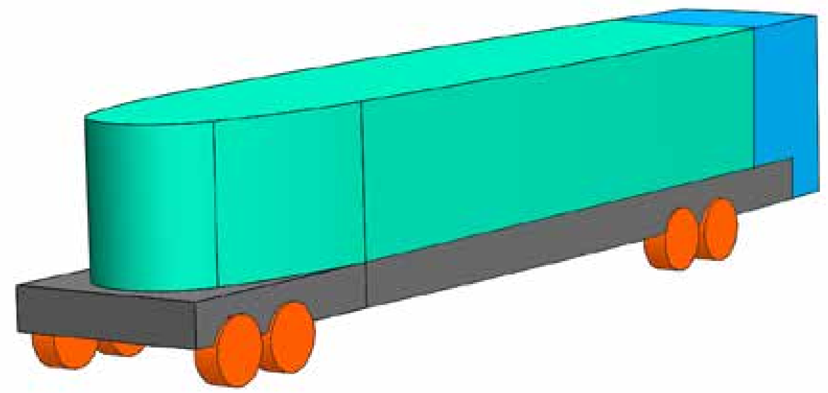


Fig.132: coach volume model (Claus, 2014)

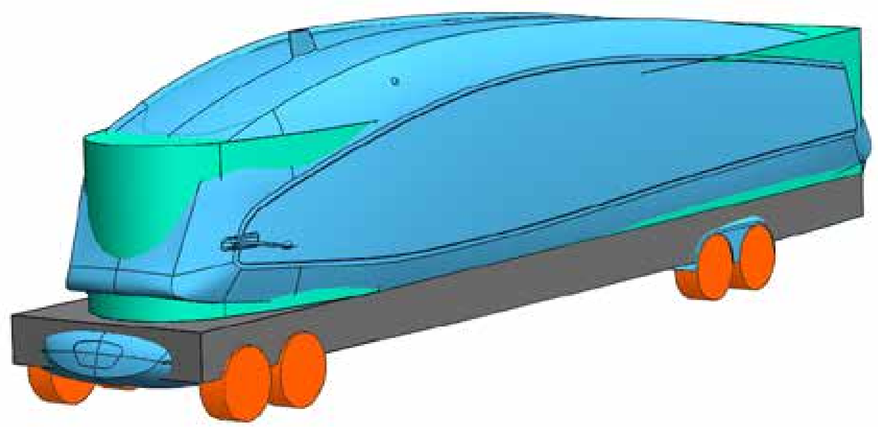


Fig.133: overlay of the coach volume model and the final exterior design (Claus, 2014)

18.1.1 Interior space volume verification

Overlaying the 3D coach volume model with the 3D model of the finalized coach concept quickly revealed areas that would need attention when the concept would be further developed. It is seen in the bottom left picture on the previous page that at the front and the rear of the vehicle, the volume model exceeds the boundaries of final the model. This is, however, not a big issue as these zones are not areas in which people will be standing upright. In fact, the protruding areas are zones in which the dashboard is located (front), seats are positioned (rear) and the luggage room is installed (back end).
Looking at the model overlap with the seats fitted, attention must be paid to the last two rows of seats, as they are slightly sticking through the surface of the model. Further examination of the model proved this was a SolidWorks related error due to a faulty mate combination. A quick fix resolved the problem without affecting the contemplated arrangement and available interior space.

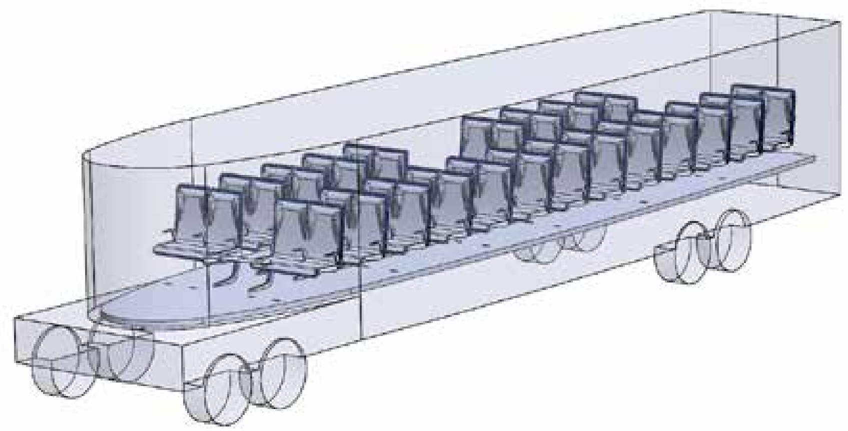


Fig.134: coach volume model with seats(Claus, 2014)

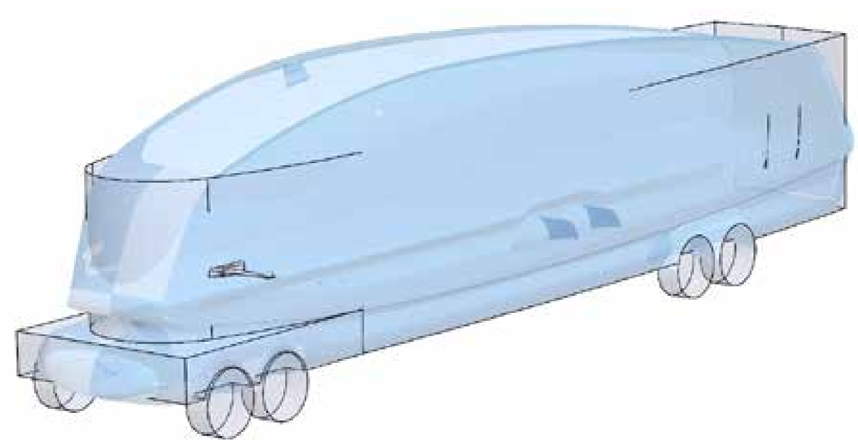


Fig.135: overlay of the coach volume model with seats and the final exterior design (Claus, 2014)

18.1.2 Conclusions on interior space

Virtual verification volumes confirmed that the predefined interior volume figures comply with the final stage of the concept's bodywork. The next step is to check whether the new body shape aerodynamically performs as desired.

18.2 Aerodynamics

As part of the design verification, a brief study on aerodynamics is conducted, using SolidWorks Flow Simulation. This study targets to identify whether the new 2030 body shape generates a more efficient airflow than current day coaches. To meaningfully come to a conclusion on the subject, a VDL Futura FHD2-122 was pitted against its 2030 counterpart in the virtual SolidWorks windtunnel. Due to the limited amount of time available for this project, only a frontal negative airflow will be examined. For a completer view on aerodynamical performance, crosswinds would have to be taken into account.

18.2.1 Simulation set-up

Both models were tested using the same method: an external SolidWorks Flow Simulation on a selected geometry, in this case a self-made model of A) a VDL Futura FHD2-122 and B) the Next Generation LDC. Standard air temperature and pressure were maintained for both simulations. The VDL Futura FHD2-122's cruise speed is around 90 kph or 25 m/s, hence the model was tested at this velocity. The optimal cruising speeds for the Next Generation LDC is expected to start from speeds around 120 kph or 33.33 m/s. The 2030 concept was thus tested at 33.33 m/s in longitudinal direction. For reference and double checking, the concept was also tested at 25m/s. The result of this second test were in accordance of the first simulation, and are not visualized in this document. A boundary condition (real wall) was set for the surface: an asphalt road (16 micrometres).

