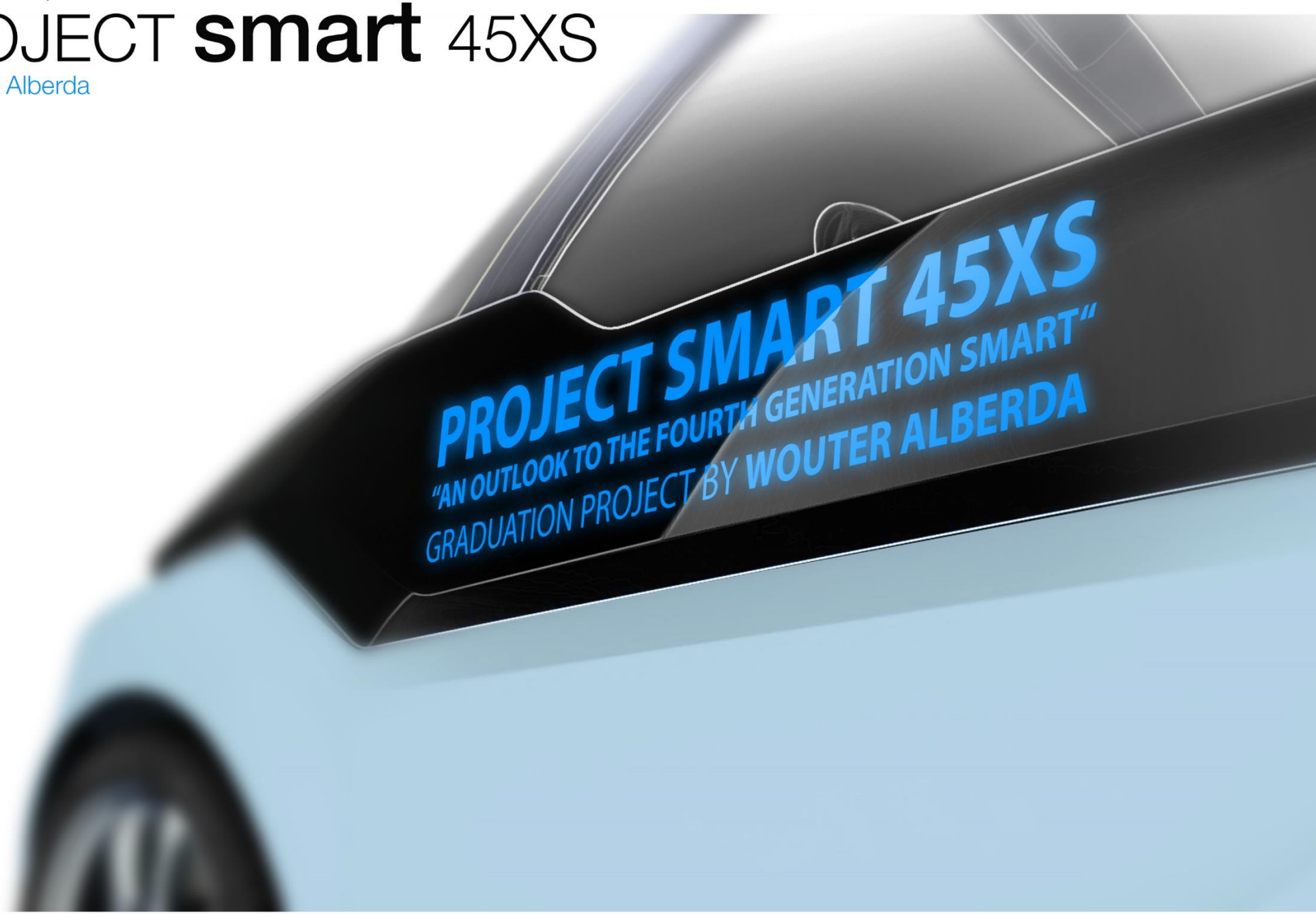
Graduation Report

PROJECT **smart** 45XS

by Wouter Alberda



supervisory team
Elmer D. van Grondelle
chair
Dr.ir. Sacha Silvester
mentor
Ir. Alexander Pothoven
company mentor

DAIMLER smart TU Delft

Preface

An incredible educational experience and an amazing time. If I had to summarize the last eight months I spent at smart in one sentence that would be how I'd say it. I feel extremely lucky to have shaken hands with the makers of the smallest car on the streets and doing this project for the Daimler-owned brand.

Although I have had interest in cars for quite some time and know a thing or two about them, each new thing I learn makes me realize how much there is yet to learn. When I started at smart, it quickly became clear that indeed I wasn't done learning, by far. Fortunately I am an open book, because the amount of stuff I could learn from the team was overwhelming. In a positive way of course, because it has offered me the chance to experience the actual car industry.

I learned about the graduating opportunity at smart via my friend Olaf Kampinga and eventually got in touch with Alexander Pothoven, chief of the Overall Design and Package team at the 'smart Entwicklung Konzepte' department. After our 'Kennenlernen' conversation I knew this was a great opportunity to show my skills as an Industrial Design Engineer from the TU Delft, and learn some German while at it.

I was very happy to accept the challenging assignment that smart offered me, since it covers almost each aspect of the car design; a true integral design project. The great colleagues I could work with taught me all about the aspects of safety, packaging, styling and the entire smart philosophy. The energy and open-mindedness of the team made a very pleasant and stimulating environment to work in.

I would have to admit that I did not know an awful lot about smart before I started my graduation, but I have come to respect it much more than I had foreseen. The coolness of driving a smart – especially a BRABUS or electric drive – and the complete philosophy behind the car has really impressed me and made it even more enjoyable to work on a future generation myself. I had great fun in developing my concept and I believe that I succeeded in creating a concept that clearly has smart-DNA, but also a little DNA of my own.

I am very thankful to all those who supported me during this project, without whom I could not have realized this project. In the first place I'd like to thank my company mentor Alexander Pothoven for all the energy, effort and limitless enthusiasm with which he supported me. Alexander has been a teacher, motivator and mood-setter like no other and he truly made me part of the team.

Next I want to thank my supervisors Elmer van Grondelle and Sacha Silvester for enthusiastically supporting and supervising my project, challenging and encouraging me and making time to come all the way to Böblingen for meetings.

Furthermore I'd like to thank all executives; Herr Markus Bibinger, Herr Markus Riedel and Frau Dr. Winkler for providing the opportunity to graduate at smart. My gratitude also goes to my predecessors; Matthijs Ravestein, Benjamin van Rooij and Olaf Kampinga for establishing and maintaining the relationship between smart and the TU Delft.

Thanks again to everybody who has been involved and made this project possible. As said, it was an incredible educational experience which I could not have done without you! Thanks!

General information

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Project information

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Abbreviations

ABB.	MEANING
BR	Baureihe / internal series number
SMART	Swatch-Mercedes Art
450	1998 smart city coupé / smart fortwo
451	2007 smart fortwo
452	2003 smart roadster
453	2014 smart fortwo / smart forfour
454	2004 smart forfour
45XS	Future generation smart, Xtra small, Xtra smart
MOPF	Modelpflege / facelift
3PS	Passive Passenger Protection System
NCAP	New Car Assessment Program
NHTSA	National Highway Traffic Safety Administration
IIHS	Insurance Institute for Highway Safety
DBW	Drive-by-Wire
GM	General Motors
SBU	Strategic Business Unit
MB	Mercedes-Benz
BIW	Body in White
CBS	Custom Body-panel System
RBS	Resilient Body-panel System
I-ZONE	interactive- intelligent- individual-zone
RR	Rear engine Rear wheel drive
PC	Polycarbonate (transparent plastic)
ED	Electric Drive
HVAC	Heating, Ventilation and Air Conditioning
NVH	Noise, Vibration and Harshness

Contents

Executive Summary

This design project has been done in order to give an outlook to the fourth generation smart fortwo, regarding its overall package and exterior design. The project investigates the core qualities of smart and shows how they can be translated into a concept for 2020 and beyond. The concept that was created – the smart 45XS – is based on four 'pillars' that formed the backbone of the project:

SMART

The original smart thanks a great deal of its success to its unique compactness and 2.5m length, making it 'unschlagbar parkbar' (unequalled parking ability). However, over time the smart gained volume and has grown in length to over 2.7m, mainly due to safety regulations and limiting the costs. Within the context of continuous urbanization and increasing mobility density, an easy-to-park urban micro car will become increasingly practical. Therefore the smart 45XS concept brings the length back to <2.6m and regains its small volume, without compromising safety and performance.

SAFE

The small smart faces a mayor challenge when it comes to safety, especially regarding pedestrian protection. The fourth generation will have to deal with world-wide regulations and standards. Therefore the smart 45XS integrates the best solutions for occupant protection (the best structure smart can make and a crash-optimized front-end package), unique pedestrian protection design (3PS) and supports active safety assist systems.

STRATEGY

In order to stay competitive on the market, smart needs to maximize the market occupation of the fortwo. Therefore smart needs to offer their three main customer groups (private, commercial and car2go) more specific and appropriate products. The 45XS concept suggests that smart amplifies the flexibility of the car in order to easily create derivatives based on one basis. Therewith smart provides its customers with a variation of products, all containing the core qualities of smart.

STYLE

smart is also about individual and stylish mobility. The customizable plastic body-panels allowed the user to change its colour every once in a while, but this is currently hardly used and is no business for smart anymore. However, expressing individuality will increase in the future, especially through digital and interconnected devices. The 45XS concept suggests that the exterior of the smart car plays along with the behaviour of its customers and supports individualization via digital and interactive elements.

Merging these four pillars resulted in the 45XS concept vision. Rather than providing one concept car, the 45XS concept suggests that smart can create more customer-specific and individual products – all based on identical technology, safety and design characteristics – by using the following 4-STEP build-up plan:

STEP 1: TECHNICAL BASIS

The basis of the 45XS concept is a fixed platform, which is on its own a drivable, 'naked' car. It includes a rigid construction, the full electric powertrain, the passenger compartment and a crash- and pedestrian safety optimized front-end design.

STEP 2: DERIVATIVE MODULE

The second step is to create various architectures by mounting different modules to the basis. With a simple roll-over bar, a beach buggy is almost instantly created. Different modules allow to build up e.g. a roadster, a coupé or a micro van architecture.

STEP 3: EXTERIOR CHARACTER

Thirdly, the derived bases are cladded with exterior panels; partly identical, partly unique. Each archetype can be cladded with various exterior modules, e.g. a full translucent roof, a removable hard-top roof or customized storage system. Each derivative shows the characteristic metal Tridion, a 'greenhouse', a layer of resilient plastic body panels with an identical leitmotif, and something new: 'i-zone' areas.

STEP 4: i-ZONE CONFIGURATION

The last step is the configuration of the i-zones. The i-zones include everything that has to do with individuality, intelligence, interaction and innovation. With the i-zones, the smart adapts to the user's varying and changing needs and preferences. Besides, the i-zones can be updated with new features and technologies during its lifecycle; therewith responding to the rapidly changing technologies use of digital devices.

This project shows that with these four steps the 45XS concept enables smart to offer immense flexibility and adaptation to various customer needs while preserving the smart core qualities, using standardized safety- and performance elements and playing along with new ways people use to individualize and express personality.

Introduction

smart is an automobile brand of Daimler AG and is known for its iconic micro compact car: the smart fortwo. smart cars are seen as small, agile and playful vehicles. The smiley face, the recognizable steel Tridion Cell, plastic body panels and unambiguous mono-volume proportions make smart the iconic city car everybody knows.

smart is about being clever in city traffic. Micro cars, electric propulsion, e-bikes; it's all part of smart's vision on urban mobility. Besides, smart is about character. Owning a smart means showing a certain personality: you want to park crossways in the small parking spaces that others can't use and manoeuvre through small streets and openings. smart is about making inner-city traffic easy and fun. smart has always played along with the fickleness of the city life and enabled people to change the looks of their car by interchanging the plastic body panels. Next to that smart has put a lot of effort into making the car safe and they communicate it by showing the steel Tridion Cell on the exterior.

The production of the third generation of the smart fortwo is being prepared as we speak, and so smart's designers and engineers start looking towards a next generation. This project started simultaneously with the pre-development phase, and is intended to give a prospect of the fourth generation fortwo. Based on smart's experiences and knowledge, four challenges were given that needed to be taken into account.

Challenge 1: SMART

The first generation smart fortwo (450) that was introduced in Europe in 1998 had a length of 2500mm: the width of a longitudinal parking place. With this length the smart could be parked crossways ('quer-parken'); one of smarts unique characteristics, making it 'unschlagbar parkbar'. To make the second generation fortwo (451) U.S.-eligible (regarding safety requirements) and to improve the car's dynamics it grew to a length of just under 2700mm. 'Quer-parken' already became trickier, and the third generation (453; built together with Renault) will grow even more. smart therefore wants to investigate a package for the fourth generation that aims for the original smart length, compactness and volume, without compromising performance, safety and quality. At least a length of under 2600mm has to be achieved for the fourth generation.

Challenge 2: SAFE

In the context of safety, smart must cope with the high standards of today's automotive industry. Besides worldwide regulations, several (independent) safety examiners like Euro NCAP, NHTSA and IIHS push the industry to keep on developing on protection people in mobility. An important challenge for smart is pedestrian protection; the minimal front area of the fortwo makes it challenging to make 'soft' areas for when a pedestrian is hit by the car. Options for the fortwo have been investigated by smart (primarily passive pedestrian protection systems (3PS) by M. Ravestein, 2011) and will be implemented in this project.

Challenge 3: STRATEGY

smart never achieved the intended amount of sales that matches its plant maximum capacity: 200,000 pieces per year. At the moment, smart sells a little over 100,000 pieces per year, but that is not near enough the 150,000 per year that they once sold. Introduction in the US boosted the sales, but dropped again the year after. Currently, sales in China show potential growth, but European sales are mediocre. Therefore smart aims to gain customers world-wide by strategically placing the new smart better into its markets. It will be investigated how smart can further expand its portfolio by deriving various cars from one concept.

Challenge 4: STYLE

smart was created from the idea of a stylish and individual micro car. Therefore exchangeable plastic body panels were used, unlike the automotive industry had ever seen. The innovative idea was received well, but people didn't use this feature as often as foreseen. The second generation conserved the idea, but exchanging body panels is not a profitable business for smart, neither do people make use of it. The third generation fortwo does not support exterior individualization (in the use-phase) anymore. For the fourth generation, individualization will be investigated and reinterpreted for smart, since it is one of the brand values to offer individual urban mobility.

Assignment

The assignment of this project is to investigate the smart brand and design the fourth generation smart for 2020 and beyond, dealing with the previously mentioned '4S' challenges – the 'pillars' of the project. In parallel with the internal investigation of the fourth generation smart fortwo a teaser or preview will be created, showing off its maximum potential for the company. The name is smart 45XS. Xtra small. Xtra smart.

The investigation and design will be based on the technology, fully utilizing the knowledge that is available at the engineering departments of smart and Daimler. Experts in the fields of safety, design, marketing and engineering will be contacted and interviewed. Also, the design will be driven by the smart brand- and product values that define smart.

In this graduation project the focus will be on the overall package and exterior design of the concept. As being a part of the engineering department the strength of the project will be that the concept will be based on a feasible technical basis, serving as a backbone for the exterior and features that the final concept contains.

Project Outline

During the project in smart's headquarters in Böblingen, first the design and engineering of the previous and current smart fortwo generations were analysed ('Lessons Learned') based on the '4S pillars': SMART, SAFE, STRATEGY and STYLE. Furthermore the brand's history, identity and portfolio have been analysed, as well as the competition of the fortwo. Next to this, the user and the context of urban mobility are described in order to identify what the role of smart currently is. These elements are described in PART 1: ANALYZE.

Secondly, an outlook of the future is being described, based on an extrapolation of the current context. Based on trends and developments, the context of 2020 and beyond is described and how the user uses the smart car in that picture. The goal of this part is to put the user in a new context, to ensure that the concept that is designed fits the time it will be used in. This will be covered in PART 2: DREAM.

Next it is being investigated how, based on the 4S-pillars, the design of the smart 45XS will be approached. PART 3: INVESTIGATE describes how each challenge is dealt with and what choices are made. Input of internal and external experts, alongside new investigations are used to create a framework in which the concept will be designed.

In PART 4: SYNTHESIZE it is described how the findings in each pillar are merged together into the 45XS concept. The concept is described through images and details that support the design.

In PART 5: REVIEW the concept is being reviewed, overall conclusions are drawn and the project is evaluated. Conclusively, recommendations are given for continuation of the 45XS project.

The data that was collected and researched within the company was based on information of each of the smart fortwo generations. Due to the sensitive information of the 453 model, detailed information about the car will not be included in this report. The 451 is, besides being the current model, also most well-known by the engineers at smart. Where technical comparisons are made between the existing model and the concept 45XS, the 451 model is thus used as reference.


smart
smart
smart

PART I: ANALYZE

1.1 | Writing History

The first smart car was introduced to the market in 1998, but the history of the characterful brand started much earlier. It is hard to say exactly, but the idea for an urban two-seater was already put on paper in the 70s [Figure 1.01]. Not until two parties – Daimler-Benz AG (Mercedes-Benz) and SMH (Swatch) – came together it became a serious project.

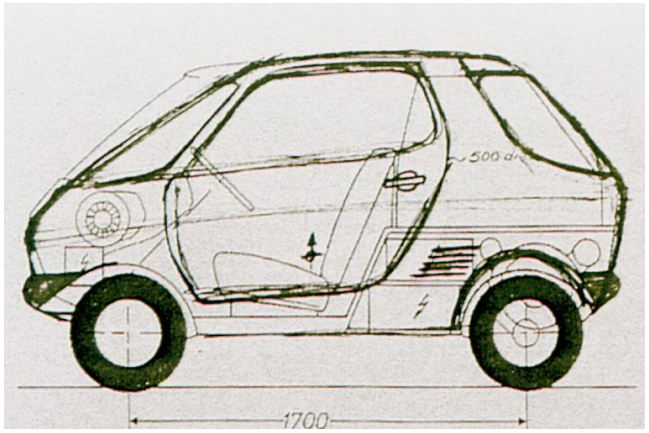


Figure 1.01: 1972 sketch of Mercedes' 'super compact automobile'

The ambitious CEO of the watchmaker firm – Nicolas Hayek – believed in the idea of a small and stylish car and looked for an automotive company to partner up with. After being rejected by several carmakers, he eventually made a deal with the manufacturer of Mercedes-Benz cars.

Daimler-Benz had already been working on a low-consumption micro cars – the Mercedes NAFA [Figure 1.02] – which eventually resulted in the 1993 eco-sprinter, eco-speedster [Figure 1.03 & 1.04] and the 1990 Vision-A concepts [Figure 1.05]. The latter came to be the first A-Class, but the micro cars were considered too much of a risk for the prominent Mercedes-Benz brand image.

Figure 1.02: 1982 Mercedes NAFA concept

Partnering up with Swatch was ideal for Daimler, because they could therewith reduce the risk by creating a separate brand: smart, an acronym for Swatch-Mercedes Art. Their partnership was announced in 1994, together with aforementioned eco-sprinter/speedster concepts.

From this moment, the development of the smart city coupé – later called the smart fortwo – began. In 1998 the car was launched in Europe, but SMH's foreman Hayek was not satisfied with the final design. The hybrid drivetrain he pushed for was discarded by Daimler and replaced by a relatively conventional gasoline engine. Shortly after the launch Daimler bought out SMH's share, making smart a brand owned wholly by Daimler-Benz.

The history of the brand is in its DNA: smart is a merger of Mercedes-Benz's experiences in building safe and qualitative cars and the creative thinking of Swatch. [1] [2] [3] [4]

Figure 1.03: 1993 eco-sprinter and eco-speedster concepts

Figure 1.05: 1990 Mercedes-Benz Vision-A 93 concept

Figure 1.04: 1993 eco-speedster concept

1.2 | Brand Identity & Image

Identity

smart is without a doubt one of the most characterful brands and probably the easiest to recognize on the street. It is truly a stand-alone passenger car, considering its unparalleled size and ability to park crossways. smart considers its position in the automotive industry as provider of 'unique urban mobility' [5] and its brand values as functionality, innovation and joy of life [Figure 1.06] [6] [7].

As provider of 'urban mobility', smart principally excludes nothing that fits that description. This philosophy has given smart space to develop for example the e-bike next to the fortwo [Figure 1.07].

Figure 1.06: smart brand values around the smart logo

Figure 1.07: 2012 smart e-mobility

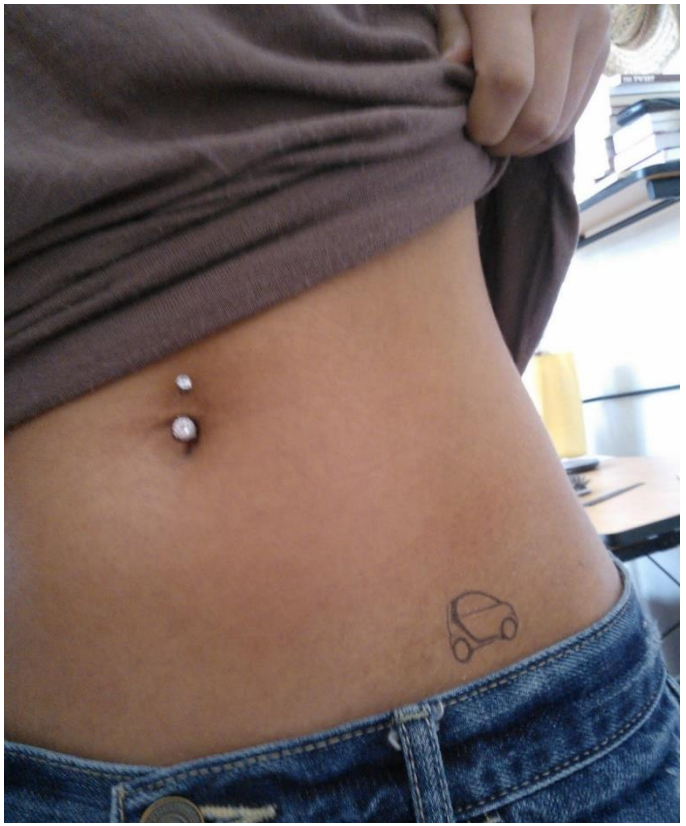
Image

The unconventional smart has received mixed comments all its life. Especially at the launch there was a ‘hate it or love it’ relationship between people and the smart car. Many people saw the smart car as a toy car which they would never ever drive, others praised its agility, driving pleasure and polarizing character [8].

smart’s biggest problem is that people are not aware of the smart and what it offers. It is subjected to presumptions about its reliability and comfort. smart tries hard to market the brand and bring awareness among the people. For example smart started a 35 million dollar ‘Unbig. Uncar’ campaign in the U.S., an important market for the brand [9] [10]. Of course, the overall American idea about smart is not the leading factor of the brand, since its home environments are compact cities.

smart has also dealt with technology image problems. The first generation was often commented on its sluggish gearbox and questionable stability. With the newer generations, these problems are as good as fixed, but the brand continuously needs to invest in persuading and enticing people, because many who have experienced smart properly, might just change their opinion to positive. Quite recently, smart has gotten positive feedback about the new electric fortwo and their CAR2GO services, which might just boost the brand’s image in the coming years.

~~*Hate it*~~ *envy it…*



…or love it

1.3 | Brand & Product Portfolio

Daimler portfolio

Since the launch of smart it has always been part of Daimler [Figure 1.08]. This means that in the portfolio of Daimler's Mercedes-Benz Cars, smart is a strategic addition to Mercedes, since as a whole they have to meet certain CO2-emission values. With the low-emission smarts, the Mercedes-Benz Cars portfolio meets these requirements. Daimler therefore counts on smart since the emission targets (especially in Europa and U.S.) are getting tougher in the coming years.

As part of Daimler and the prominent Mercedes-Benz portfolio, smart needs to have high standards on technology and safety. This also resulted in the fact that, apart from whether people liked the performance of the smart or not, the quality is very good and the safety scores have always been sufficient despite its short front end [11] [12].

smart and Daimler obviously need each other and although Daimler calls the shots and could theoretically cut off support, Daimler can provide the capital for smart to develop good products for the future.

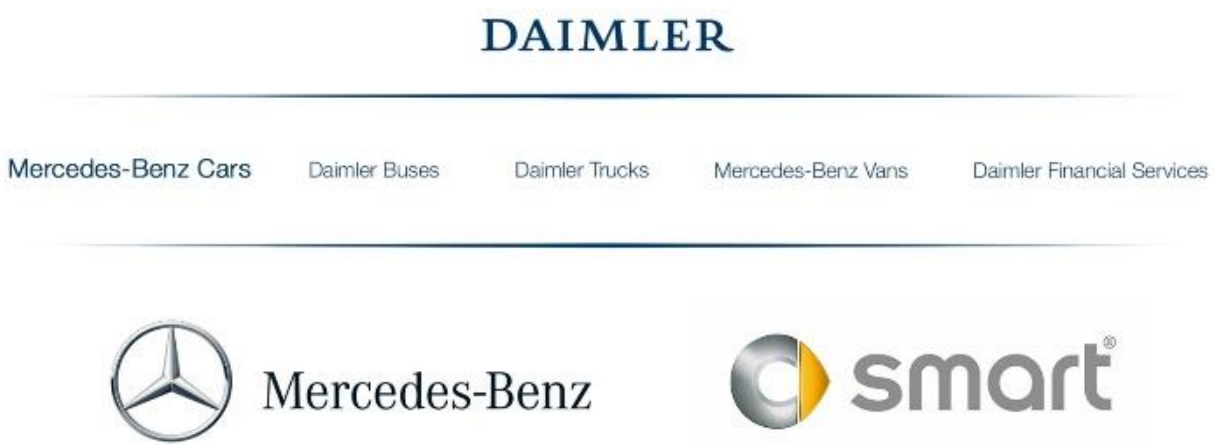


Figure 1.08: Daimler's Mercedes-Benz Cars portfolio

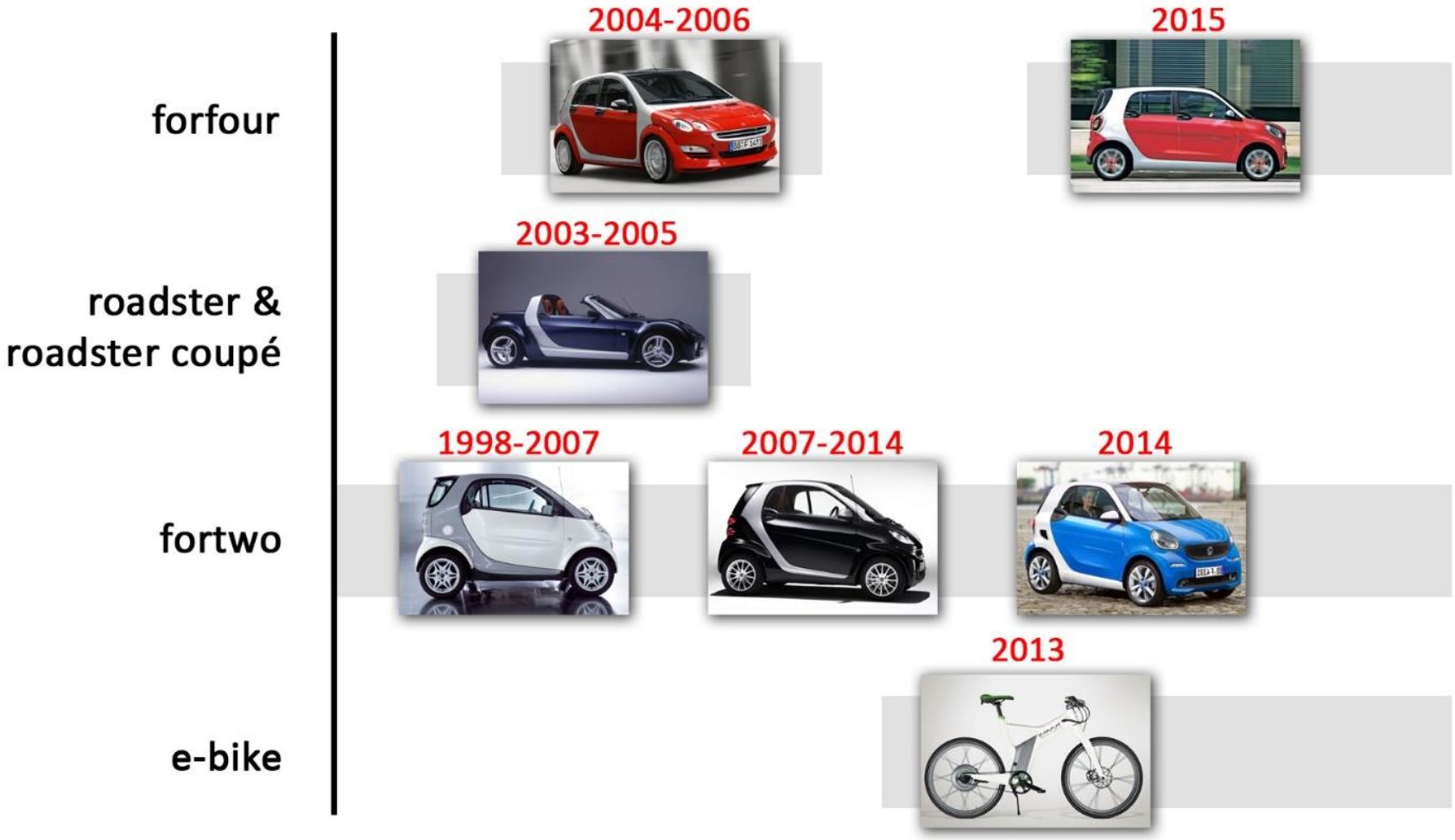
smart portfolio

The smart fortwo is the brand's core model in the portfolio [Figure 1.09], but its two other models are also well known. First there is the smart roadster/roadster coupé), which is a small rear engine sports car, based on the fortwo. Secondly there is the smart forfour, a four-door front engine car, built on the platform of the Mitsubishi Colt in the Dutch NEDCAR factory.

They were both, however, only shortly produced; respectively from 2003 till 2005 and from 2004 till 2006. They were both cancelled when after a time of poor sales smart was integrated into Daimler (DaimlerChrysler at the time) fully, and the then Daimler-chief ordered smart to focus only on the fortwo model.

Currently, a healthier and optimistic smart, led by Frau Dr. Annette Winkler, starts expanding the portfolio again with an urban e-bike and will reintroduce the forfour soon.

Figure 1.09: smart's Portfolio



smart fortwo (sub-portfolio)

smart's flagship model (that sounds rather weird in this case) – the fortwo – has been available as coupé and cabrio. Since 2008, the electric drive (ED) coupé and ED cabrio were available too [Figure 1.10].

Besides, smart has built a derivative – the Crossblade (limited to 2000 pieces) – and many limited edition fortwo's with certain themes, like the BoConcept, CityFlame and ForJeremy [Figure 1.11]. Next to that, since 2002 smarts have been available as BRABUS version with more power and an upgraded body kit and tailor-made upholstery [Figure 1.12]. On top of that, countless unique, personalized smarts can be found over the world [Figure 1.13].

The smart fortwo portfolio shows that the brand strives to offer unique products and communicate a refreshing and playful character.

Figure 1.10: smart fortwo variations

Figure 1.11: smart ForJeremy, BoConcept and CityFlame

Figure 1.12: smart fortwo BRABUS

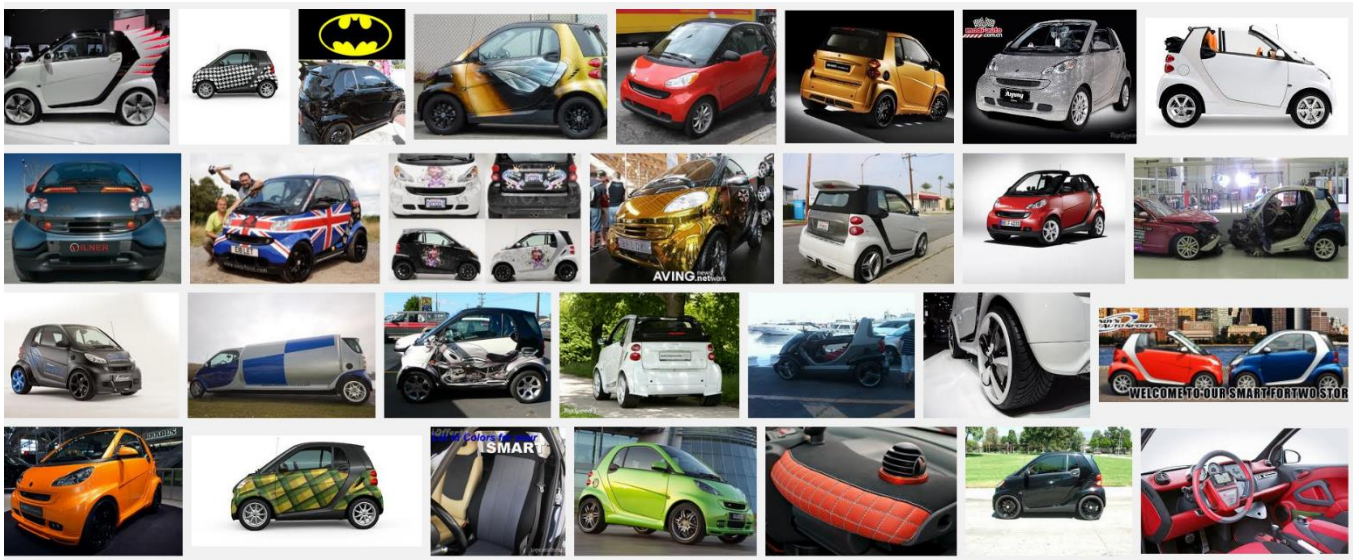


Figure 1.13: Various unique smart fortwo's

smart concepts (sub-portfolio)

In 2011 smart presented an interesting set of all-electric concept cars [Figure 1.13], showing the direction they headed for. A new fortwo (the forvision), a Crossblade (forspeed), and two lifestyle micro roadster/micro utility vehicle concepts (the forus and forstars). In 2013, smart showed the fourjoy concept at the IAA, another lifestyle concept with hints of the new forfour.

Figure 1.13: five smart concepts 2011-2013

With the forvision smart indicated that a 2.5m car is still the vision of a pure smart. With the forstars and forus smart hints towards a focus on suburban lifestyle vehicles.

The concepts are interesting, because urban lifestyle cars have a huge potential as people become more individual and expressive. Also, the concepts show a lot of clever features, like the solar-energy powered temperature management [Figure 1.14] [13], and the projector in the bonnet of the forstars to project movies somewhere on a screen or wall [Figure 1.15].

Figure 1.14: ventilator in the rear light of the forvision

Figure 1.15: Bonnet-projector in the forstars

1.4 | Product Deconstruction

1.4.1 | The smart 450

Introducing the smart

The 1998 smart city coupé – internally called BR450 – was something else. For its time it was a very innovative idea that engendered manifold reactions. People loved it, or hated it. This subchapter describes the innovative design thinking behind the 450 in relation to its context.

First some fortwo facts:

- 1998 launch smart city coupé
- 2000 launch smart city cabrio
- 2002 facelift I
- 2002 launch smart Crossblade (limited edition)
- 2004 name change to smart fortwo
- 2007 pilot smart fortwo electric drive (100 pieces)
- 2007 launch new smart fortwo (BR451)

The smart city coupé defined urban mobility in many ways. It was small, agile, individual, resilient and bold in its environment. Its integral design can be broken down in the following interesting elements.

Basic Layout

The basic layout of the smart package is the key to its one-box volume. A short overhang, just two seats, the engine on the rear axle and a double floor construction for the gas tank, start-battery and brake booster allow the smart to be only 2.5m long [please unfold Appendix 1 for layout].

Tridion Safety Cell

The Tridion Safety Cell – the steel structure of the car aka Body in White (BiW) – (indirectly) carries all the car's components and protects the occupants during a crash. Almost all modern cars are based on a BiW, but smart has chosen to emphasize the steel structure on the exterior of the car. Although the outer steel panel is purely an optical and tactile element, it communicates the structure behind it, ensuring the user that it is in fact a safe car [Figure 1.16] – unlike what many sceptic people believe when they first see it.

Off-set seats layout

To keep the car's dimension proportionally acceptable, the two seats are relatively close to each other in width. To avoid that the two occupants have to sit shoulder-to-shoulder, the zero-position (or SRP: Seating Reference Point) of the passenger seat is set 125mm behind the driver seat.

Powertrain

The smart's drivetrain is a rear engine rear wheel drive (RR) configuration. The semi-automatic transmission and three-cylinder engine – built by Mercedes-Benz – and suspension – De Dion – are mounted on a substructure, which is as a module mounted on the BiW. This was part of the plan to build the car up out of modules, decreasing assembly costs and time in the production plant.

In the last six months before its launch, the dynamics of the car were improved by among others widening the track. This explains why the rear wheels seem to be bulging out of the rear so much.

CBS

The CBS (Custom Body-panel System) was designed as a set of plastic panels that were interchangeable by the customer. Plastic body panels were chosen for their low weight compared to steel and the design freedom it provides. Besides, the different material emphasized the difference between the 'functional' steel structure and the personalizable outer skin. Also, the plastic body panels are much more resilient and scratch proof than steel or aluminium. Plastic fender- and bumper parts therefore are characteristic design elements of a smart.