18.2.2 Comparison

The final Flow Simulation test results marked a visible difference between the two models. Relying on the graphical test result

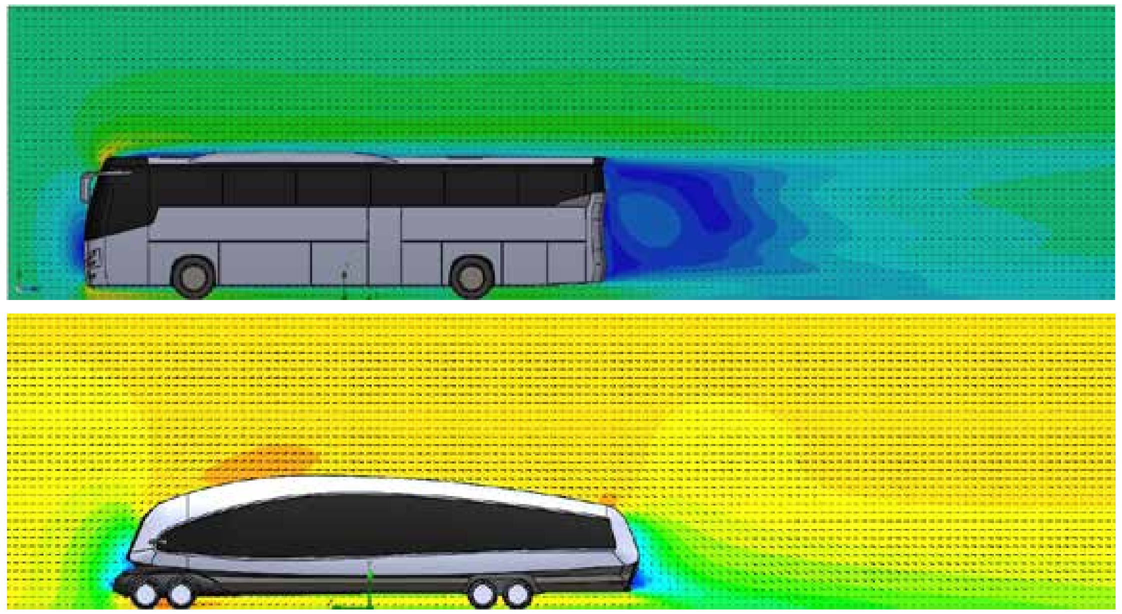


Fig.136: comparison between CFD wind tunnel results between old (above) and new (below) (Claus, 2014)

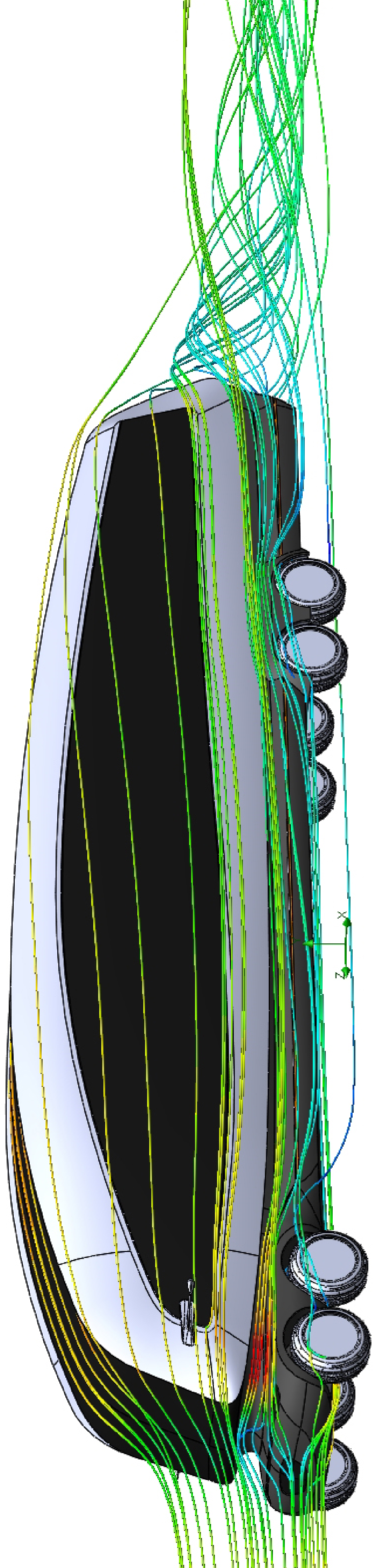


Fig.137: Flow Simulation visualization of airflow at 120 kph (Claus, 2014)

images, the 2030 concept (second image) has a drastically reduced wake and turbulent area behind the vehicle (bluish zones). Less turbulent air signifies a drop in aerodynamical drag, from which energy consumption benefits a great deal.
At the front, the blue turbulent zone with slower moving air is also reduced in size, compared to the 2014 VDL model.
As the 2030 concept is somewhat wing shaped at the cross-section, it will have to be investigated whether any lift force is acting on the model. If this should be the case, additional spoilers will have to be installed, diminishing the positive effect of the aerodynamical shape. The investigation of this potential problem was, however, well beyond the scope of this design verification and will not be discussed any further.
Looking at the test result data, it became apparent that the 2030 concept is about 30% more efficient in terms of aerodynamical drag, compared to the 2014 model. This figure of 30% will probably be corrected to something around 25% in the real world, as Computational Flow Dynamics are real sensitive to the slightest change in mesh settings.

18.2.3 Conclusions on aerodynamics

When it comes to compairing the claims made by MAN concerning their ConceptS and KRONE AeroLiner (up to 25% increase in aero efficiency), it can be concluded that the Next Generation LDC concept is in the same efficiency-league. Looking at the graphical displays of the airflow around the concept, it is safe to conclude for now that the 2030 concept's aerodynamics performed as anticipated.

18.3 Turning circle

The final design verification is there to check the turning circle, and if it remains within acceptable limits compared to the current day situation.

18.3.1 All-wheel steering

To ensure an optimal turning circle and to improve the agility and maneuvrability of the coach, all wheels can steer independently. Due to the steer-by-wire system, no mechanical connections are needed to steer the wheels: a simple electrical actuator suffices. With all eight wheels having a maximum steering angle of 45 degrees, a turning circle of 16.8 metres is obtained. Compared to the VDL Futura FHD2-122, which has a similar length as the concept and a turning circle of 20.5 metres, the turning circle is improved by 3.7 metres. Moving the rear wheel assembly further backwards would enhance the turning circle even more, yet this was not feasable for the 2030 concept, as the rear overhang is needed for the housing of the luggage room and the waste container for the toilet. The front wheel assembly is shifted to the front to create enough space for battery packs or hydrogen tanks.

18.3.2 Conclusions on turning circle

The all-wheel steering enables the Next Generation LDC to have a shorter turning circle than today's coach with comparable dimensions.