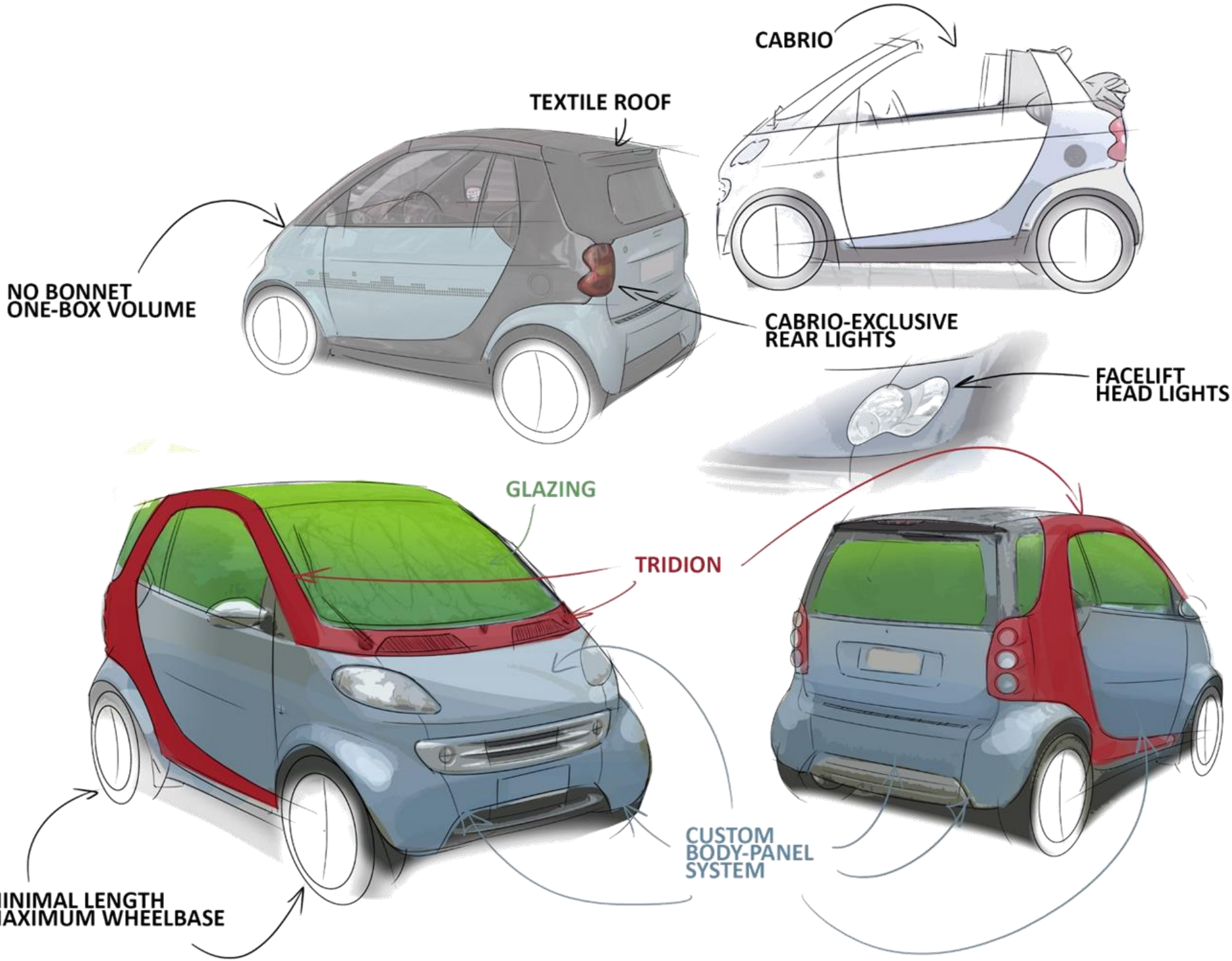
Smiley face

The 1998 city coupé had a rather friendly expression, but the first facelift really put a smile on the car's face. The lights and grill were slightly adjusted and the hipline was accented, making it friskier too.

Cabrio

The smart city cabrio came about two years later for a reason, namely that it had to be derived from the coupé. What smart technically did was cut away the upper part of the Tridion, and replacing it with a removable part. Although this part guides the sliding mechanism of the textile roof through a rails, it has no structural function, meaning that both the A-pillar and floor needed to be reinforced.

Figure 1.16: the strength of the Tridion


CABRIO
TEXTILE ROOF
NO BONNET
ONE-BOX VOLUME
CABRIO-EXCLUSIVE
REAR LIGHTS
FACELIFT
HEAD LIGHTS
GLAZING
TRIDION
CUSTOM
BODY-PANEL
SYSTEM
MINIMAL LENGTH
MAXIMUM WHEELBASE

The competition

The smart fortwo was such an unconventional car because it combined two daring aspects: its size and its personalizable plastic body panel system. Where most small cars had back seats, the engine up front, and steel sheet exterior panels, smart choose everything to make it as small as possible, without underperforming safety. Therefore smart created a big leap between small cars like the Mini Cooper, Renault Twingo, Volkswagen Lupo and Fiat Seicento. Therewith smart showed that it wasn't afraid to 'go unconventional all the way'.

1996 Mini Cooper (Mark VII)

1992 Renault Twingo I

1998 Volkswagen Lupo

1998 Fiat Seicento

An attempt of Renault confirmed that a rear engine layout was the only solution to make a 2.5m car. When they tested a front engine layout (by simply shortening the Twingo) the car bounced heavily when braking hard.

Brake test with a shortened Renault Twingo

Next to unconventional design, smart looked at urban mobility in broader way. Already in the early 2000s, smart made partnerships with rental companies, parking services and public mobility providers in order to provide customers with a more flexible use of mobility. [3]


smart
fortwo

1.4.2 | The smart 451

Introducing the successor

In 2007 the new smart fortwo had to drag the brand out of the well after having stopped the production of the smart roadster and forfour because of financial problems. Regarding the situation smart was in, not surprisingly the new fortwo would be largely based on its predecessor to save costs and time. The essentials of the car are indeed much like the 450, nonetheless some things have changed.

First some fortwo facts:

- 2007 launch smart fortwo coupé
- 2007 launch smart fortwo cabrio
- 2009 launch smart fortwo electric drive (EV II)
- 2009 launch CAR2GO car sharing program
- 2010 facelift I (interior)
- 2013 facelift II (exterior)
- 2013 launch smart fortwo electric drive (EV III)
- 2014 planned launch smart fortwo coupé (BR453)

9 years after the introduction of smart, the micro compact car was still a stand-alone vehicle in the market. No other manufacturers tried to compete with an 'under 3m' car in Europe yet, until the 2009 Toyota iQ. So what did smart do to continue their iconic fortwo?

Tridion, CBS & powertrain

As said, the concept of the 451 was similar to the 450, and therefore one will also recognize the same engine layout, the off-set seat position, the visible steel Tridion Cell and plastic body panels [please unfold Appendix 1 for detailed layout]. The body panels were now made from a Polypropylene: a cheaper but more flexible plastic with a different surface look and feel. A new three-cylinder gasoline engine – built by Mitsubishi – replaced the old one.

Safety and regulations

Not only to apply for the U.S. market, but also because the European safety regulations increased for occupant and pedestrian protection, smart had to redesign and add safety elements. The result for the car's dimensions were that it grew about 200mm to a length of 2700mm.

Cabrio & electric drive

After the coupé was built, a convertible was derived from it (same art as with the 450), as well as an electric drive (ED) version. The fortwo ED gained about 200kg weight due to the battery module, but other than adjusted suspension it has not changed in relation to the combustion version. It was deliberately chosen to not change the styling, in order to let this 'new technology' keep its 'familiar' face. The 2013 EVIII was received particularly well because of its new (German engineered) electric motor and battery [14].

Markets

The 450 was a Europe-focused car, but smart wanted to expand their market occupation to the U.S. and China with the 451. The introductions there in respectively 2008 and 2009, boosted the sales, however shortly after they sunk when the Banking crises hit the U.S. and Europe. At this moment smart operates in 45 countries worldwide, of which the biggest are Germany, Italy and China [15].

CAR2GO

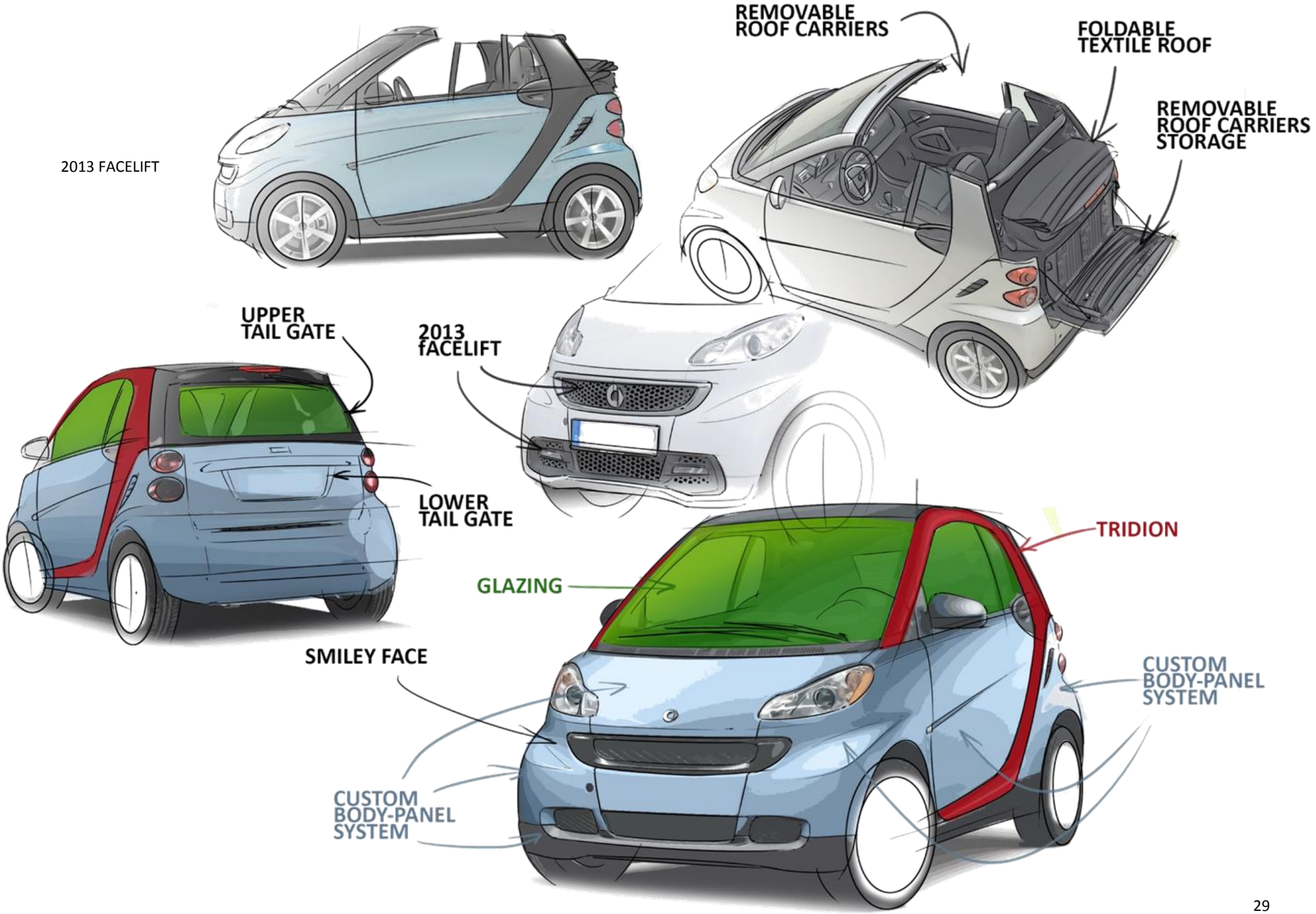
The in 2009 launched CAR2GO car sharing program is something interesting. It does not so much consider the car itself, but the function it has in cities. The car sharing program allows many thousands of people to use a handful (meaning 300 up to over a 1000 per city at the moment) of smart cars when they want it – no strings attached. It is an addition to the transportation possibilities in cities, creating a link between ownership of cars and public transport. The CAR2GO program is the largest customer of smart at the moment, and Daimler has billion-dollar expectations of it [16]. At this moment, about 9000 smarts (of which about 1000 electric) operate in 24 cities.

Design

The designers at smart did a good job giving the car a face that matches the character. Its wheels in the corners and its compact boxy volume fit well with a smiling face. The declining nose and the relatively low position of the lights and grill give it, despite its length-height ratio, a sporty and frisky appearance.

2007 smart fortwo characteristics and leitmotiv

2013 FACELIFT



Competition

In the micro compact car category, the 2009 Toyota iQ comes closest to the smart. Being 2999mm in length, the iQ and the fortwo are often compared as ‘under 3m cars’.

Toyota iQ

The iQ is about 30cm longer than the current fortwo and offers four seats (rear seats for small children, but still). It has a front engine layout, but (technically like Daimler had to do for smart) Toyota had to develop the engine and many other parts especially for the iQ, making it more expensive than for example the Aygo, which shares most of its parts with the Peugeot 107 and Citroën C1. The iQ, however, is announced to be discontinued by Toyota.

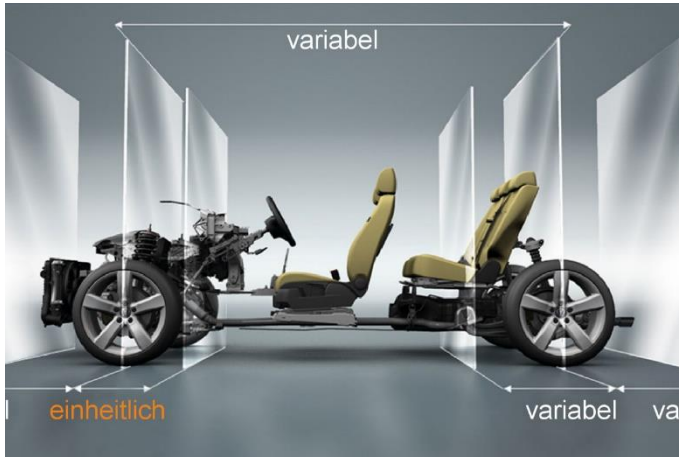
2009 Toyota iQ

Volkswagen Up!

The 2011 Volkswagen Up! is interesting because it is a very functional urban car. With a length of about 3.5m it is considerably larger than the smart, but it is a compact, fuel-efficient car with space for four or five people plus luggage with reliable technology for less money than the smart. Also, its simplistic design – without random lines and forms – emphasizes its modesty and practicality.

What Volkswagen does well is how they use their ‘Modularer Querbaukasten’ platform (MQB) for a huge range of cars. This platform that is adaptable in nearly all directions allows VW to build many car types (from Up! to Passat or Sharan) with various engines (gasoline, diesel, hybrid, electric). The Up! for example has already showed that more urban cars can be derived from it, such as the e-Up!, Buggy Up!, e-load Up! and more (about 10 in total).

2011 Volkswagen Up!



Volkswagen MQB platform

The Mini Cooper, Opel Adam and Citroën DS3 are interesting too, since they all offer individualization, by choosing a combination of colours and/or prints. Although they are bigger and more expensive (except the Opel) than the smart, they increasingly attract people that want a compact car with an expressive and personal character.

2012 Opel Adam

2009 Citroën DS3

BMW i3

Although the 2013 BMW i3 is much more premium and not a direct competitor of smart, it does get people familiar with new design elements and technology that can be linked to urban mobility and lifestyle. And BMW seems to succeed in presenting a premium car with plastic body panels, just like smart!

2013 BMW i3

Renault Twizy

Another way of filling in urban mobility is how Renault did it with the Twizy. This 1+1 vehicle/quad shows that micro mobility can be extrapolated even further. Although it lacks some 'car-aspects' such as a closed cabin, it shows that if one seat and space for a briefcase is enough this is how compact you can be. Considering smart's brand value 'unique urban mobility', the Renault Twizy could just as well be a 'smart forone'.

Urban concept cars

Considering unique urban mobility, various concepts are also interesting for smart. There is the Hiriko City Car, the folding car that can rotate around its center. It was already piloted in Spain, but plans to continue the project in Berlin are delayed due to financial difficulties. It is however a challenging idea about what a shared car in micro city traffic could be in the future.

2013 Renault Twizy (Cargo)

2013 Hiriko City Car

Also interesting is the Toyota ME.WE concept, showing a new interpretation of exterior customization. By using foam plastic panels the car can be 'dressed' with various skins, varying in color, texture and shape. Although the material is not production ready (it is not resistant to UV-light [18]), it is a challenging idea of how individualization could be interpreted by using less conventional materials.

2013 Toyota ME.WE Concept

Car-sharing services

The successful CAR2GO program also has its competitors. DriveNow (BMW and Sixt), Multicity (PSA Peugeot Citroën and DB Rent), Autolib, Zipcar and GreenWheels offer comparable services. Until now they mostly had their own 'domains', but they will shortly be competing in each other's cities, which should have a positive effect on prices (from customer's perspective) and quality. It also means that smart has to make sure that their position remains strong. For example CAR2GO is forced to consider offering a wider range of cars, for users who occasionally need more seats or boot space.

Autolib car-sharing with Bluecar

1.4.3 | The smart 453

Coming next year

Scheduled to come in 2014 is the successor of the 451: the 453 (452 was already taken for the roadster). As the production plant in Hambach prepares the start of the production of the new coupé, some things can already be said about it.

But first some ~~facts~~ notes:

- 2014 scheduled launch smart fortwo coupé 453
- 2015-2016 expected launch smart fortwo cabrio 453
- 2016-2017 expected launch smart fortwo electric drive 453

Renault

The 453 is being developed together with Renault-Nissan, who closed a deal with Daimler in 2009. For smart the deal meant that the new fortwo and a new forfour would be developed alongside the Renault Twingo two- and four-seater. Remarkably, a rear engine layout was chosen for the platform (1-0 for smart) but Renault discontinued their two-seater Twingo. How it will turn out for smart, will become clear in the next years. For now, let's take a brief look at the new fortwo coupé's technical data.

Tridion & CBS

The unofficial images give a pretty accurate idea of the new fortwo (and forfour). At first sight, the separated Tridion and CBS are visible, but when looked closer it becomes clear that the steel Tridion has 'won territory' and now covers two vulnerable spots: the rear fender and side skirts.

The kinks in the leitmotiv also expose that the overall design was not initiated as a two-tone vehicle like the 450 and 451. This makes sense, since Renault built the car and is more focused on low cost development.

Powertrain

Not a lot has changed for smart in the powertrain layout, but the engine compartment has evidently grown in order to fit a three- ór four-cylinder engine with a manual gearbox. Also, the wheels have grown in order to improve dynamics and/or for styling to compensate the large nose.

Safety

These days – and more each year – safety is a big issue. Besides occupant protection, protection of pedestrians cannot be by-passed. To 'soften' the front of the car, it has gained a lot of volume, as can be seen from the technical drawing. More on the topic of safety later.

Overall

Although the new smart has not gained that much in length, it has grown substantially in volume and mass. The consistent use of relatively low-tech cost-cutting technology, has caused the smart to lose some valuable qualities, such as its all-round resilience and compact one-box shape. The focus has been mainly on improving dynamics further to make it better than the 451, but the question remains whether users will love it as much as the current one.