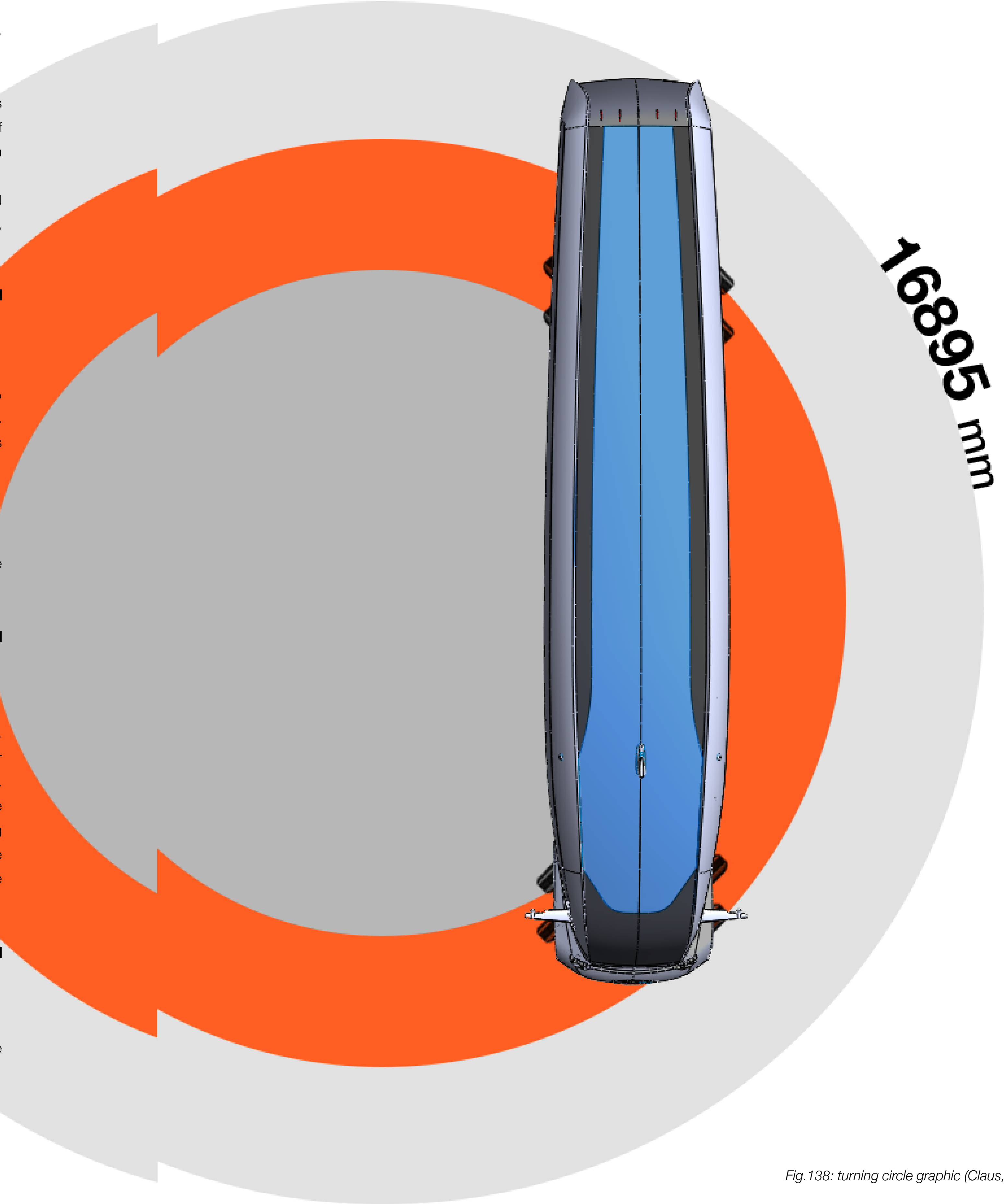


Fig.138: turning circle graphic (Claus, 2014)

19 Materialization

The final design was verified in the previous chapter. This chapter, an impetus to final materialization is proposed: the chassis and bodywork superstructure will be assessed, together with an overview of the assembly of the coach. A final chapter is dedicated to the seats.

19.1 Chassis and bodywork

From the NPP chapter, we learned that the future will bring multifunctional materials which will cause vehicles to become increasingly lightweight, without compromizing on any rigidity on the contrary. This chapter will elaborate on how the chassis and bodywork of the Next Generation LDC will be perceived in order to accomplish a lighter and more structurally capable vehicle.

19.1.1 Sandwich panels

Sandwich materials are yet well established in aerospace and marine industries. Techniques are at the brink of a breakthrough in the automotive sector. Sandwich panels are already being utilized by VDL for their latest Futura coach: side panels and the entire roof are made out of sandwich material. The panels are prefabricated on location and are bolted and glued together in the final stages of coach assembly.

Aluminium composite material

Cook (2003): “Sandwich structures offer significant advantages over traditional monolithic designs. These advantages can be attributed to high flexural stiffness-to-weight ratio for sandwich materials. This superior flexural stiffness results in smaller out of plane deflections, higher buckling resistance, and higher natural frequencies, which enhance structural performance. Hence, for a known set of loading conditions superior performance can usually be obtained by using a sandwich structure that is lighter than the traditional structure.” Sandwich panels are best known as ‘aluminium composite material’ (ACM). This material, often produced in large, flat panels, consist of two layers of aluminium and a non-aluminium core, which are glued and/or sewn together to form a solid bond.

Vacuum Assisted Resin Transfer Molding

Flat ACM panels are produced by pulltrusion. The three material layers are pulled through a machine, which glues and sows the material together. The core material is often a 3D structure like glass fibre, which prevents delamination of the material. However, this way of manufacturing the panels only allows for extruded panels, whether or not with a cross-section profile. Vacuum Assisted Resin Transfer Molding (VARTM) can offer a solution to this issue: this closed-molding technique works with a vacuumized mold. JHM Technologies (2014): “The composite is molded using a rigid mold to provide part geometry and a thin flexible membrane over the fiber, with outer atmospheric pressure compressing the fiber tight against the rigid mold surface.”

Conclusions on sandwich panels

Advantages for using ACM are numerous: good thermal insulation properties, non combustible, excellent acoustic performance, reliable mechanical performance, and the ability to select numerous colour finishes (Rockwool, 2014). ACM can help future mobility towards increased energy consumption and rigidity. Once the manufacturing process costs have been minimized, the VARTM technique will prove to be the solution for mass produced double-curved sandwich panels.

19.1.2 Superstructure

Both the chassis and bodywork are constructed from ACM and are ultimately combined to form a ‘superstructure’. This radical new way of structural architecture provides the coach with an unprecedented stiffness-to-weight ratio.

The chassis

The chassis is most similar to a life size DIY-kit. Constructed from flat ACM panels, each partition or structural element is laser cut from a thick piece (15 cm) of sandwich material. The separate components are then glued together to form the chassis of the vehicle. The space between the partitions is reserved for the housing of battery packs or hydrogen tanks, depending on the chosen drivetrain configuration.The top panel of the chassis is in fact the passenger floor and doubles as the mounting point for the upper structure to be fitted on. The image below clearly shows the double sandwich floor, made from ACM panels. At the front, the lightweight carbon fibre reinforced suspension assembly, which is bolted onto the chassis. The suspension assembly bears the majority of the load forces, instead of transferring them to the chassis. This way, the chassis can be made out of thinner ACM panels, which the total weight of the vehicle will benefit from.
More images on the chassis can be viewed in chapter 20: Overview.