2014 smart fortwo coupé (unofficial image)

Basic leitmotiv of the two-tone exterior

2014 smart fortwo (unofficial image)

2015 smart forfour (unofficial image)

Spyshots 2014 smart fortwo coupé

1.5 | The user

The smart user

In order to create a sensible and user-centred smart concept, it is key to understand what smart means to its users. Therefor data was collected within Daimler and complemented with owner's reviews of the smart. Based on internal sales and customer research, three smart user-groups are identified: PRIVATE, COMMERCIAL and CAR2GO [19]. Considering the close to 50/50 ratio between privately and commercially registered smarts and the huge amount of CAR2GO-members, each one of them is considered equally important. These three groups were used to identify and describe the varying characteristics of smart customers.

The private smart owner loves his/her smart

The PRIVATE smart user

People know that driving the unconventional smart doesn't go unnoticed. Although owning a small car is often a practical and financial decision, but owning a smart is not. Despite the sublime practicality when it comes to parking, most people would choose a four-seater with a little more boot space. People who choose a smart do it because it is exactly the opposite of the big over-dimensioned SUVs that annoyingly bulge out of the scarce parking spots in the cities.

smart vs. SUV

The people who drive a smart privately do it because they love the compactness, the character and the idea of using and consuming no more than you need. Although most smarts currently appear in standard colors like silver, black, white, red or light blue, the private customer appreciates the colorfulness and ability to personalize that the brand offers. From the fortwo coupé 'pure' to the tailor-made BRABUS cabrio, the smart car fits the needs of the user and makes him or her feel free, flexible and individually superb.

The COMMERCIAL smart user

The commercial customer is usually a company that purchases a small fleet of cars that are used to provide services in an urban environment. The client is one that chooses to drive a compact, flexible and economical car. The smart is for them a conscious choice as it provides the functionality that is needed, without unnecessary options. The character of the car is also used to reflect the desired character (young, fresh, responsible, practical) of the company.

The smart is well known for its stickers and logos, making it a representative and mobile advertisement for the company.

Many smarts are owned by companies and have stickers all over them

Companies often purchase a whole fleet of smarts

The CAR2GO user

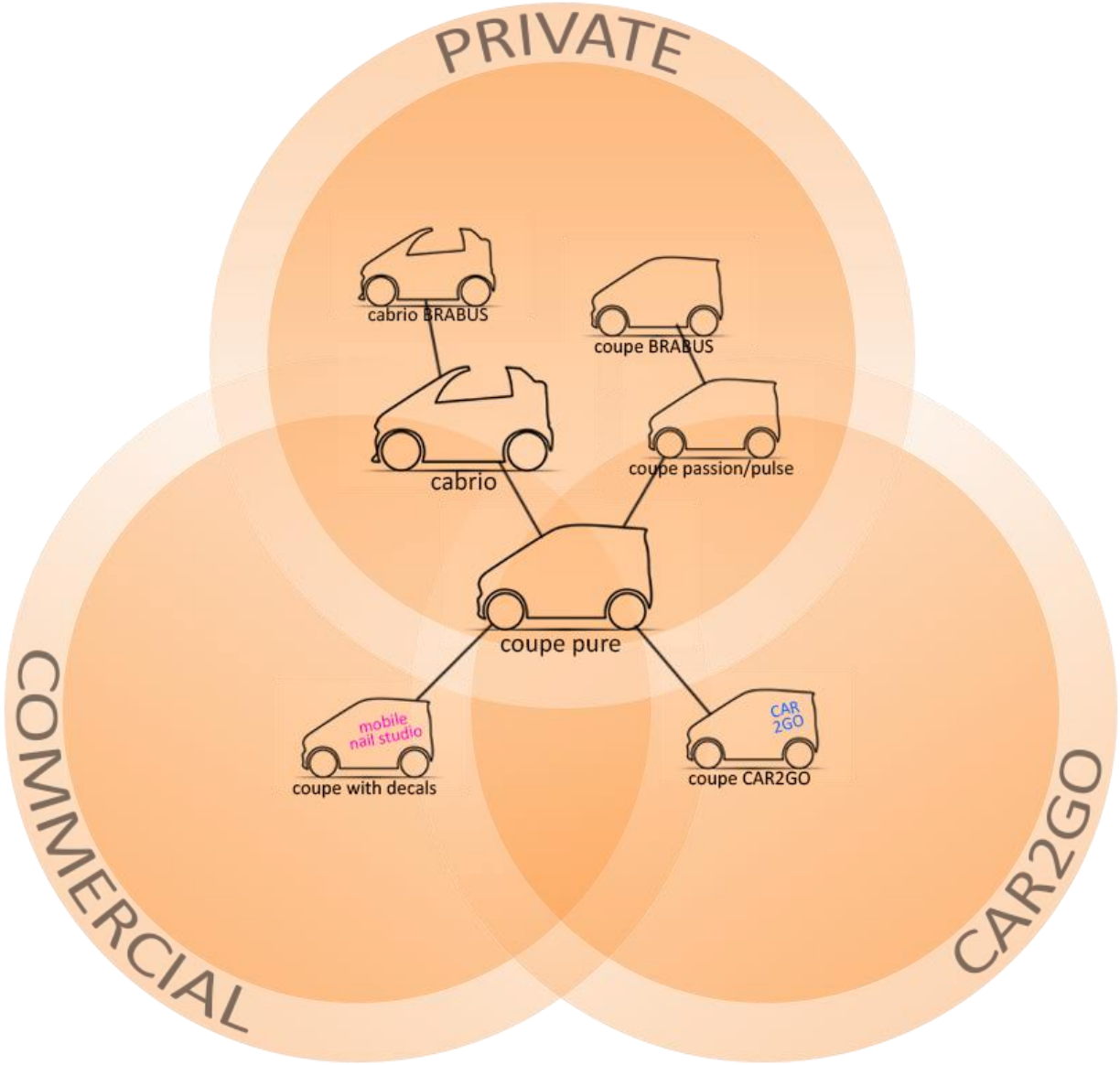
The newest and most rapidly expanding group of customers is that of the CAR2GO users. The willingness to use a shared car instead of owning one offers new advantages. It can be used as much – or as little – as possible, making it a service that fits the less wealthy just as well as the rich. The practical advantage of having a car available all around the city and being able to leave it anywhere is optimal for people who live an urban lifestyle; being mobile and traveling a lot within the city to meet people in different places at inconsistent moments, enjoying the urban life without having to care leaving your 'capital' behind on a vulnerable spot while the parking meter is ticking. Also, it fits being flexible and eclectic in the city; using whichever means of transportation is most cost- and time effective.

Since the car-sharing environment is relatively new, some questions remain about how much potential this business has, but the turnover expectations of Daimler for CAR2GO contain ten digits. It is without a doubt that car-sharing will attract many people in large cities, and many cities are yet to be introduced to the system.

All kinds of people use CAR2GO

Product placement

Relating to the three user-groups, smart serves most customers with variations of the ‘pure’ coupé smart. Commercial and CAR2GO vehicles are altered or customized versions of the coupé (and coupé Electric Drive). Of the private customers, about 20% choses a cabrio or BRABUS edition [20]. Illustrating that within the three groups, which were defined as currently equally important, shows that the focus is mainly on private users.



1.6 | The context

Urban environment

The context of the smart car is simply said the urban environment. ‘Urban’, however, is a broad thing. Cities may also contain highways and rough terrain. Urban mobility is not just about cars for city centres, but it is about mobility for people who live in the city. This means that more than just the size of the car makes it earn being labelled ‘urban’. To found out what does, four clusters were selected that describe the quality of urban life: URBAN LIFESTYLE, BEING MOBILE, HEALTH & SAFETY and ENVIRONMENT.

URBAN LIFESTYLE

Living in the city is about being among other people all the times. It is also about finding new things to experience within an area that is always reachable. Depending on the situation, it could be a necessary practical decision or a matter of preference to live in a city. Next to daily working life, people in the city go out to meet and experience things with others. These experiences add to their social identity, which people use to reflect their positive personality. For example, good experiences are often uploaded in social media, creating a likeable and sympathetic image of yourself.

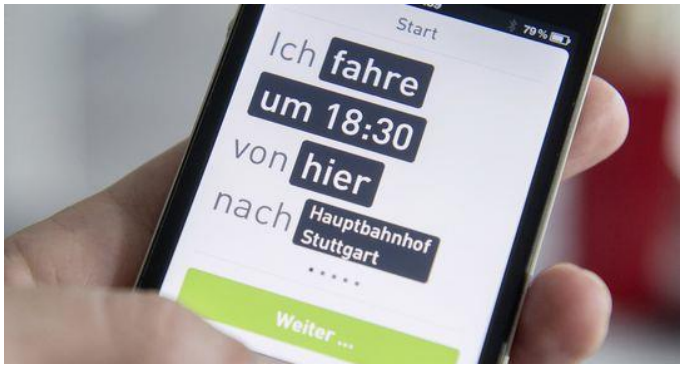
Urban lifestyle is about meeting people

An urban lifestyle is characterized by being occasionally spontaneous and being connected with others all the time. Today meeting a friend for lunch is instantaneously planned with smartphones. Even during social interaction, the connection with other people continues.

Always being connected

BEING MOBILE

Living in the city means that being mobile is not only having a personal means of transportation, but also using public transport for cost- and time effective mobility. Public mobility is already a big part of the urban infrastructure and with car sharing coming up, public and private mobility are becoming linked together. With for example Daimler’s mobile app ‘moovel’ people can plan a trip from A to B including public transport ánd CAR2GO.



Daimler’s moovel app

Studies have shown [21] that most people prefer a car that is practical in all situations. So even though people mostly drive alone with no or little luggage, their car needs to be usable with more passengers too. smart simply does not offer that in a fortwo (obviously), and therefore the gross of the people would not even consider a smart. It is however interesting that the CAR2GO service has attracted 400,000 customers in the first 4 years [22], showing that many people are willing to drive a two-seater car if it is not their own main car.

Parking in cities is commonly known as difficult. Just walk around in Stuttgart West around 6 or 7 o’clock and you’ll see cars driving crisscross trying to find a spot. A small smart almost always finds a small spot somewhere and makes mobility faster and more convenient.

HEALTH & SAFETY

People car about their safety and that of others. Especially in urban environment, where lots of pedestrians are part of traffic, an accident easily occurs. As long as people are getting hurt or killed in traffic, the stakeholders of mobility will continue developing safe products and systems. With pedestrians currently in focus, car manufacturers develop new innovative solutions on the front end of the car.

Volvo pop-up bonnet with pedestrian airbag

Also the use of active mitigation systems is being implemented quickly, therewith relying on computer systems that detect and act, therewith overwriting the actions of the driver. Basic systems will detect an approaching object with sonar, sophisticated systems detect the curvatures of traffic lanes, distinguishes people from objects or even recognize bumps in the street. Being aided by these systems becomes a natural thing rapidly, since people tend to quickly get used to computerized systems these days.

ENVIRONMENT

It is nothing new that we think about our environment, and not much has changed about how people deal with it. Although 'green' and eco-friendly cars are much more common these days, not much has changed in how cars are used. The focus is mostly on improving local environment: exhaust fumes and noise. Considering exhaust fumes, electric driving is the optimal solution for clean urban mobility, but the costs are at this moment too high for most people.

How people deal with the environment is always an interaction between (local) governments (that set rules and influence/stimulate the industries and people), the companies (that take directions that are long-term profitable) and the people (who consume what they want and can afford). Almost all car manufacturers offer electric mobility or will do so in the coming years [23], people are slowly, but surely getting more acquainted and interested [24] [25] and some governments (the Netherlands, Norway) make hybrid and electric cars financially attractive. Exactly here you find that electric cars do well (for example the Tesla Model S was the best-selling car in Norway in September 2013 [26]).

People are increasingly interested in electric mobiliy

The biggest change in use of cars is without a doubt car-sharing. Although people use it for practical and/or financial reasons, it results in a situation where a relatively small amount of cars is frequently used, rather than a huge amount of cars that usually stand still. This can ultimately reduce the total footprint of cars in the urban environment.

Car-sharing fleets could reduce the amount of cars in cities

1.7 | Conclusions of the Analysis

Based on the analysis of the brand, the product, the user and the context, this conclusion summarizes what and why things changed. To link the analysis to the 4S challenges, each one is separately described.

SMART

The first smart successfully showed that a 2.5m car was possible. The cleverly engineered car managed to package all the necessary components within the width of a parking place, allowing parking crossways. Updating the car and making it US market eligible, resulted in a just under 2.7m second generation. Although it maintained the smart design qualities and was received positively as being more of a normal car than a toy, parking crossways became debatable. With the third generation, rearrangement in the package and more conventional engineering resulted in further growth. In order not to surpass the 2.7m length (too much) it had to grow in width and volume.

Cities become more crowded and parking is increasingly challenging. Therefore the benefit of having a super compact car is more than useful. Because regulations and expectations of safety and quality are unlikely to drop, cars will tend to grow further. The smart brand profits from being the exclusive provider of a car that is ‘unschlagbar parkbar’, therefore an investigation must show how the smart can retain its compactness without compromising driving experience and comfort in the future.

SAFE

Daimler justly decided to make the smart as safe as other cars on the market in order to be taken seriously. Within the package of the 2.5 car, smart managed to deal with European safety criteria for occupant protection, mainly by using a rigid steel cell (Tridion) and a good crash absorption structure. To make the smart US-eligible, larger crash constructions had to be used, which was the leading factor in the growth of the second generation. Because the third generation has to deal with the European regulations on pedestrian protection, the front end has grown in volume.

An investigation will be done to identify with what elements the world-wide safety criteria can be met, without compromising the compact package that is aimed for.

STRATEGY

The first smart was specifically designed as a stylish and individual car for Europe. Next to the fortwo coupé, also a convertible was made. The colour combinations and exchangeable body panels were meant to attract as many as possible customers. From the second generation, also an electric version was derived. Also, the CAR2GO service was launched in order to provide urban mobility to more people, which has been a good step, considering the brand motto of being more than a car manufacturer, namely provider of unique urban mobility.

It has been identified that smart has three mayor customer groups: PRIVATE, COMMERCIAL and CAR2GO. The rapidly growing CAR2GO fleet and the 50-50 relation between privately and commercially registered vehicles make each of them equally important. In order to address to the different customer needs and stay competitive in the market, smart needs to be able to easily create dedicated variations of the smart, each based on the core qualities of smart fortwo, but modified to specific needs. Therefore smart has to create derivatives. This can be seen as vertical deviation: flexibility within a contract segment, instead of flexibility in all directions.

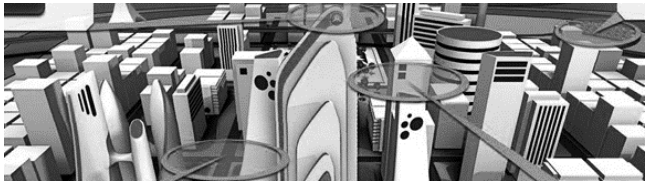
STYLE

The stylish appearance and ability to individualize the plastic body panel system put smart ahead of its competitors with the first generation. But because it is currently hardly used by customers and since there is no business in it for smart, the custom body panel system was discontinued with the third generation. People do like to make things individual, but it is mainly being done on a different level, namely more with gadgets and within digital environments. Therefore it is key to explore a new way to provide individuality in mobility, which puts smart back in front compared to cars like the Citroën DS3, Mini Cooper, and Opel Adam etc. that also offer two-tone exterior colour combinations.

Next to individuality, the strong design qualities of smart need to be maintained in order to keep the brand highly recognizable and true to its core qualities. Among them are of course the Tridion, the plastic, resilient layer around the car and its proportions and stance.

PART II: DREAM

2.1 | The future urban context



In this part of the report the contemporary context is being extrapolated towards the context of the smart 45XS. The 45XS is expected to 'live' between 2020 and 2030, so that is the context this project focusses on. By using the same four factors as before (URBAN LIFESTYLE, BEING MOBILE, HEALTH & SAFETY and ENVIRONMENT), the new context is described and related to smart. [27] [28] [29] [30]

URBAN LIFESTYLE

In the following decades urbanization is expected to continue, creating more and bigger cities and mega-cities (>10,000,000 habitants). Especially in economically developing countries – where agriculture-economy shifts to a mass-production, technology and service based economy – many people will migrate from rural areas to urban agglomerations [31]. In this continuously growing mass, people try to find their personal space and identity. By being connected through mobile electronic devices, people identify their various 'social groups' they operate in within the crowd, basically by being blind for what happens around them and relying on personal devices. Technologies like augmented reality (e.g. Google Glasses) and next generation OLED and wireless communication make the virtual life an integral part of real life.

Being connected through various personal devices

Being an exemplary person will be important for acceptance in social groups. The digital personalities, or avatars, that people use in communication tools are reflections of ideal self-images that are fed by positive actions and experiences. People will look for them in daily life in local urban- and natural environments. Therefore they are making quick and impulsive decisions.

People will organize products and devices around them according to how they prefer to interact with it. In crowded places, intelligent systems allow devices to be used by different people to, by simply adapting to this person's individual digital preferences. This trend is characterized by products that are more standardized from the basis, but have a layer of interchangeable, usually digital elements that determine the interaction between people and product.

BEING MOBILE

In order to cope with the increasing amount of people travelling towards the same destinations, certain automated traffic flows are used to deal with this. Commuter- and commercial traffic increasingly uses autonomous mode to bridge long distances. Besides, large non-residential areas are isolated from private traffic and use well regulated public mobility solutions.

Public car-sharing services will serve millions of people who use it mostly alongside public transport, creating a widespread network of mobility solutions. Also, communities are created that solely use a 'reserved' fleet of shared cars. These communities are combinations of residents and offices, enabling their fleet of cars to be always flowing between the communities, instead of shifting from residential areas to office areas without them being used in the meanwhile.

Being mobile in the city means using a combination of means of transportation, dependent of particular preferences and time-efficiency. Travelling is usually planned last-minute, relying on instructions given by digital devices.

HEALTH & SAFETY

Next to looking for good experiences, people continuously are informed about healthy and safe choices. People rely on being informed correctly and collect lots of information in order to make conscious choices in life.

As ever, safety is a key factor in mobility. The focus for car manufacturers lies at complex crash-prevention, using advanced sensors and algorithms in order to warn and correct drivers. Next to real-time danger recognition, cars communicate with other cars and road users, in order to monitor and control potentially dangerous situations before they can exist.

Cars communicate with each other

ENVIRONMENT

The world tries to manage the environmental consequences of the enormously growing industry in developing countries. The high density mega-cities (especially in BRIC countries) require different mobility systems, focused on time- and energy efficient mass-transportation and excluding private traffic in certain areas. This will be a combination of line services (trains, subway, busses) and a continuously flowing fleet of publicly usable vehicles.

In large European cities (also compact, but more scattered) the focus is on creating a healthy local environment. Combustion cars are discouraged or banned (to a certain level), creating zero-emission zones and therewith improving the overall air quality. Each city strives to be an exemplary establishment, since they are being subsidized by (European) governments.

In residential rings around city centres, zones are created with the people centred; a high quality of life is translated into more green and recreational areas, putting the car on the background. Urban cars are designed more as honest and practical products that are helpful and useful rather than an obstacle.

Green zones for people and isolated roads

2.2 | The user in the new context

In this part it is described how the smart user fits in the new context, and what the smart means to them. The three user groups are again used to distinguish their various connection with smart.

The PRIVATE smart user

As a private car, the smart is the ultimate experience of practicality and joyful driving. Within the creeping traffic, fun at low speeds is what makes driving a smart enjoyable. The smart thanks its practicality to its footprint and easy accessibility. Also, the interaction with the smart is completely according to the customer's satisfaction.

To complement the customer's positive life experiences, he or she chooses a smart that best fit their lifestyle. Some are more practically oriented and choose a coupé type which usable in all weather conditions. Others choose the more fun side and like to have a more open-top experience when the wetter is good.

The private smart is the car that creates joyful experiences and evokes social interaction with other people. The private smart is ideal for the user that wants to have a practical, personal vehicle that is always at their disposal for commuting and various other activities.

The COMMERCIAL smart user

The commercial customer is attracted by smart because of the urban efficiency in both consumption and practicality. Especially door-to-door services and fleets that move within a large urban environment profit from a compact and agile vehicle that is customized to their tools and needs.

Above that, more interactive ways of communicating company advertisements and services make smart very interesting for small and medium sized companies.

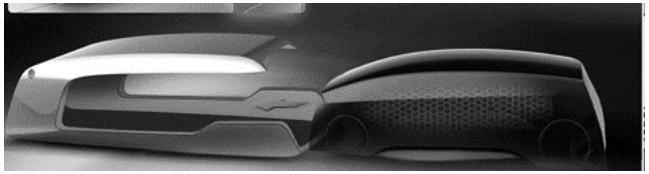
The CAR2GO user

Millions of people will make use of the CAR2GO system in the future. These free floating fleets exist of various smarts, therewith offering functionality on demand. The CAR2GO user relies on continuous availability and uses the program in combination with public transport and first-and-last-mile solutions (e.g. foldable bikes or electric rollers that can be folded, stored and transported).

The CAR2GO user also carries around a personal digital environment, to which the cars quickly adapt, providing them an individually configured and comfortable ride.

Since the owner of the CAR2GO fleet is not the driver but mostly the city or municipality, they are also used to boost the image of the city through public functionality and advertising.

2.3 | The Far Future smart

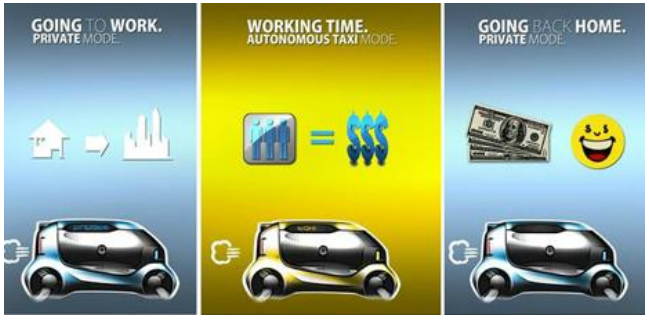


As provider of unique urban mobility, smart gets a new role in the future context. With people being increasingly mobile, independent and making quick and impulsive decisions, the function of the car must adapt to that.

The following paragraphs are a selection of interesting thoughts for a future smart car that fit the brand character. They are not per se technically feasible, but show how the fourth generation smart could ultimately be used, envisioning its life up to 2030.

Double purpose

Most cars stand still the gross of the day. smart cars are always on the move. A private smart could do some 'work' when the user does not need to drive it. During work for example it goes into autonomous mode and can function as a taxi or delivery van. This would mean that you could give your car assignments and have it do something for you, or provide something for others, in return for money. [32]



Cars could do autonomous chores in return for money

Dress for the occasion

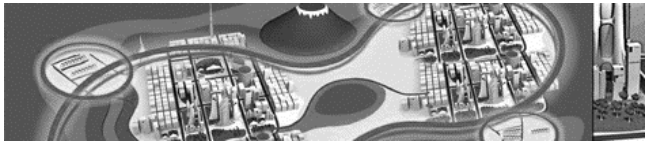
Using urban mobility exactly like you need it: all the necessary functionality and nothing more. smart is the brand that allows people to choose between variations of the car. Commuting to work alone, going out with your partner, cruising through the 'Schwarzwalt' or moving to your new apartment: the right smart is always there. In autonomous mode, a fleet of shared cars can change their module, for example providing commuter smarts during rush hour, delivery and service smarts during the day and taxi-mode smarts at night. Depending on for what or by who the smart is used, it adapts functionally (features) and emotionally (settings, appearance).

Giving back to the city

The development and integration of computer technology in cars has led to ideas of multifunctional cars. With integrated exterior displays and communication systems, cars could have an added value on the streets of the city. They can for example feedback information about the environment to people on the street, show commercials, allow on-the-spot online shopping or even recognize a person in distress and inform the authorities. This way a parked car becomes a useful aid in the urban environment. [32]

Cars could have be function for other people too

2.4 | Conclusions Dream



The outlook to the future of urban mobility gives a rough idea of the future context. The extrapolation of today's trends shows what will be important for the 45XS concept. To briefly conclude this chapter, each of the 4S-pillars is being described.

SMART

Since city traffic is becoming denser and people's agendas tighter, it is key that an easy parkable car is highly practical. The ability to egress and ingress quickly and easily is also part of smart parking.

SAFE

Most important factor of safety is to have the driver keeping attention on the road and other users. Sensor systems will aid and mitigate when necessary, but the main function of intelligent safety systems is to monitor and inform the driver.

STRATEGY

To serve people in various actions, it is desirable to provide various functionalities within a mobility system. A selection of derivatives within a car-sharing system for example will attract more people to use such a system because of its all-round functionality.

STYLE

People are used to digital features and create a virtual layer around them. In order to make people comfortable in a car, a feeling of individuality adds to the positive experience of driving a smart car.

PART III: INVESTIGATE

3.1 | ‘4S’ Investigation

Building on the prior parts, investigations are done in order to design the 45XS concept, built on the 4S-pillars. To meet the goals of the four challenges, the following things were investigated:

SMART

On top of the analysis of the basics of the fortwo, a more detailed package analysis (‘lessons learned’) was done to identify what particular components were key in the development of the current generations. Using this knowledge and looking into general development of car elements, it was identified with what components a smart under 2.6m package can be achieved.

SAFE

In order to make the 45XS safe too, an analysis of the context of safety was done to determine what facets and which stakeholders play a role in safety. Subsequently it was investigated how smart deals with crash and safety, and how that influences the package of the 45XS.

STRATEGY

It is also being investigated how to best create derivatives in order to create a saturated smart portfolio to offer the three user groups, based on a concept that always provides the smart quality and safety.

STYLE

While conserving the core design qualities of smart, a new design hierarchy is looked for; integrating a reinterpretation of individualization and modular flexibility.

The following chapters describe each of the four investigations.


step 2/4 derivative module
step 3/4 exterior character
step 4/4 mood expression

3.2 | SMART

From the analysis it was concluded what drove the changes in the smart's packages. It is clear that the length of the car is a communication tool for the brand, since it makes 'quer-parken' possible. However, for agility and the ability to park easily, also width, volume and weight are important dimensions for the car's compactness.

The package analysis showed that applying conventional and cost-cutting engineering will not result in a shorter car. Therefore the focus of this investigation is on showing what is needed for an ideal package, rather than a focus on cutting costs.

With the use of CAD-data [33] and documentation [34] of the 451 and 453 packages, the most important elements of the package were identified that caused the changing package. They are:

Larger engine

Because the fortwo 453 is a shared platform with the Renault Twingo and smart forfour, the carried-over engine compartment must fit Renault-built three and four-cylinder engines, making it substantially larger than the 451. This forced the back wall of the passenger compartment forward [Figure 3.01].

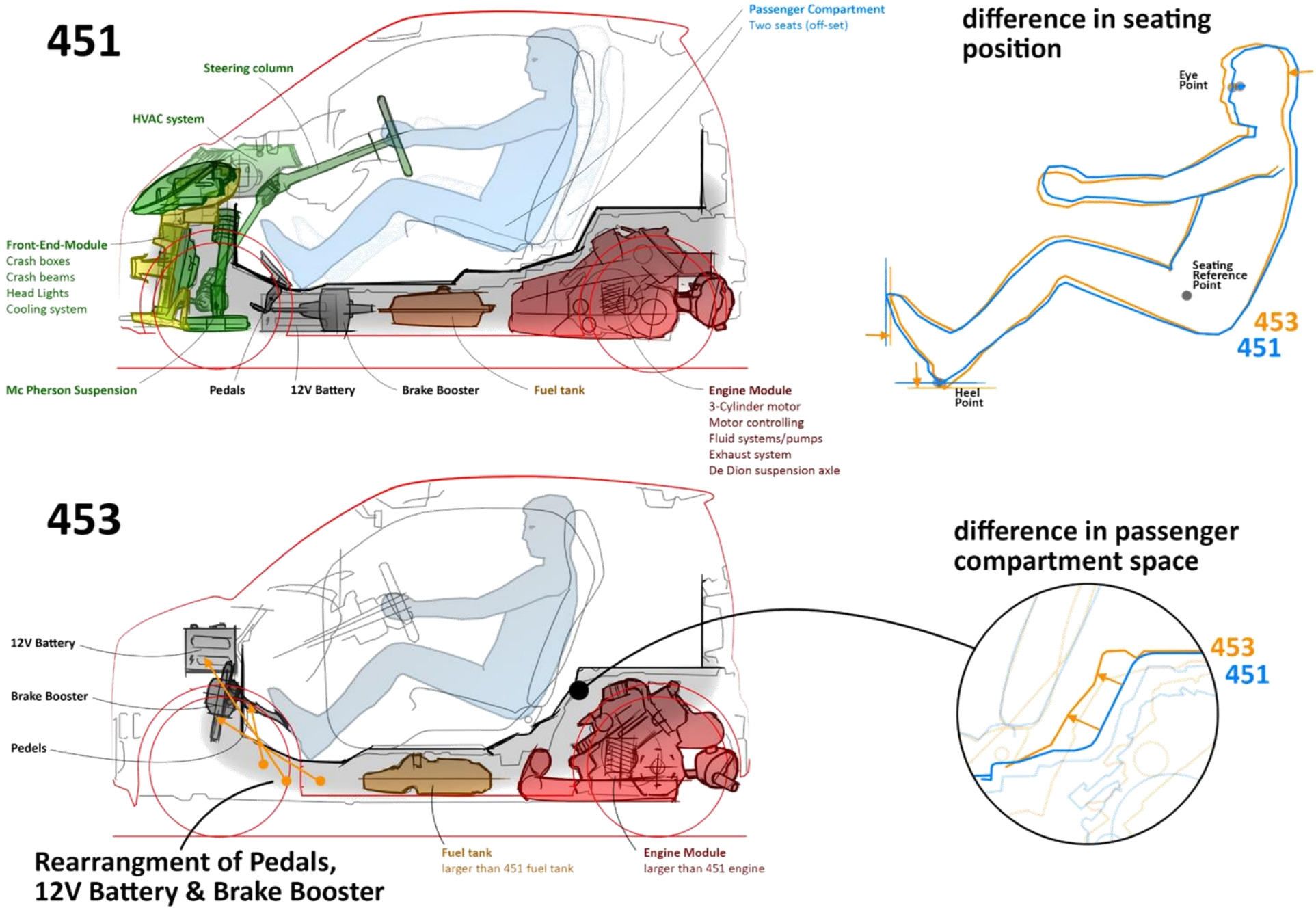
Seat position

Due to the latter, smart was forced to put the seats next to each other, forcing them outward and making the car wider [Appendix 1]. To minimalize the length, the seat position was slightly altered, making it more upright. Therewith the firewall could be slit backwards. To keep the car in proportions (limiting the height), the space for the driver's feet was lowered into the floor [Figure 3.01].

Relocating components

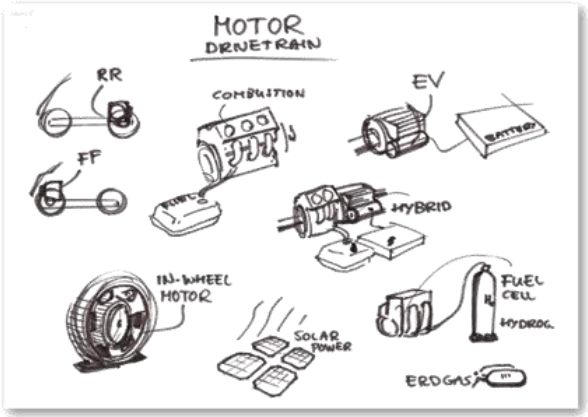
Due to the latter, the floor did not contain enough space for the brake booster, pedals and 12V battery, which were all relocated to the front area [Figure 3.01].

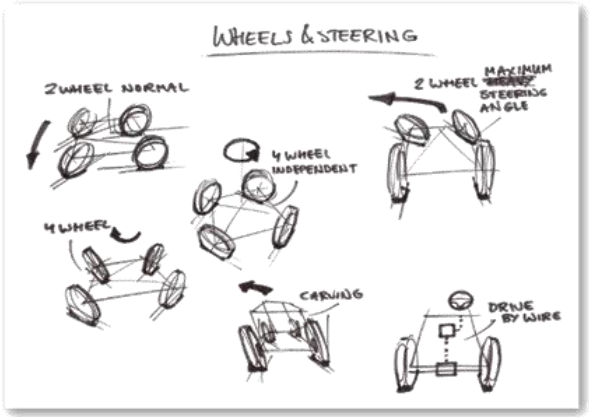
Figure 3.01: main differences in package 451 and 453

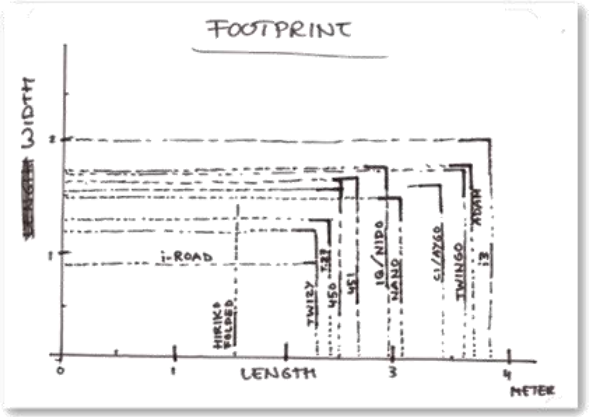


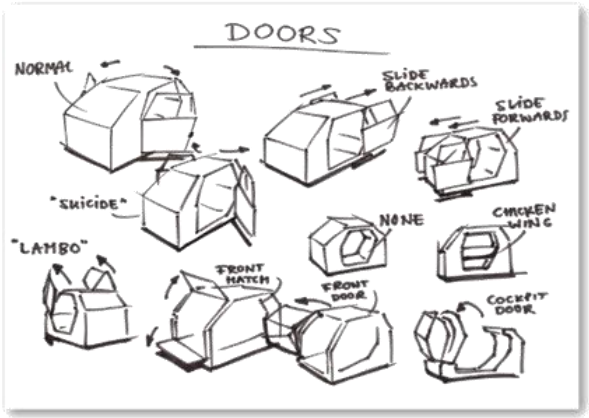
With the help of Packaging experts at smart and online research, it was identified which components are needed for the 45XS package. Within this project it was chosen to use the best of 451 and 453 as a starting point, and complementing it with elements to reduce the package to under 2.6m. New technologies that potentially downsize the package, were looked at and reviewed.

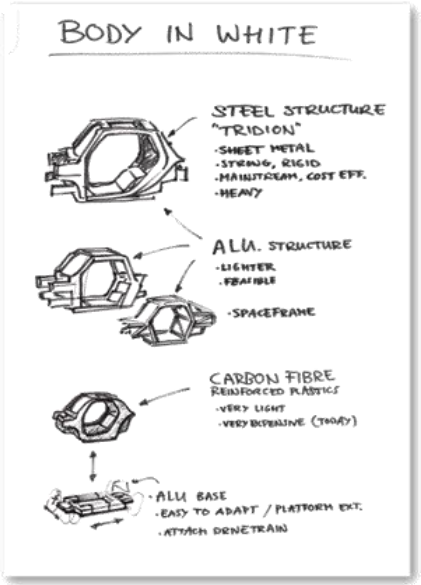
Morphological matrix helped identifying basic components

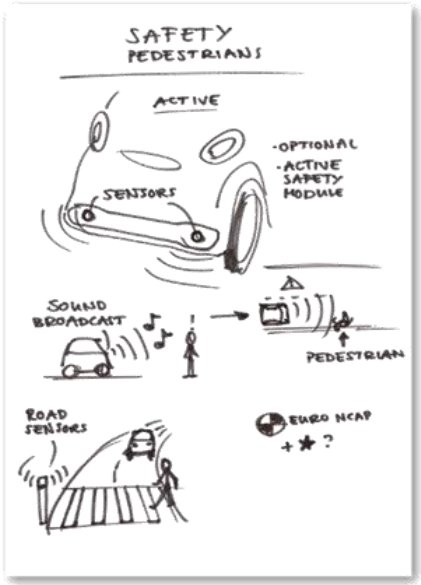


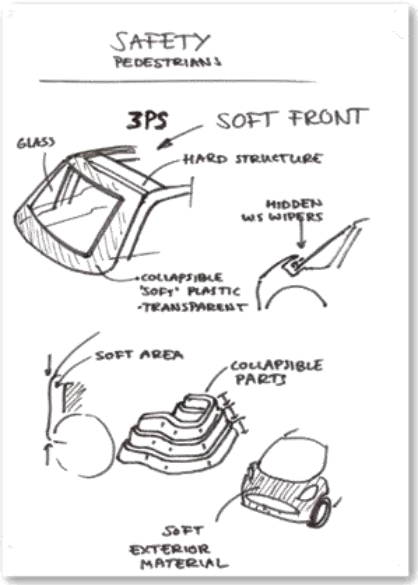












It was concluded that with the following leading elements, a package of 2555mm can be achieved [Figure 3.02 & Figure 3.03, next pages]:

Pure electric rear engine

Although debatable in the current market, it is assumed in this project that the smart 45XS concept is ideal for electric mobility. The investigation showed that the packaging space for an electric engine module [Figure 3.04] is considerably compacter and more flexible than a combustion engine package. Besides, it fits the future context in which electric mobility in cities will be stimulated or even the only way to go. Also, the driving experience of an electric smart has been received as very positive. Therefore the choice has been made to use a pure electric drivetrain.