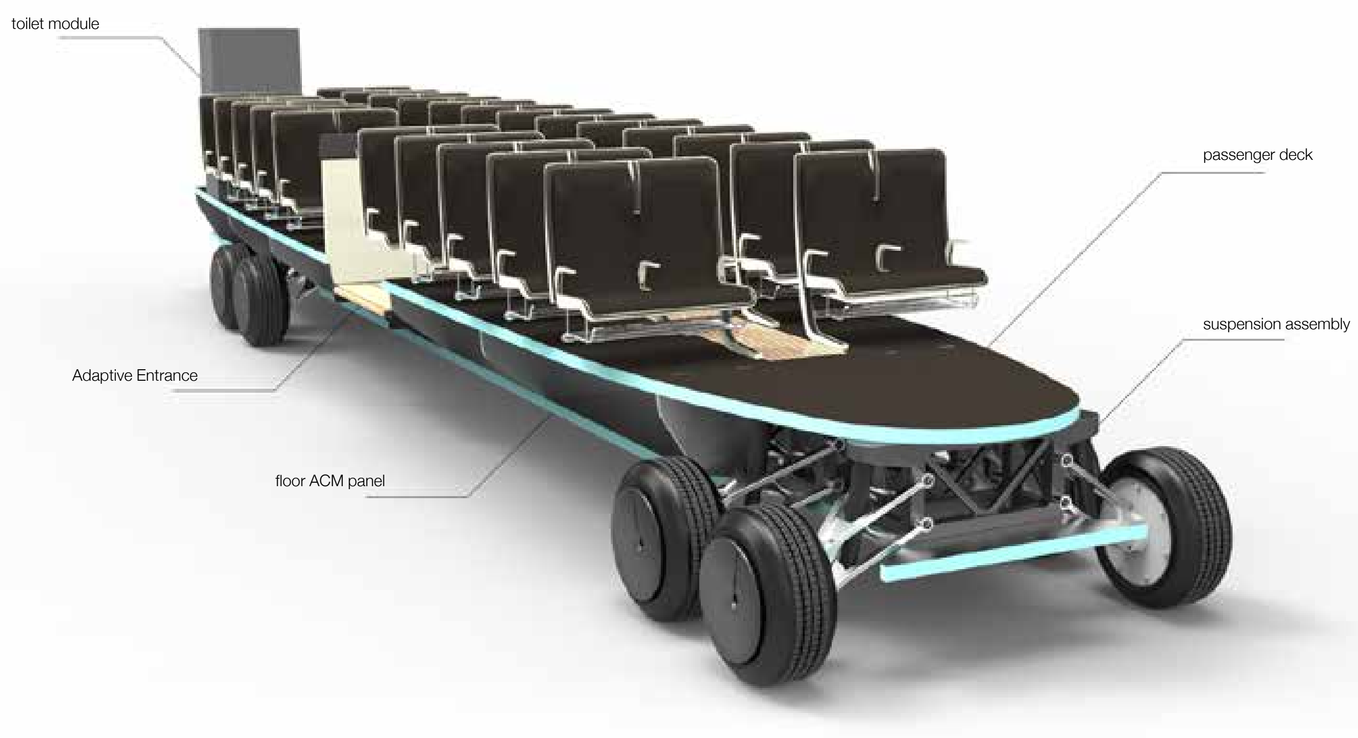


Fig.139: Next Generation LDC chassis rendering (Claus, 2014)

Bodywork and windows

The bodywork of the upper structure housing is made out of VARTM produced ACM panels. The panels are constructed in different phases, after which they are glued and welded together to accomplish a seamless piece of bodywork. A special feature is the V-shaped carbon fibre frame which is glued between the windows. The glass area is in fact a sandwich structure on its own and does not diminish the structural integrity of the vehicle. This clever solution is yet again an innovative way for lowering the total gross weight of the vehicle.

Emergency exits

The Design Drivers for Safety stated that the windows should be used as it is today: they function as exit ways whenever an emergency has occured. Another innovative feature was thought up to tackle this issue: along with the V-shaped frame between the two glass layers runs a resistive wire. In case of an emergency, a high voltage is put through this wire, causing it to heat up quickly. This rapid change in temperature causes the windows to fracture and ultimately break. The windows are laminated Gorilla Glass, a lightweight and scratch resistent glass used mainly in smartphones these days. Gorilla Glass is an alkali-aluminosilicate sheet toughened glass manufactured by U.S. glassmaker Corning Inc.

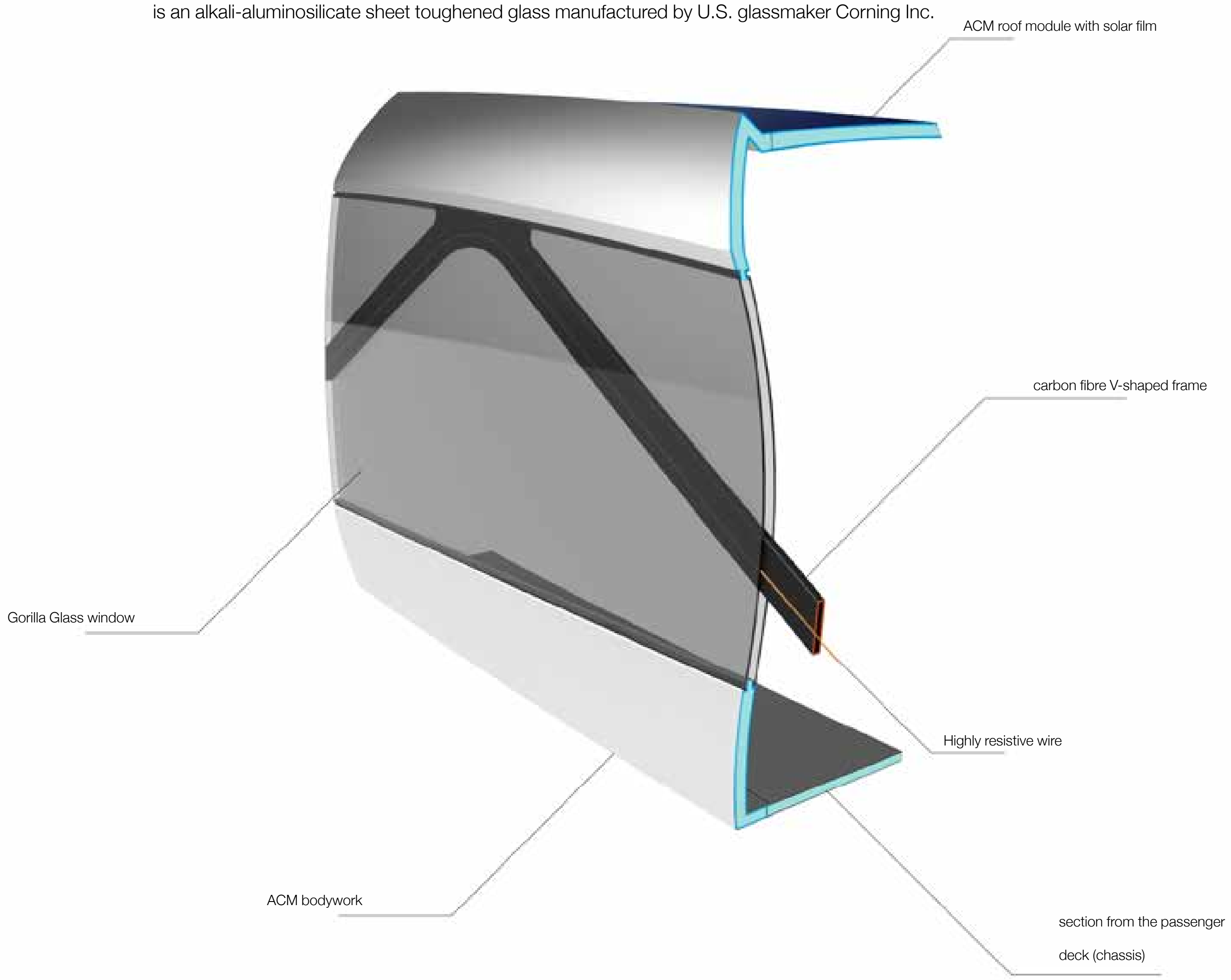


Fig. 140: cut-out section of the concept's hull (Claus, 2014)

19.1.2 Assembly

VDL Bus & Coach has a unique and innovative way of assembling their Futura coaches. Much like the Next Generation concept, the Futura coaches' exterior panels are seperately assembled from sandwich panel modules, which are put together after the chassis has been completed and the seats bolted on. This way, coach assembly happens faster and more economically.

Final assembly

The roof (including wind shield, solar panels, airconditioning, skylight and antenna), complete side panels and chassis are seperately constructed on location. In Final Assembly, all prefabricated modules are brought together: the naked chassis (inclusive carpeting and wooden inlays) is fitted with seats, which are positioned in-place with an overhead crane, capable of transporting all seats simultaneously. The second phase is the mating of the chassis and side panels. When all lines up correctly, the roof is added to the assembly. During the third assembly phase, the drivetrain (WPT or fuel cell) is installed into the designated chassis space. These components come in trays which are shoved into the chassis slots. The trays are prefabricated modules as well, containing batteries or hydrogen tanks plus one side of the vehicle's underbody (see next pages).