In-wheel motors were looked at too, because of the obvious packaging freedom they provide [41]. There are however, too many questions about reliability and durability, e.g. due to the complications that concern spring-loaded and non-spring-loaded mass. [33] This therefore was assessed as non-feasible for the 45XS concept.

Figure 3.04: Electric engine module (smart 451)

Seat position 453

In order not to deteriorate comfort and adjustability (fitting the 95% percentile man), it was chosen to use the occupant space that is found in the 453.

'Square-parking'

Although the main goal was to create an under 2.6m length, the width is even so important if it comes to compactness for parking. Therefore, to compensate for the gained width that comes with the parallel seats, the smart 45XS uses a double-hinged door concept [Figure 3.05]. This creates a compact and more comfortable egression and ingression space [44], therewith making the smart truly 'unschlagbar parkbar'. With two open doors, the footprint of the car's dimensions is square.

Figure 3.05: Mini Rocketman double hinged door

Electric By-Wire systems

Various projects in the past (e.g. GM Hy-Wire concept) showed the packaging potential of by-wire systems. By-wire systems namely have one mayor advantage: the mechanical components are replaced with sensors, computers and actuators. For package space and crash management, this is very useful and it was concluded that the 45XS package needs these systems.

Looking into current development of drive-by-wire systems revealed that on a short term, production car approved components can be expected [42] [43] in the coming years. Therefore it was chosen to implement electric by-wire systems, therewith removing the brake booster and steering column. This solves the problem of the 453, where there was no space for these components in the floor.

Also, the 12V battery will be replaced by a more compact battery that is positioned under the driver seat.

Front-End-Module

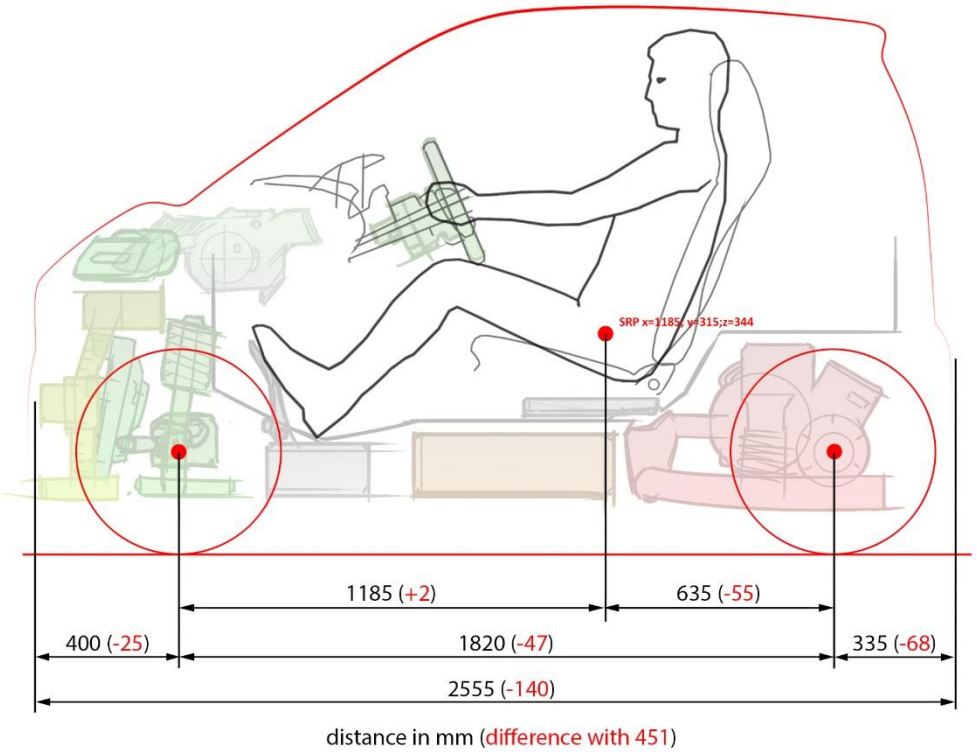
The FEM, as known from the 451 [Figure 3.06], will be used again as an integral carrier of crash structures and front end components, including LED head lights and a compact cooling system. With the use of the FEM the compactness of the 451 front end is regained, while at the same time improving its crashworthiness. [36]

Figure 3.06: smart 451 Front-End-Module

Minimal length, maximal wheelbase

For dynamic reasons the wheelbase should be as long as possible (in the context of the length of a smart). It was also decided that the wheelbase could not be smaller than that of the 450. Therefore the overhang will be minimalized and the wheel diameter may be no longer than 580mm.

Figure 3.02: package sizes side view and plan view



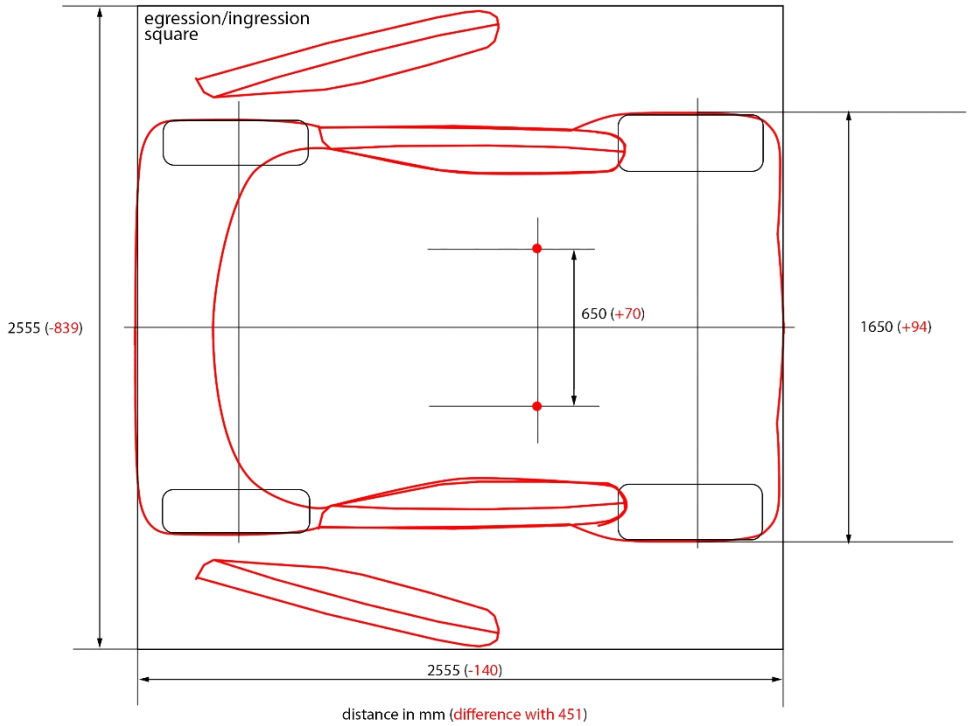
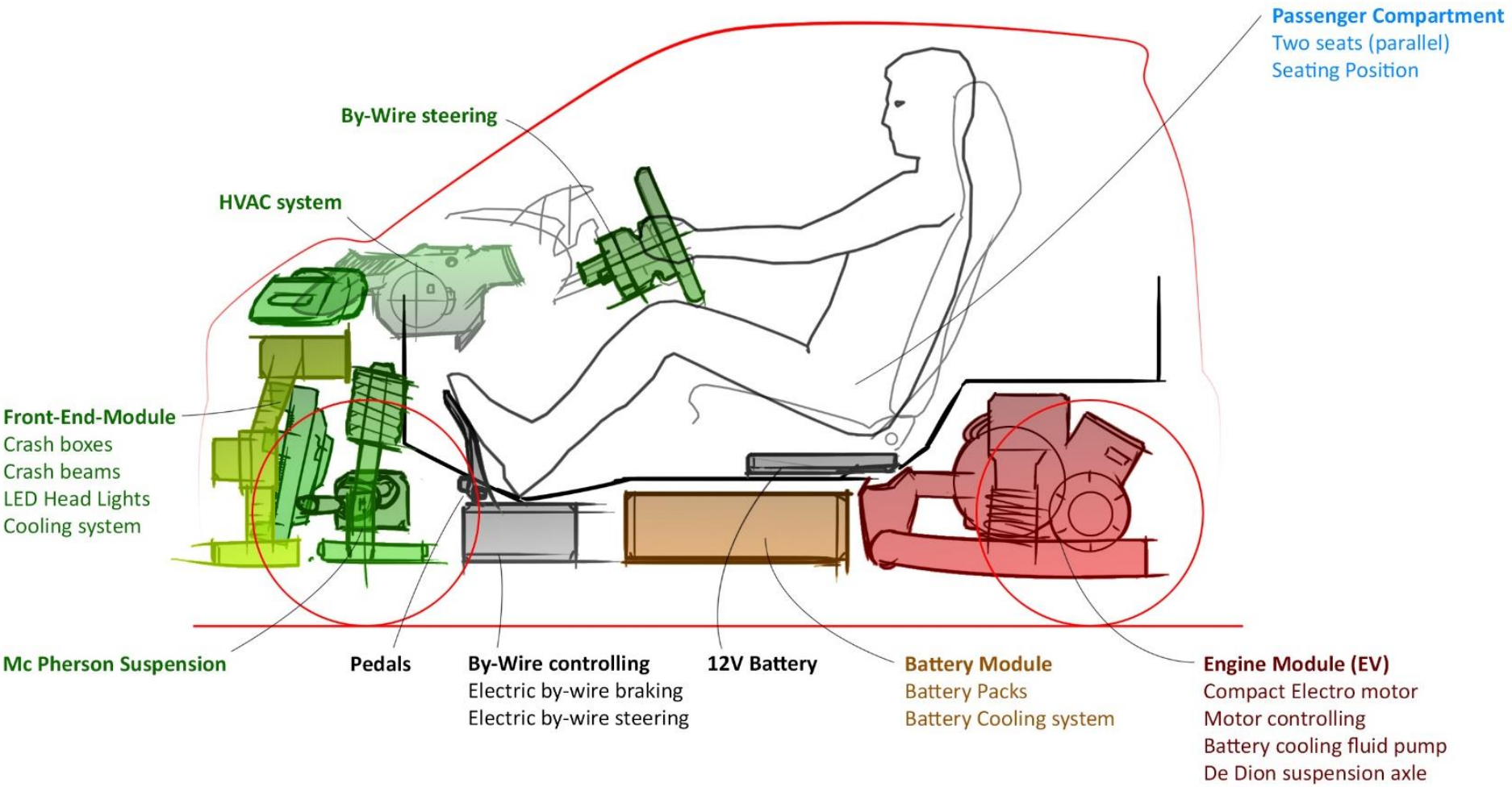


Figure 3.03: package layout side view



3.3 | SAFE

To ensure the safety performance of the smart car, it was investigated what has to be implemented to meet world-wide requirements and standards. It was concluded that the changes and differences in safety regulations were the driving reasons of the previous smart models to have grown in size. An investigation has been done to identify what factors are involved in crashes and which stakeholders are leading for car design. More about this has been documented in [Appendix 2].

It has also been investigated what factors in crash and safety influence and determine the package of the smart car. From previous research on pedestrian safety [35] elements were identified that were needed for that. Also, sensors and/or radars will be part of integral safety in the context of the 45XS concept and will therefore be integrated in the package from the start.

To describe the facets of safety, the three leading in crash testing and regulations are used: occupant protection, pedestrian protection and safety assists.

Occupant protection

From cooperation with experts at Daimler's crash and safety department [36] two main factors were identified: first the passenger compartment, which has to be rigid and prevent intrusion of objects; and second the package of the front-end, which has to be clear of 'block-builders' (hard objects that do not collapse and absorb energy) and absorb energy as linear as possible.

The passenger cell will be made from high strength steel, because of its excellent weight to strength ratio and lower costs compared to aluminum and carbon fiber reinforced plastics. Although lighter materials would make the car lighter, it was concluded that these materials are too expensive for smart [37] and that newer types of steel can already reduce the weight of the Body-in-White (BiW) with 10 to 20% [38]. The BiW is optimized for frontal, rear and side crashes as well as roll-over and roof drops.

In order to create an ideal absorption field in the front area, block-builders need to be replaced. Among them are the 12V battery, brake booster and steering column, which will all be relocated or replaced with electric by-wire systems.

Pedestrian protection

The investigation in pedestrian safety that was done at smart [35] resulted in a number of innovations that create a soft front end. These innovations [Figure 3.07] were carried over in the 45XS package [Figure 3.08].

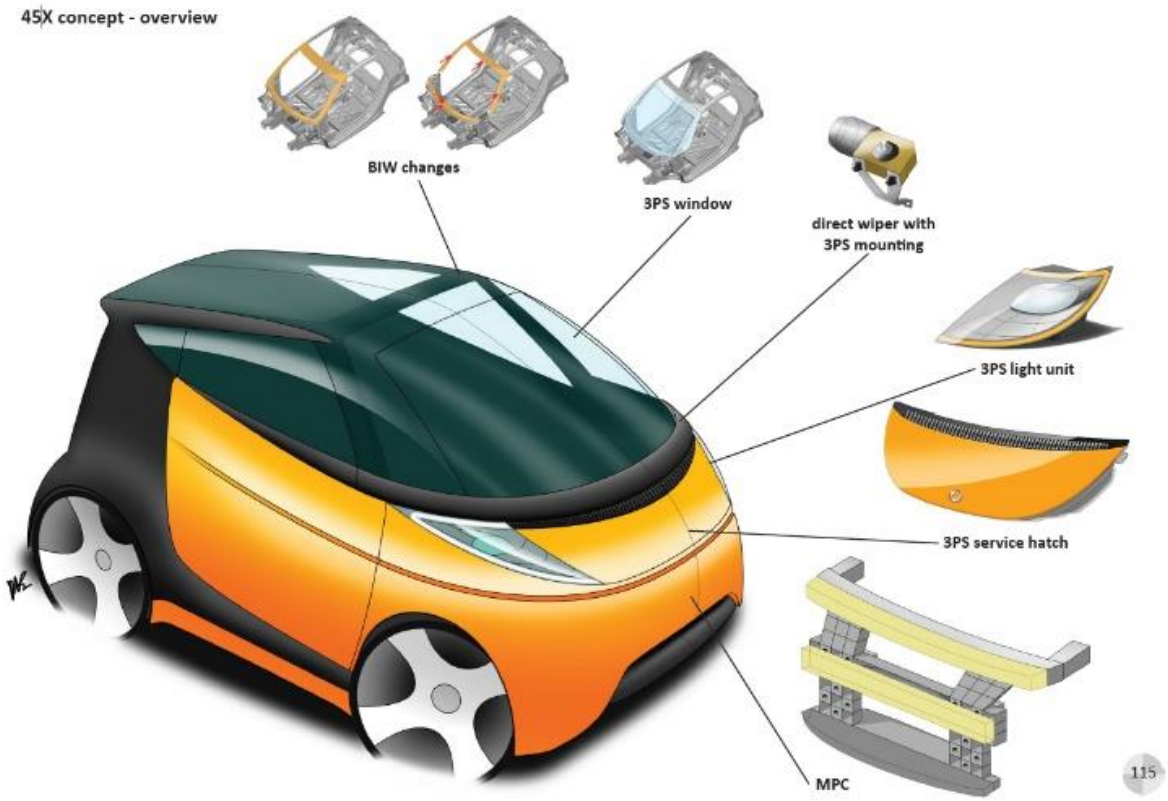
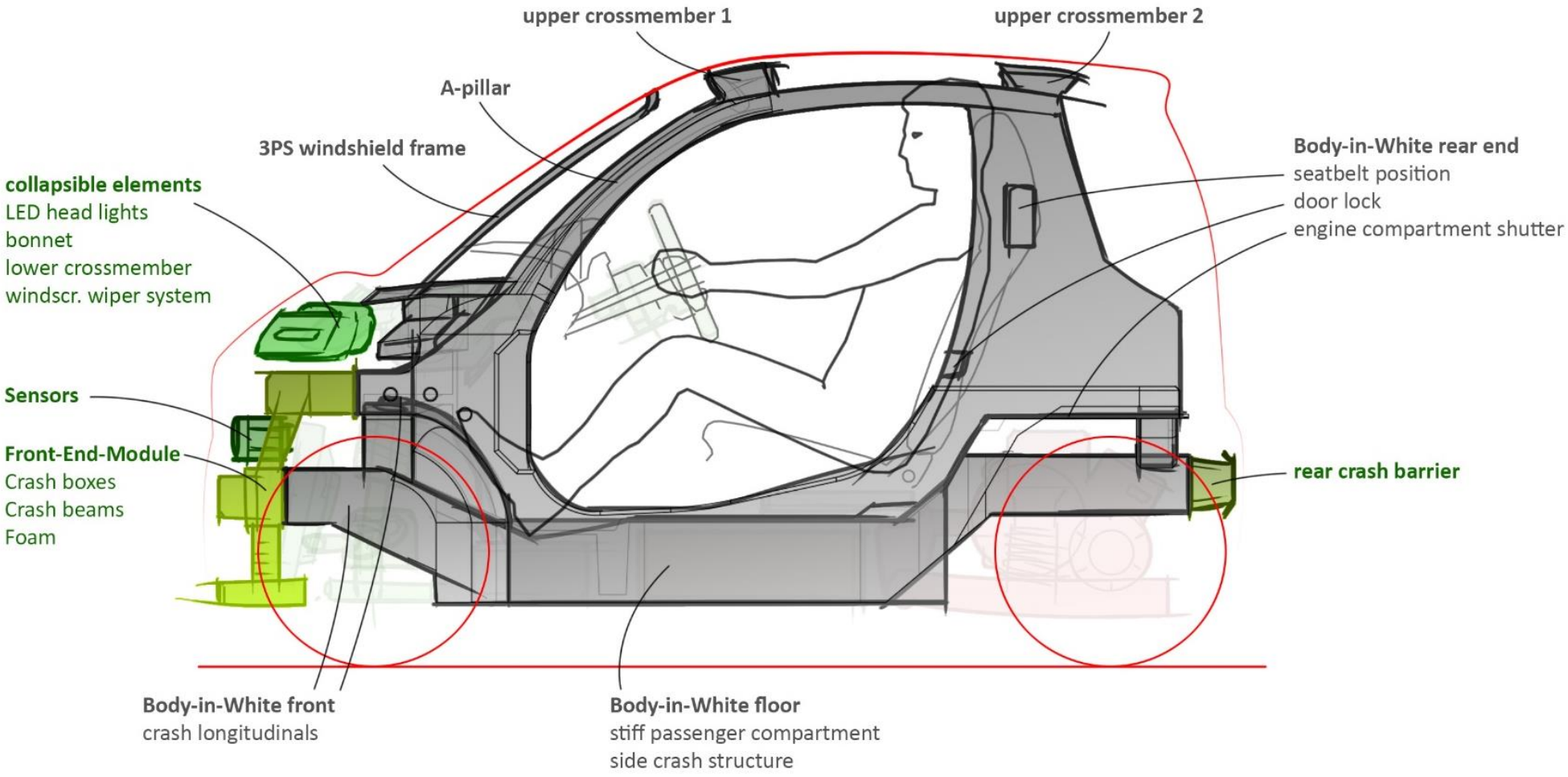


Figure 3.07: 3PS solutions by M. Ravestein, 2011

Safety assists

A new aspect of safety for smart are crash prevention systems. Currently on the market in many premium brands, but soon part of mandatory systems. Within this project it was determined that the package would get a 'reserved' area for sensors in the front end of the car. It is assumed that this space is sufficient for various cameras and or radars.

Figure 3.08: package layout side view



3.4 | STRATEGY

In order to boost smart's sales in the future, a different strategic approach is needed. For the 45XS generation, smart needs to address each customer group with dedicated products, since it was concluded that the three user groups: PRIVATE, COMMERCIAL and CAR2GO are equally important to the brand's business. Also, in order to compete with brands that use clever platform and component modularity, smart needs to diversify with its two-seater platform 'vertically' [see Figure 3.09].

Through brainstorming and sketching it was investigated what types of variations – or derivatives – smart needs. This was done by keeping in mind the three user groups, as well as the core smart qualities. Numerous ideas were found [Figure 3.10] and clustered.

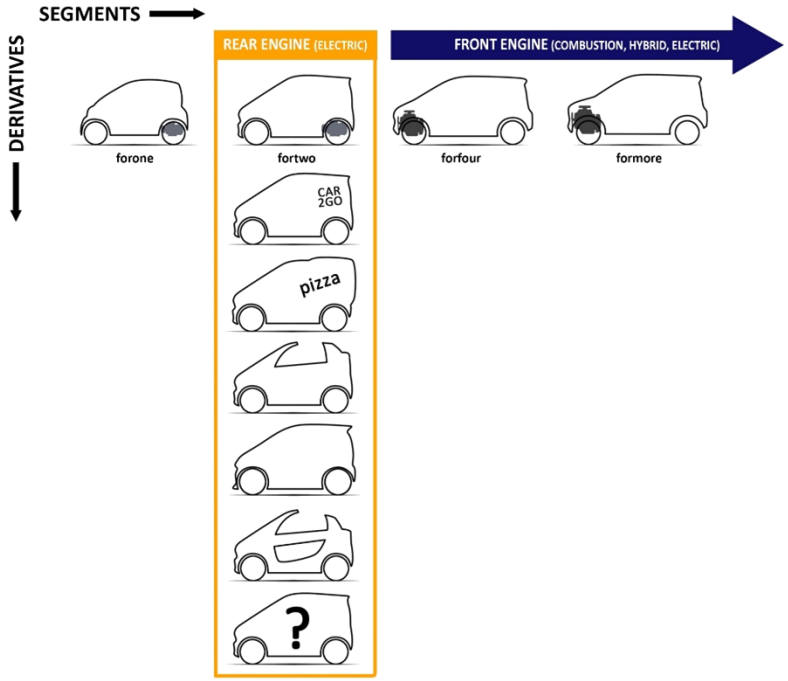


Figure 3.09: Vertical derivation of a single platform

Derivatives

In order to continue, it was determined that the flexibility of the concept has to be in the 'functional space'. In other words, the front end and powertrain layout remain equal in order to provide safety and compactness, and the rear end is modular. Therefore it was investigated with what technology flexibility could be created without compromising the SMART and SAFE package [Figure 3.11]. This resulted in the following conclusion:

Cabrio-based

Since the idea of this project is that creating derivatives as part of the strategy, it is key that each one has the same quality and safety performance. The flexibility that is needed however, means that the rear module (from the engine shutter up to the upper crossmember between the A-pillars) must be modifiable. From the two possibilities, it was chosen to go for cabrio-based, because of the full flexibility. The decisive factor was the flexibility, which is necessary to support the strategic backbone of the 45XS concept.

Figure 3.09: Various ideas for derivatives

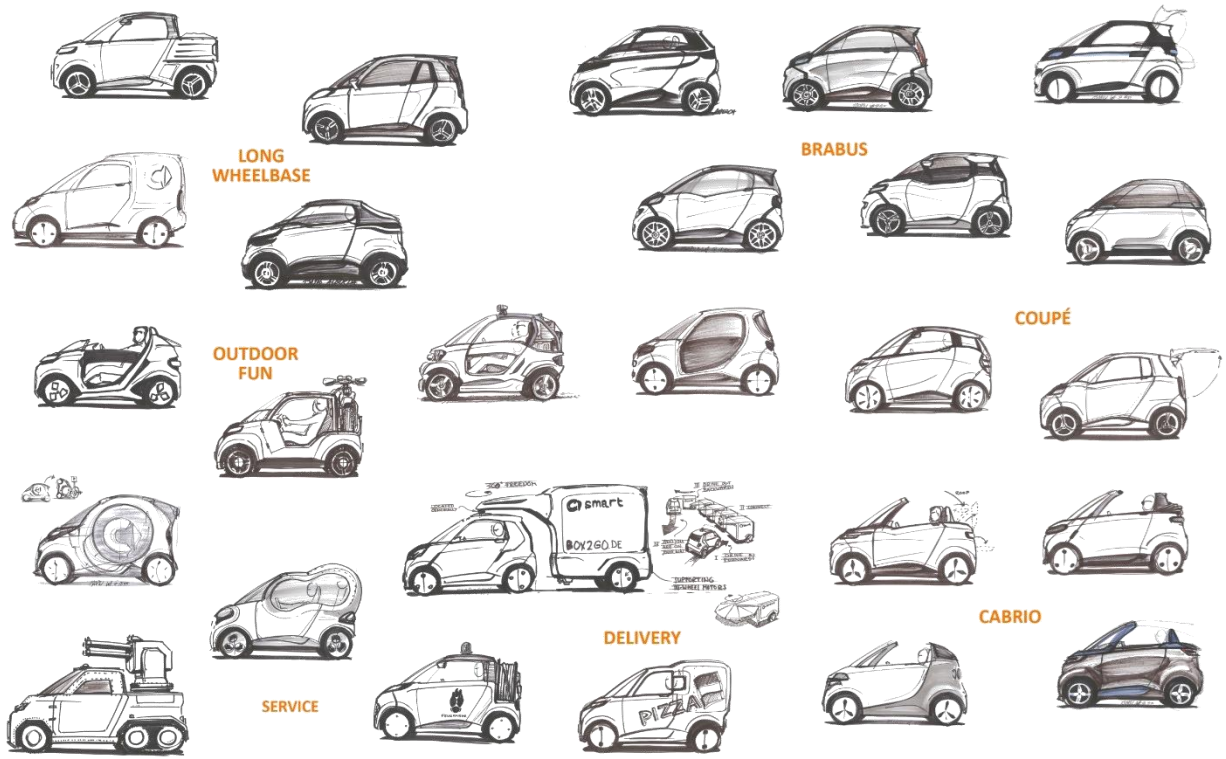
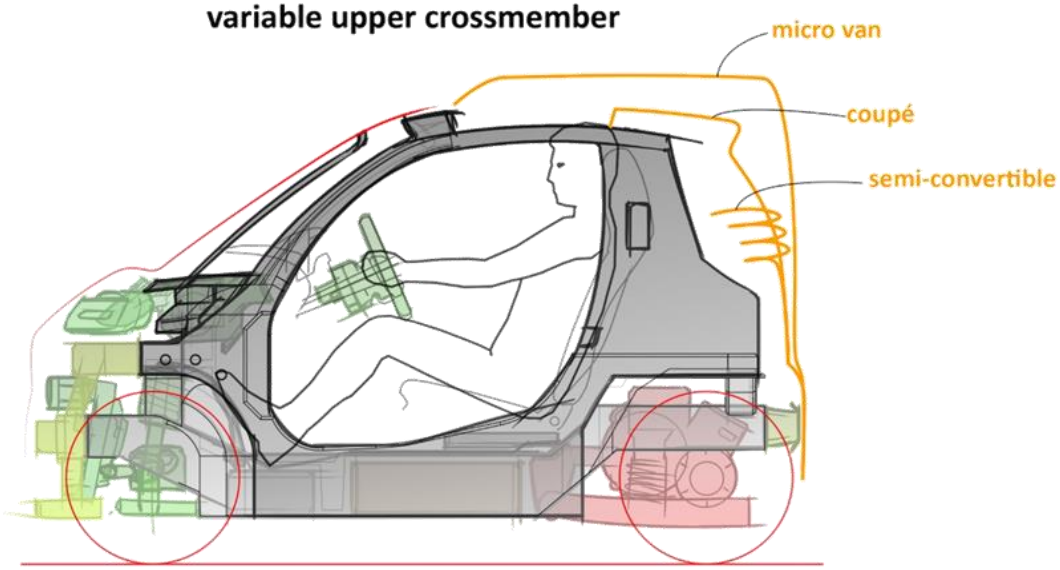


Figure 3.11: two options for flexibility

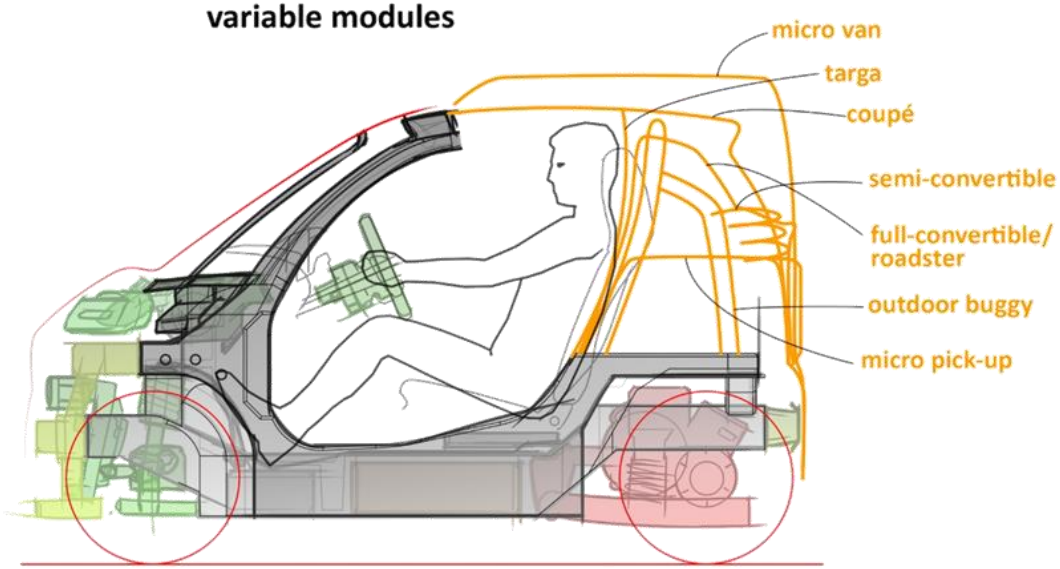
closed construction with variable upper crossmember



advantages
fully standardized structure
easier to optimize structure‘s weight

disadvantages
minimal flexibility
full-convertible types not possible

cabrio construction with variable modules



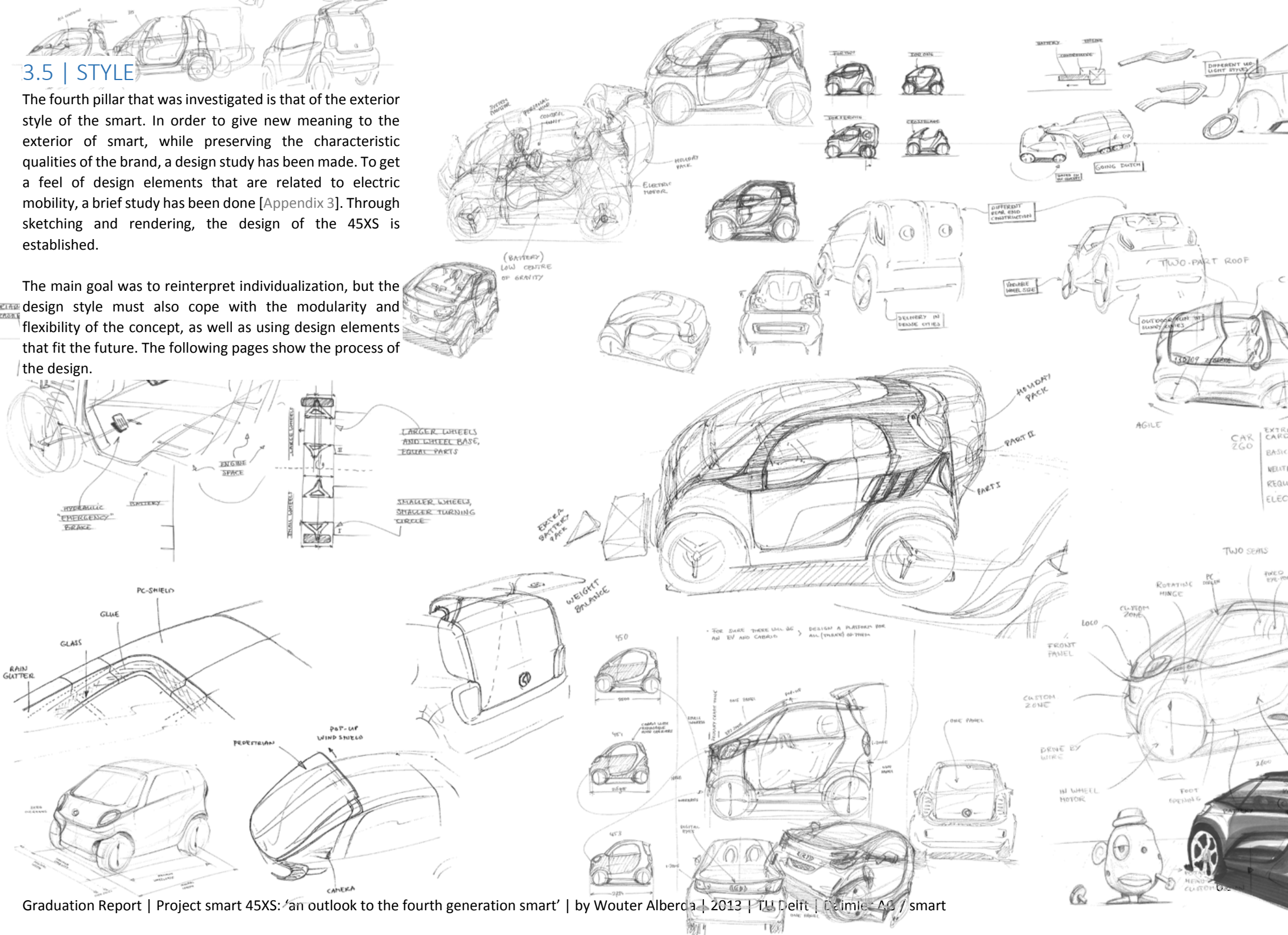
advantages
maximum flexibility
easy to create full-convertible types
lightweight modules lower center of weight

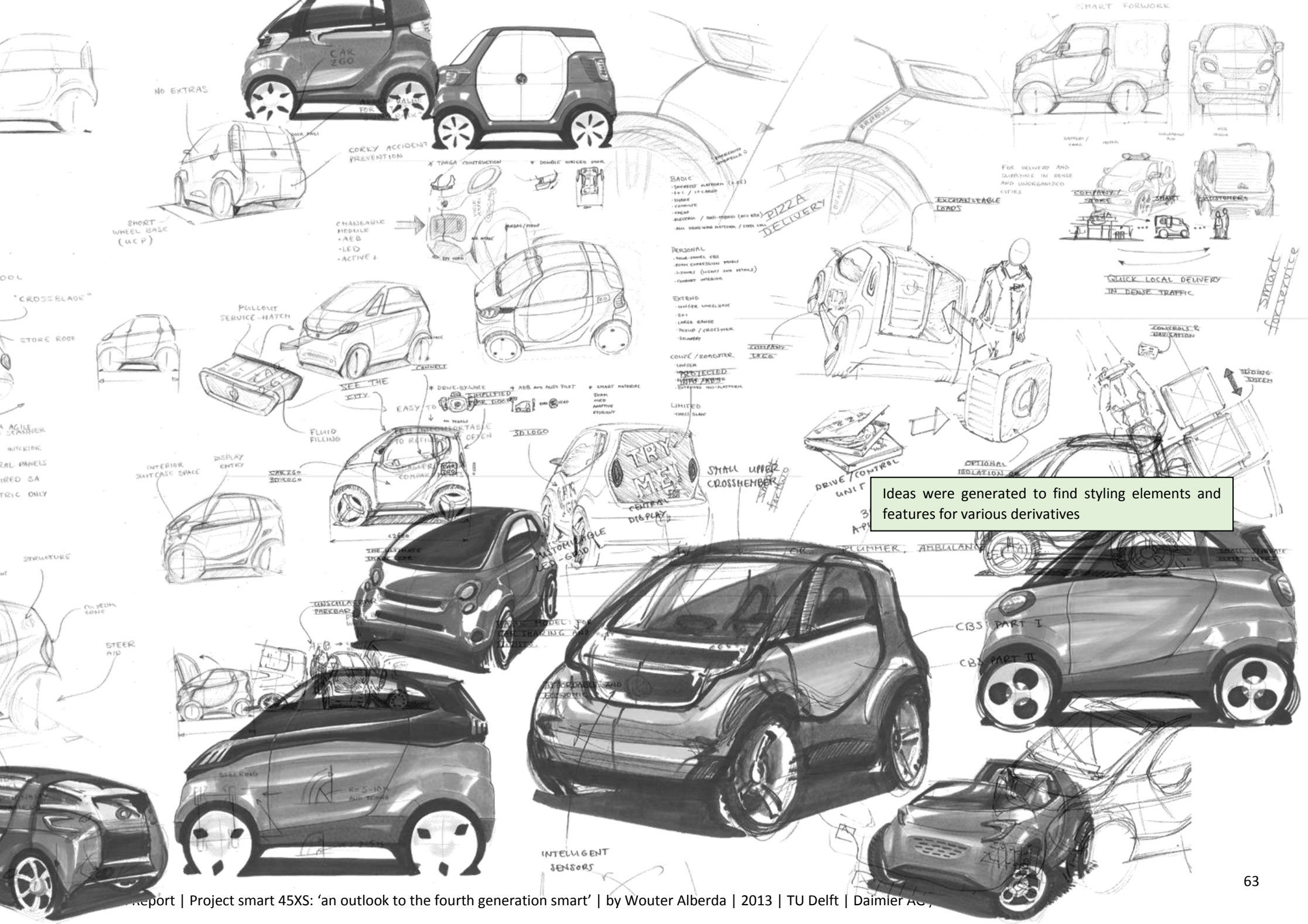
disadvantages
less standardized structure
derivative module requires structure