Fig. 141: vehicle assembly overview: Second Phase (Claus, 2014)

Battery trays

On the image below, a WPT Buse 125-150 is in the closing stages of Final Assembly, where the battery packs are being installed and connected. By design, the batteries are placed in trays, which can slide out of the vehicle's underbody on four rails. This enables quick changing of batteries when a module malfunctions or exceeds its durable lifetime, without having to partially deassemble the vehicle. The trays are locked with two bolts on the underside of the vehicle, which can be accessed by a mechanic using a special tool. The analogous fixture - instead of having an electrical lock - of the trays makes sense as the electrics on the vehicle must be cut off completely when accessing the battery packs, to avoid electrocution of mechanics.

For the fuel cell version of the coach, the maintenance principles are mostly the same: the hydrogen tanks are then fitted into the trays instead of batteries. For refuelling, the tanks do not have to be revealed from the underbody: a simple fuel filler is provided on each side of the vehicle.

The tray system offers a neat solution for retrofitting or upgrading the vehicle with newer or better parts during its lifespan.

Toilet module

The toilet module, located in the back right of the vehicle, is inspired from the systems used on airplanes and modern day yachts. Vacuum toilets combine ease to use with an unprecedented energy efficiency, using up between 6 to 8 Amps per flush (Dometic Group, 2014). According to the manufacturer, this would be less than 75% of the energy used by standard electric toilets. Another benefit from using this type of flush system is the absense of stench, which often accompanies the classical chemical toilets. The components for the toilet (a vacuum pump and holding tank) are situated in a tray underneath the toilet module. For cleaning out the 30 L holding tank, the tray is electronically unlocked by the Buse crew, so that the tank is accessible for emptying.

Conclusion on assembly

The extensive modular architecture provides a fast and economic assembly process and easy component maintenance. Cost of ownership and upgradability greatly benefit from this design philosophy, which combines smart design with low weight, costs and efficiency.

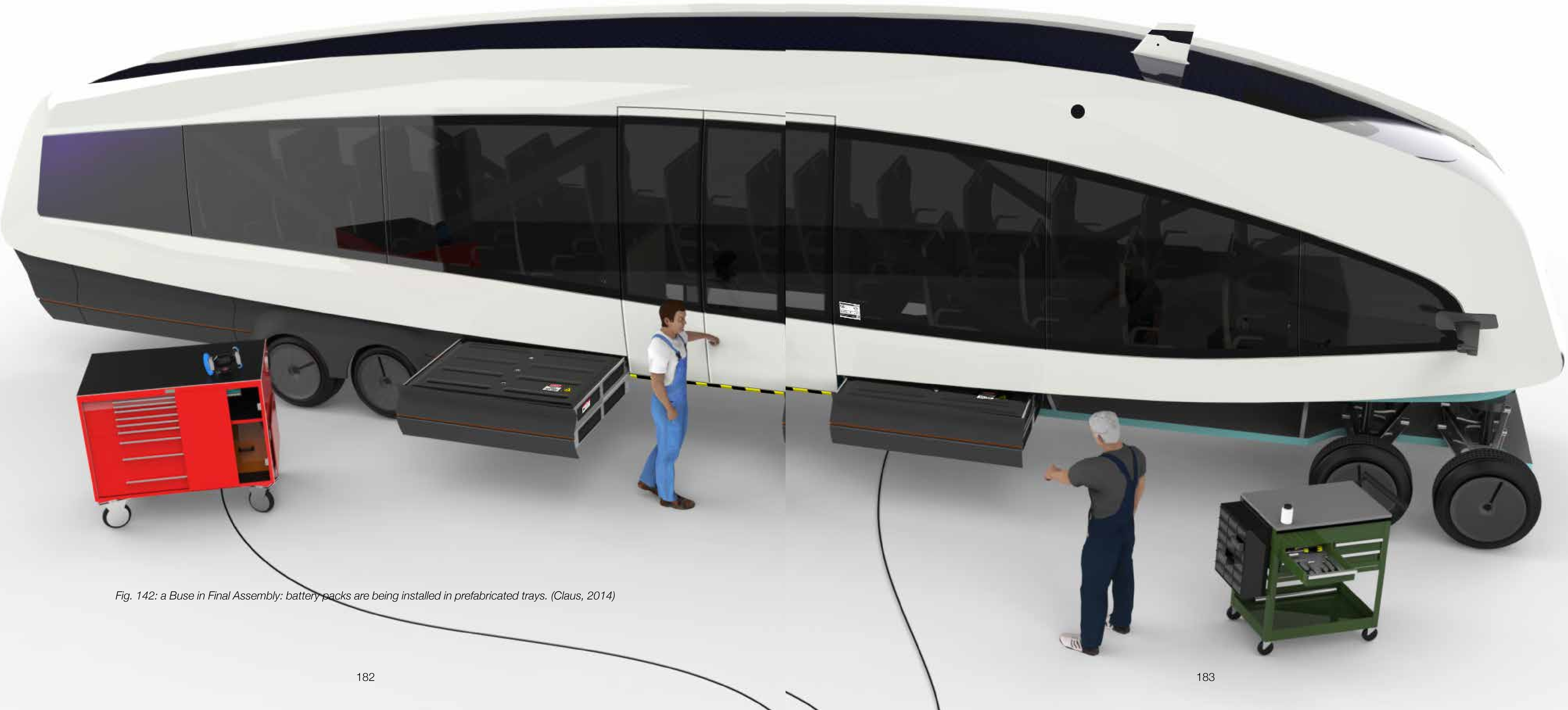


Fig. 142: a Buse in Final Assembly: battery packs are being installed in prefabricated trays. (Claus, 2014)

19.2 Seats

The final seat design is a respectful interpretation of a two-seater configuration of the original Morph seats by Seymourpowell. The selected colour scheme was chosen in order to give the coach concept a classy interior with a great sense of luxury, without having it feel old-fashioned. Dark brown fabric nicely contrasts with the shiny dark umber plastic details.To maximize the use of available space in the coach, each seat is fitted with a stainless steel rack mounted underneath the seating frame. The rack doubles as a luggage compartment and foot rest. The design of the rack - a wink to vintage coaches from the Golden Age - is conceived in a way that each passenger can use the rack mounted on the seat in front of him/her. Underneath each seat, a mood light is positioned. This mood light provides sufficient light so that passengers can see in the dark, and can be switched on or off in the settings screen of the passenger's seat. The luxury version of the seats feature two OLED wide screens, from which passengers can access the Entertainment System to watch a variety of movies, listen to music, surf the web, adjust seat configuration or personal cooling/heating, track the trip on GPS, and much more. The seats are equipped with 2 stereo speakers, for when a group of people is watching the same movie. It is, however, possible to enjoy a movie or music with headphones, in which case the headphones connect wirelessly with the coach's Entertainment System. Under the screens are two folding tables, large enough to hold a 2014 Microsoft Surface Pro tablet computer. It is plausible that, by 2030, every person will have access to a smart device. This is why the Entertainment System can be accessed from such device while on board, so passengers can wirelessly stream and enjoy their content to the desired device. The streaming function is a neat option for coaches without luxury seats: the Entertainment System is still available, even without the built-in screens.

Fig. 143: concept seats for the Next Generation LDC (Claus, 2014)

20 Project overview

The conclusion to this project is summarized in this chapter. This file bundles the research and thought process for the development of a coach concept for 2030 and beyond. The aim was to generate a concept vehicle that would inspire an entire industry, both technically and design-wise. The project started with an extensive multidisciplinary analysis of ‘the coach’, what can be expected in the future for society, coach use(rs) and technology. Results from this analysis were pitted against future trends and developments, which ultimately led to the formulation of four Design Drivers (Zero-Emission, Efficiency, Safety and Accessibility). These Design Drivers drove the System Design phase, and the final Product Design afterwards. Product design was utilized to showcase future trends and breakthroughs, as a concept is expected to do: far from being production ready, it enables the audience to fantasize and get carried away to a time and place in the near future, where anything is possible. The concept is a showcase for technology and innovation, and should be assessed accordingly, with the initial intentions in mind.

First, some background information on the name of the Next Generation concept is provided. After that, the project is reviewed per Design Driver, highlighting the coach’s functionalities, innovative features and most beautiful angles.

20.1 Buse

20.1.1 Origins of name

Every vehicle has a name, and so does this Next Generation concept. During the year, the project was often dubbed or codenamed ‘buse’ by the author and insiders. In the end, the decision was made to stick with the name for the final proposal. Although the NPP research in the beginning of this thesis uncovered the term ‘bus’ to be incorrect for this type of vehicle, the word is so often popularly misused that it really does not matter much. Although the name initially sprouted from an inside joke, some half-baked meaning can be derived from it: the additional ‘e’ after the word ‘bus’ can be explained as a reference to the full electrical architecture of the vehicle. Instead of putting this ‘e’ in front of the word, as is the custom these days, putting it after the main word is something one does not come across very often.
In French, ‘buse’ means ‘buzzard’. This is why the animal is the mascot of the coach. Buzzard Buse stickers are optional with the purchase of the coach.

20.1.2 Full designation

The full name of each vehicle indicates the type of vehicle. In this thesis, two types of Buse coaches are discussed: one with WPT power train and one fuel cell powered vehicle. The WPT variant has ‘WPT’ in front of the name, whereas the fuel cell model has HCell - from Hydrogen fuel Cell - in front of the name. The numbers after ‘Buse’ indicate the length of the vehicle in decimeters (125 dm) and the output power of the selected power train (150 kW in both occasions). This provides the full names of the proposed products: WPT Buse 125-150 and HCell Buse 125-150.

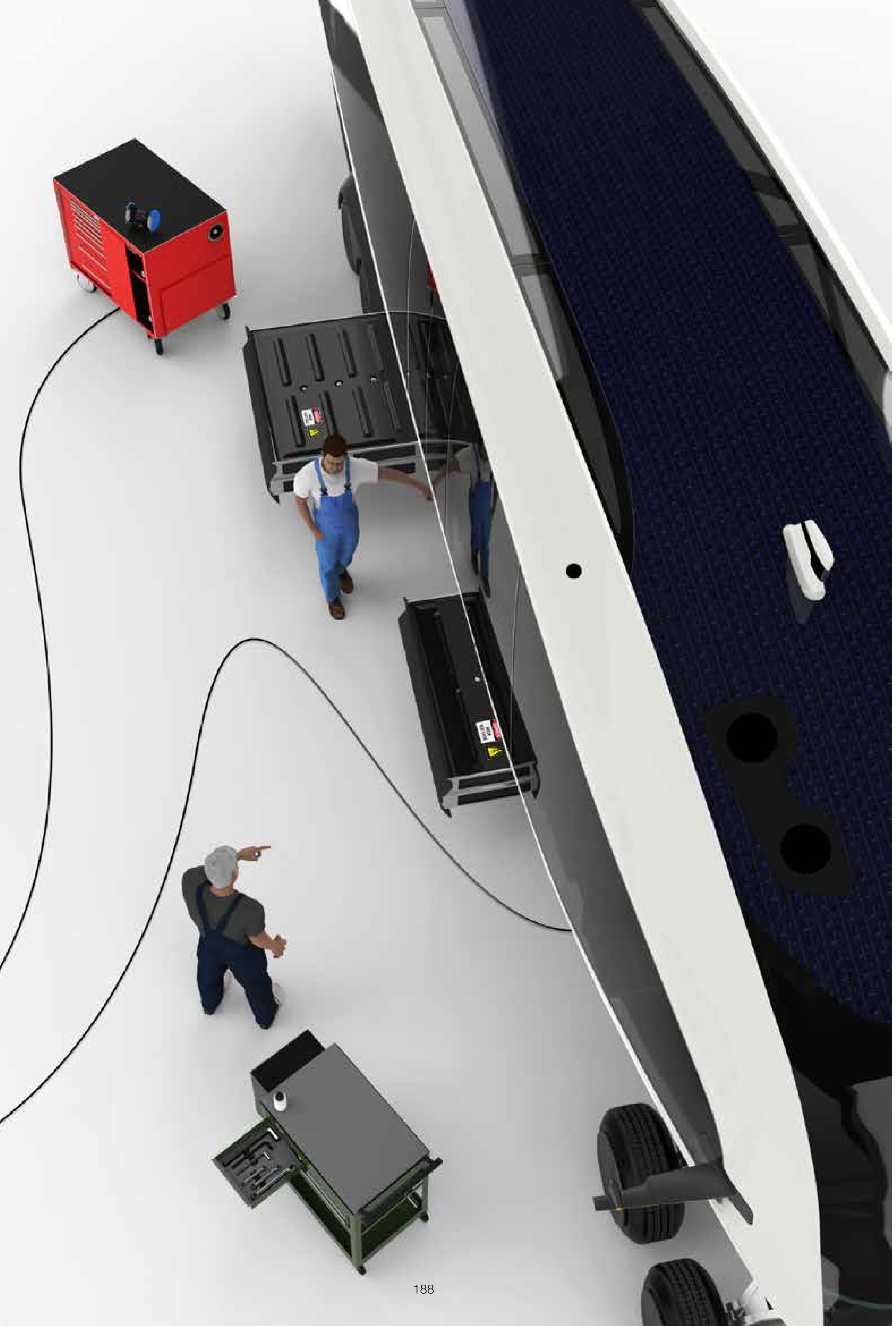


Fig. 144: a birdseye view of a WPT Buse in the works, the battery pack trays visibly exposed (Claus, 2014)

20.1 Zero Emission

In 2030, the focus on environment and renewable energy sources will be omnipresent. Cities will ban the internal combustion engine (ICE) and welcome pollution-free zones. The introduction of worldwide infrastructure for electric and fuel cell vehicles will result in an increase of hybrid-electric or full electric vehicles. This coach concept keeps up with the times: a choice between either full electric and fuel cell electric provides an increased profit of ownership during the lifespan of the vehicle. Both drivetrain technologies have proved to be more efficient and more durable than its ICE counterpart.
For the battery packs or fuel cell hydrogen tanks, a modular architecture was perceived in order to lower manufacturing costs. The energy components are located in trays, which are positioned within the sandwich floor of the vehicle. A sheetmetal casing ensures the components are easily fixed in place or can be changed rapidly if needed.

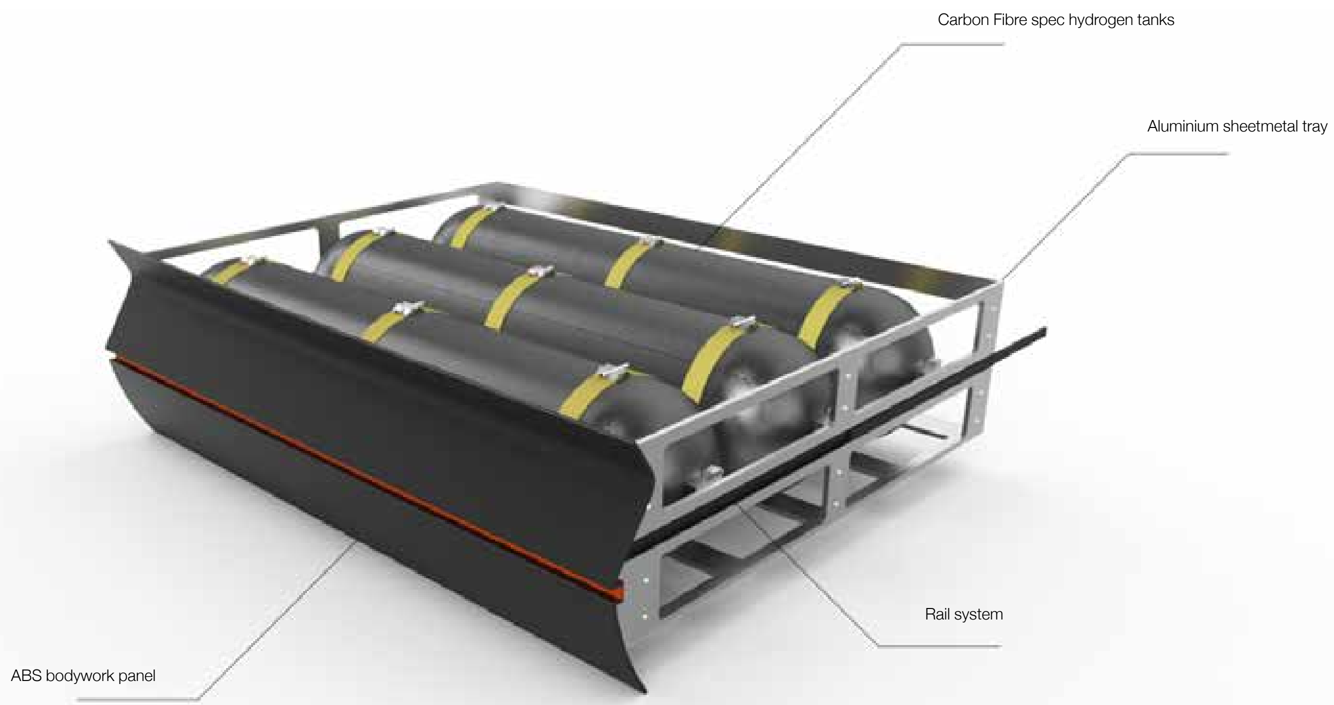


Fig. 145: a sole hydrogen tank tray (Claus, 2014)

20.2 Efficiency

Wouldn't you be left standing in awe, face to face with this machine? Everything about the Buse screams 'different'. Different thinking about current problems resulted in solutions that are miles ahead of the competition.
A radical new exterior design lead to a vehicle which is up to 25% more efficient compared to its current-day counterparts. All in all, it is not too difficult to see why: placed next to a 2014 VDL Futura FHD2-122, the streamline and seemingly small volume - while maintaining the same interior space - is nothing more than remarkable. The Next Generation concept has the same standard width as the old model (2 550 mm), but is 40 cm less tall. In terms of weight, the Buse has 4 tonnes less to carry around compared to the Futura. The decreased weight, combined with the efficient aerodynamics and low resistive tires add up to a significant improvement in the area of power consumption.

On the image below, we see a WPT Buse 125-150 parked next to a VDL Futura FHD2-122. Both coaches have a comparable length and passenger capacity.
On the bottom of the Buse, the extended WPT module can be seen. In this position, the coach can recharge its batteries wirelessly through magnetic resonant coupling.

Interesting to note on this image is the all-wheel steering of the coach concept in action.

Fig. 146: a WPT Buse 125-150 compared next to a VDL Futura FHD2-122 (Claus, 2014)

Father and child sharing a seat module: both pay according to the amount of booked comfort.

To improve capacity efficiency, the coach is fitted with transformable seats. These seats provide travellers with options on how much space and comfort is paid for. As shown on the inset picture, a parent could share seat with his child, deviding the seat according to their bodies' sizes. More seating space will cost slightly more than a regular seat. This is a valuable option for travel agencies or coach companies that offer regular trips, but struggle to operate at full capacity: by having travellers pay more for one seat, the loss of not having all seats paid for is somewhat compensated.

The image below: the interior trim with yacht deck finish provides a classy yet modern atmosphere. The overhead luggage compartments are replaced with luggage racks underneath the seats, giving the interior a more spacy feel. This sense of open space is amplified by the enormous glass surface of the side panels, which make you forget what it was like to travel by old school coach. Moodlights underneath the seats set an ambient mood and replace the individual lighting features on the overhead console of old coaches.

Fig. 147 and 148: seat configurations and a cut-out revealing the interior of the coach (Claus, 2014)

Fig. 149: Next Generation LDC alongside a BMW i8 concept (Claus, 2014)

20.3 Safety

Every aspect of the Buse is designed with safety in mind. Clear your mind in the knowledge that your family, children or even yourself are safe no matter what. Because 2030 will be a transitional period in terms of automotive safety legislation, the coach is safe both structurally and electronically.

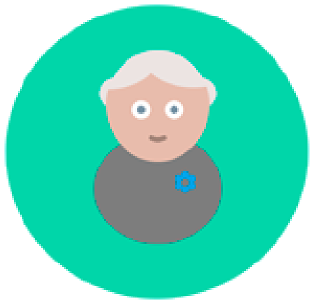
What is most striking at first glance is the protruding nose coming from under the superstructure of the vehicle. This nose covers a crumble zone which is designed to protect the driver in case of a frontal collision. The entire bodywork and chassis are made of lightweight yet rigid composit materials, which have been glued together to provide maximum structural stiffness. All around the sides of the coach, orange reflectors with built-in LEDs make sure the vehicle is visible in any wheather condition or at night. The headlights combine LED and laser technology, providing a clear high-beam to selectively illuminate the most important parts of the surroundings, and giving the vehicle a striking stance with the U-shaped day-running LEDs. The on board Artificial Intelligence 'Jeeves' acts as a driver assistent and guardian angel, featuring full Vehicle-to-Vehicle connectivity, driver monitoring capabilities and surrounding awareness. In case of an imminent hazardous situation, the computer will avoid collisions from happening, or will decrease the graveness of an accident with lightning fast reaction times- outdoing even the fastest reacting drivers. A whole shipment of sensors is installed to monitor the vehicle and its surroundings from every angle. The image on these two pages show a WPT Buse 125-150 alongside a BMW i8 concept car. Both vehicles are next generation concept cars and share the same vision as well as cutting edge exterior design.

The front of the vehicle is characterized by the prominent VDL logo. On the right of this logo, the lens for the laser housing can be seen. These lasers constantly check for traffic ahead. Working together with the LIDARs (roof and sides) and stereo camera in the windshield, the computer is able to anticipate traffic and react on other vehicle's behavior.
The voluminous A-pillar of the coach is in fact made from glass, with glossy paint coat to not disturb the lines of the exterior design. This was done as a measure to improve the driver's sight, as this seemed obstructed otherwise.
The wheels are provided with ventilated hubcaps, facilitating the cooling of the in-wheel motors.

Fig. 150 and 151: Next Generation LDC and VDL Futura headlight detail (Claus, 2014)

FUNFACT

The shape of the Next Generation concept's front superstructure A-pillar is a wink to the headlight design of current VDL Futura coaches.



20.4 Accessibility

By replacing each wheel of a conventional coach with two smaller ones, the passenger deck was able to be lowered by more than 50% compared to the 2014 VDL Futura FHD2-122. This provides a more improved step into the vehicle. To add to the ease of access, each Buse is fitted with the Adaptive Entrance assembly. The Adaptive Entrance enables an appropriate entrance solution to each occasion. The entrance can transform into a gangway, set of stairs or even a wheelchair lift. A wide door increases the perception of an open, accessible vehicle.

Fig. 152 and 153: Adaptive Entrance (Claus, 2014)

On the image below, the rear end of the vehicle is shown, featuring the hatch, leading to the main luggage compartment. This compartment has several racks on which luggage can be neatly stored by the Buse personnel. The idea is that travellers give their luggage to handling in coach stations or, when no station is available, let personnel cary their bags into the vehicle.

The inset picture shows a scene in which a boy in a futuristic wheelchair is lifted into the coach with the Adaptive Entrance. The operation is controlled by Buse personnel.

Fig. 154 and 155: Adaptive Entrance (Claus, 2014)

Passengers can enjoy a panoramic view from the inside..

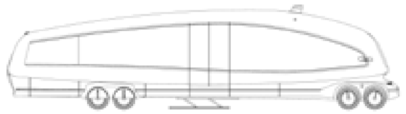
Fig. 156: Buse interior (Claus, 2014)

Cold on the outside, cosy on the inside. Yacht-style elements and ambient mood lights set the atmosphere.

Fig. 157: Buse interior (Claus, 2014)

21 Specifications

21.1 Technical specifications



Figures for the WPT Buse 125-150

Power train	
Peak power	16 000 Nm
Traction	2 first wheels per cluster of 4
Cruise speed	120 kph

Power consumption	
Est. average	110 kW
Est. highway	75kW

Battery	
Volume	5 800 l
Autonomous range	200 km

Solar panel	
Total size	12.8 m^2
Est. peak power	4.1 kW
Est. avg. power	9 kW

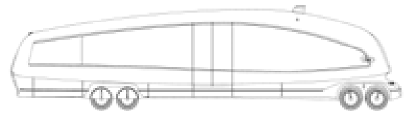
WPT	
Power	150 kW
Efficiency	>90%
Transfer distance	0 < 15 cm

Tires & wheels	
Tire	265/70 R19.5
Wheel size	19.5"
Turning circle	16.895 mm
Ride height	365 mm

Luggage compartiment	
Volume	4.5 m^2

Dimensions	
Length	12 526 mm
Width	2 550 mm
Height	3 285 mm
Est. max. weight (empty)	15 tonnes
Est. max weight (loaded)	22 tonnes

Aerodynamics	
Est. Cd value	0.4



Figures for the HCell Buse 125-150

Power train	
Peak power	16 000 Nm
Traction	2 first wheels per cluster of 4
Cruise speed	120 kph

Power consumption	
Est. average	90 kW
Est. highway	80kW

Hydrogen tanks	
Volume	5 800 l
Range	1 800 km

Solar panel	
Total size	12.8 m^2
Est. peak power	4.1 kW
Est. avg. power	9 kW

Fuel Cell	
Power output	150 kW

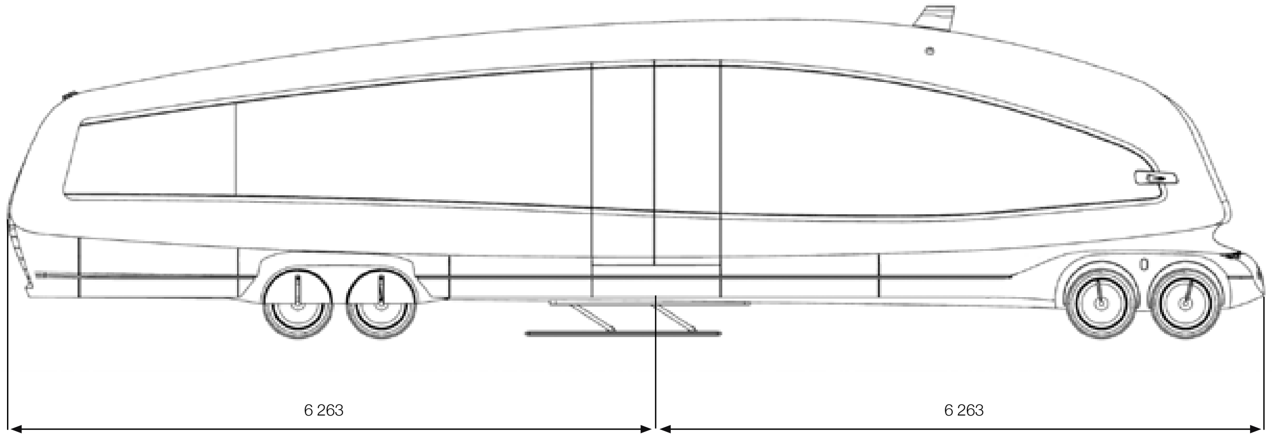
Tires & wheels	
Tire	265/70 R19.5
Wheel size	19.5"
Turning circle	16.895 mm
Ride height	365 mm

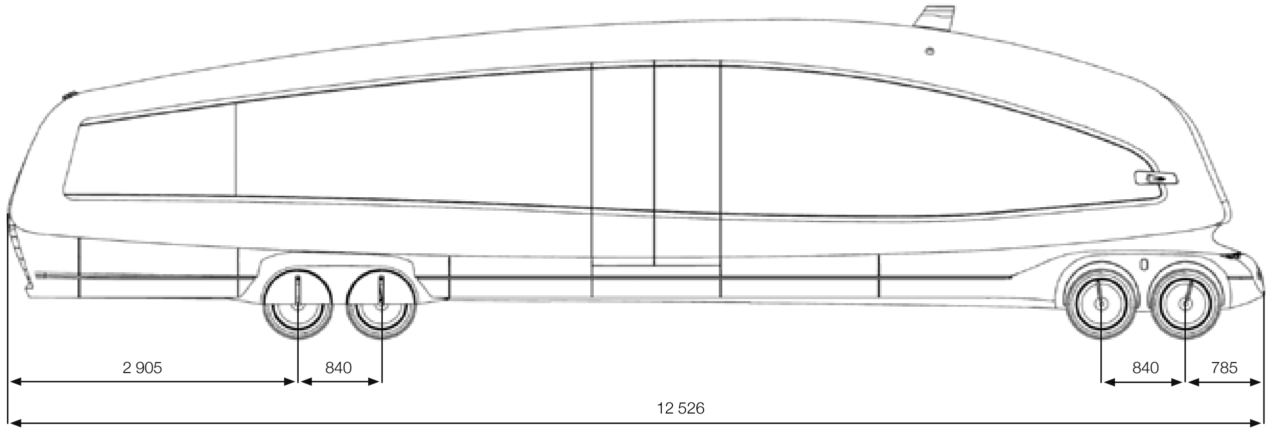
Luggage compartiment	
Volume	4.5 m^2

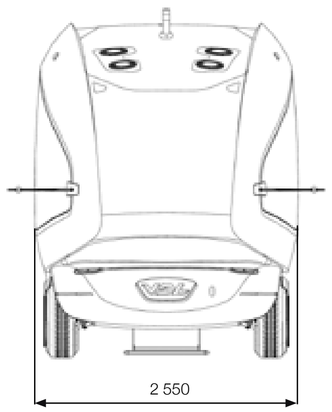
Dimensions	
Length	12 526 mm
Width	2 550 mm
Height	3 285 mm
Est. max. weight (empty)	12.5 tonnes
Est. max weight (loaded)	18.5 tonnes

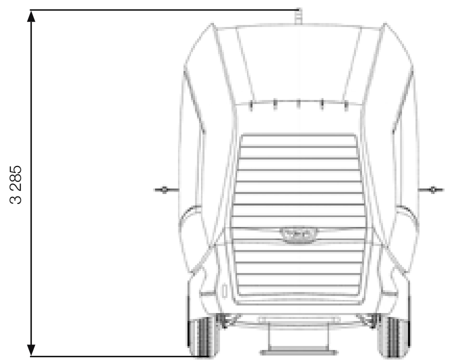
Aerodynamics	
Est. Cd value	0.4

21.2 Exterior dimensions









21.2 Dimensions overview

Figures for both the WPT Buse 125-150 as HCell Buse 125-150

Dimensions	
Length	12 526 mm
Width	2 550 mm
Height	3 285 mm
Front overhang	785 mm
Rear overhang	2 905 mm
Wheelbase	840 / 7 180 / 840 mm
Track	1 980 mm
Head clearance interior	1 950 mm
Turning circle	16 895 mm

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