3.5 | STYLE

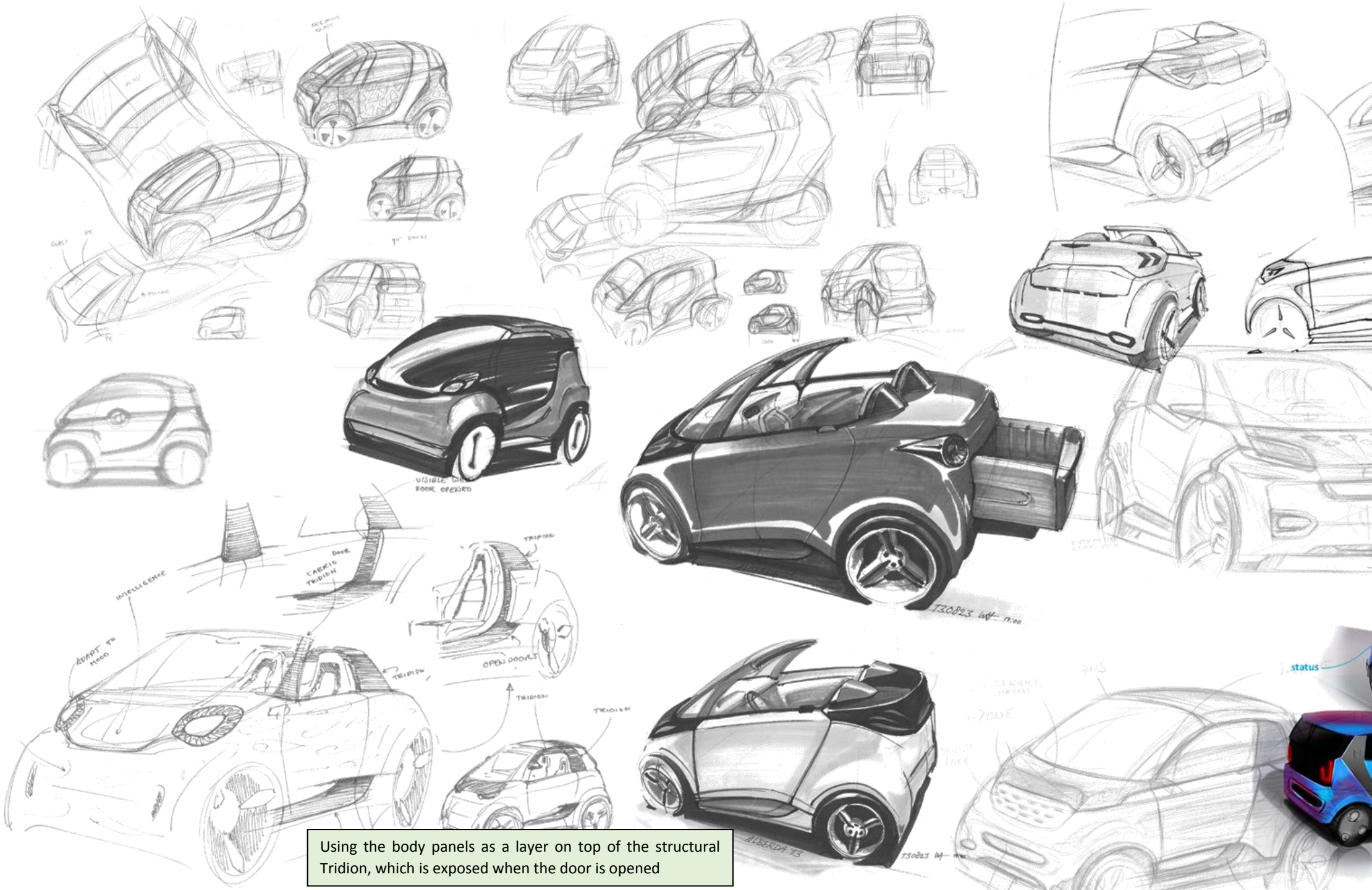
The fourth pillar that was investigated is that of the exterior style of the smart. In order to give new meaning to the exterior of smart, while preserving the characteristic qualities of the brand, a design study has been made. To get a feel of design elements that are related to electric mobility, a brief study has been done [Appendix 3]. Through sketching and rendering, the design of the 45XS is established.

The main goal was to reinterpret individualization, but the design style must also cope with the modularity and flexibility of the concept, as well as using design elements that fit the future. The following pages show the process of the design.





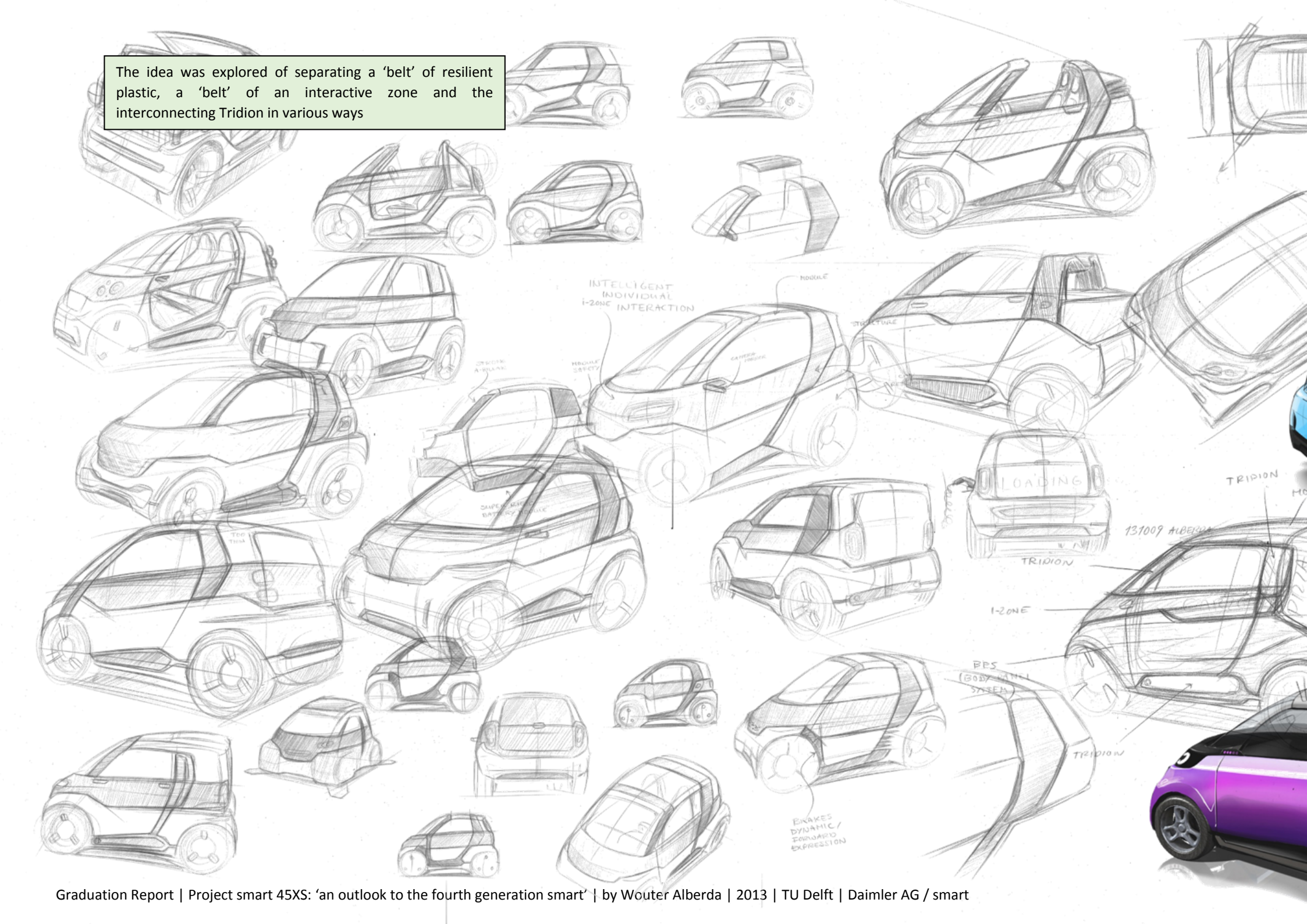
Ideas were generated to find styling elements and features for various derivatives

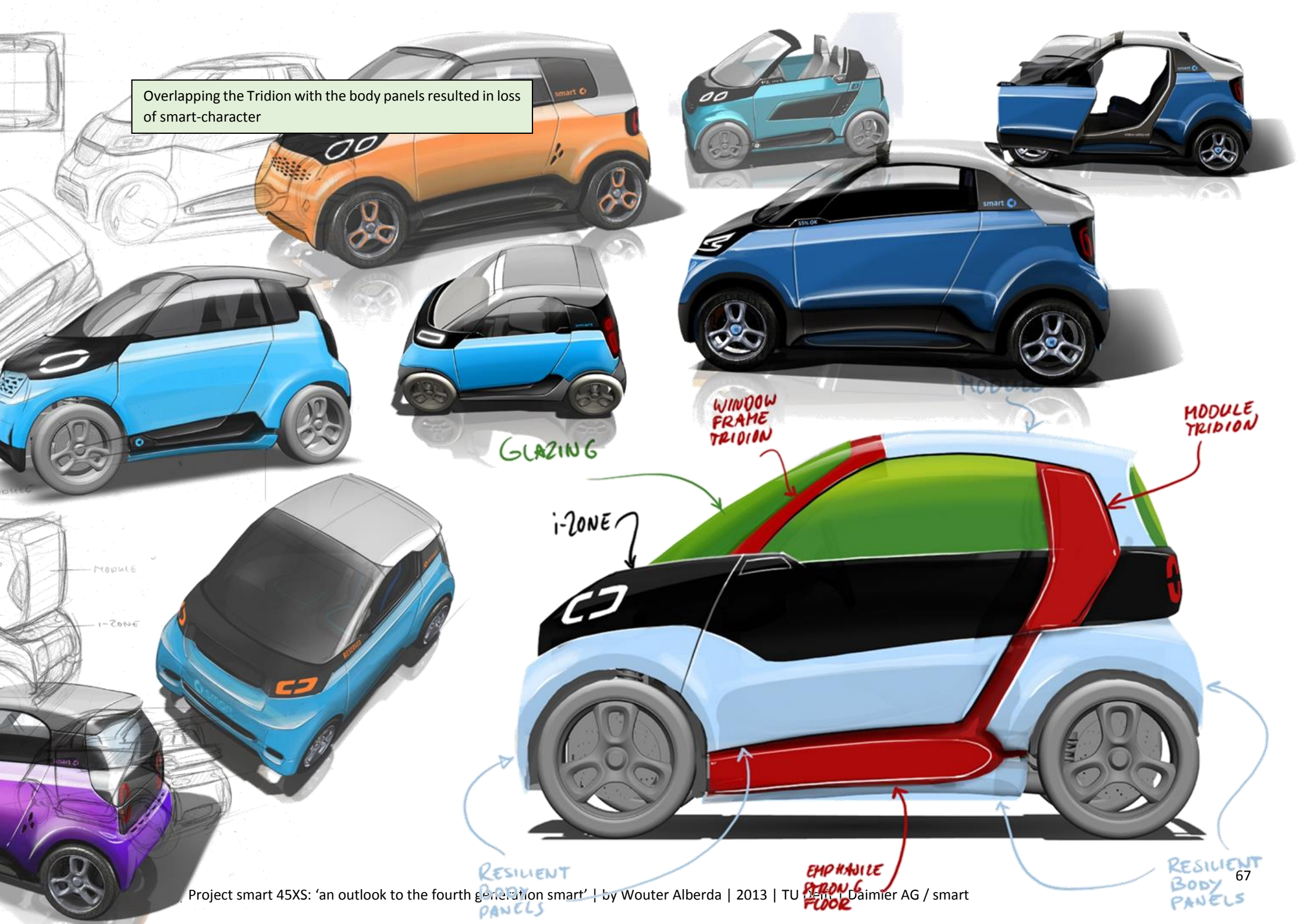


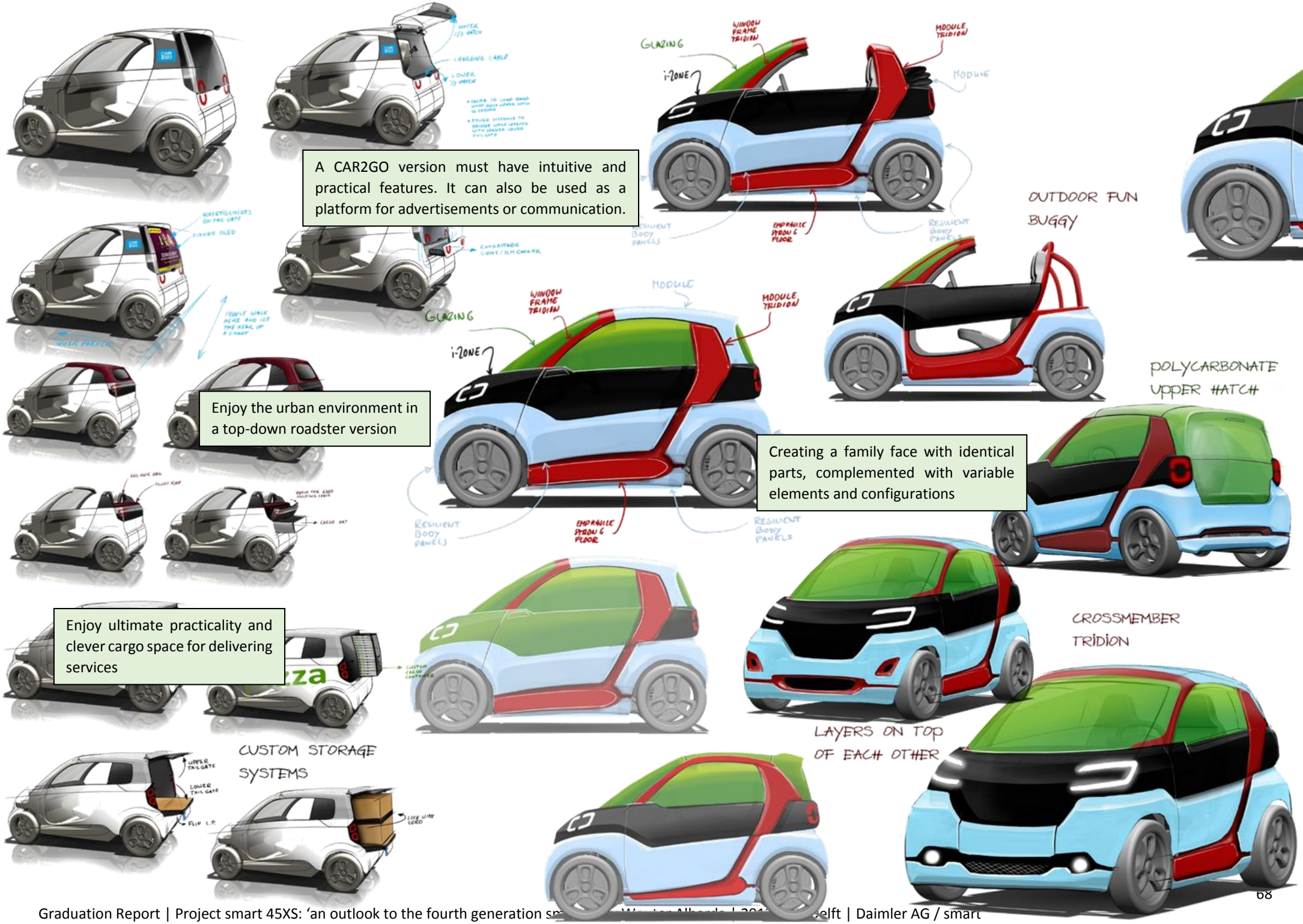
Using the body panels as a layer on top of the structural Tridion, which is exposed when the door is opened

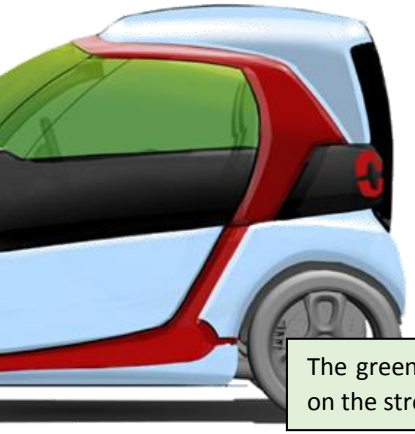

STEEL
GLAZING
CBS
i-ZONES
RESILIENCE
Various features and styling elements were explored to distinguish derivatives from one another.
LONG WHEELBASE
BRABUS
OUTDOOR FUN
DELIVERY
SERVICE
intelligent zones
advertiser
enticements
try me!
Certain zones were identified where the car interacts with its environment
SMALLER DOOR FOR "SQUARE" PARK.
BETTER VIEW
3PS W.S.
TWO-TONE
MORE FORM FREEDOM
FRIENCY EXPRESSION
TRIDION REFERENCE
SMART SENSOR
smart

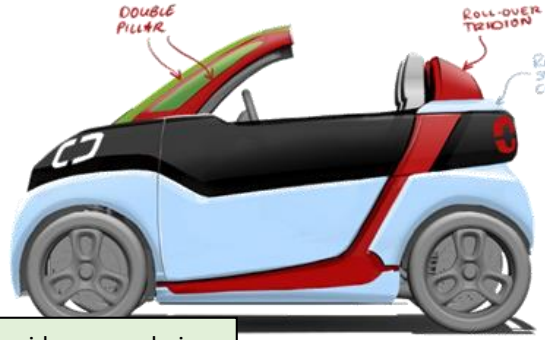
The idea was explored of separating a ‘belt’ of resilient plastic, a ‘belt’ of an interactive zone and the interconnecting Tridion in various ways

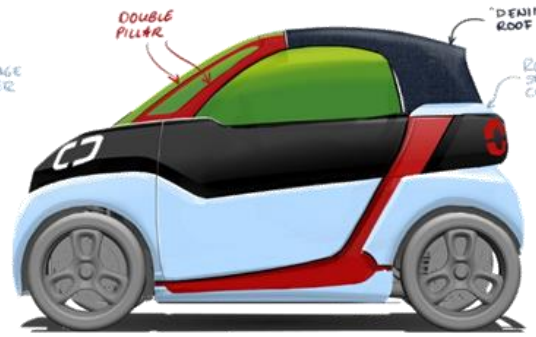



Overlapping the Tridion with the body panels resulted in loss of smart-character
GLAZING
WINDOW FRAME TRIDION
MODULE TRIDION
i-ZONE
RESILIENT BODY PANELS
EMPHASIZE BRONG FLOOR
RESILIENT BODY PANELS


A CAR2GO version must have intuitive and practical features. It can also be used as a platform for advertisements or communication.
Enjoy the urban environment in a top-down roadster version
Creating a family face with identical parts, complemented with variable elements and configurations
Enjoy ultimate practicality and clever cargo space for delivering services
OUTDOOR FUN BUGGY
POLYCARBONATE UPPER HATCH
CROSSMEMBER TRIDION
LAYERS ON TOP OF EACH OTHER
CUSTOM STORAGE SYSTEMS
GLAZING
i-ZONE
MODULE
WINDOW FRAME TRIDION
MODULE TRIDION
RESILIENT BODY PANELS
EMBRAILLE STRONG FLOOR

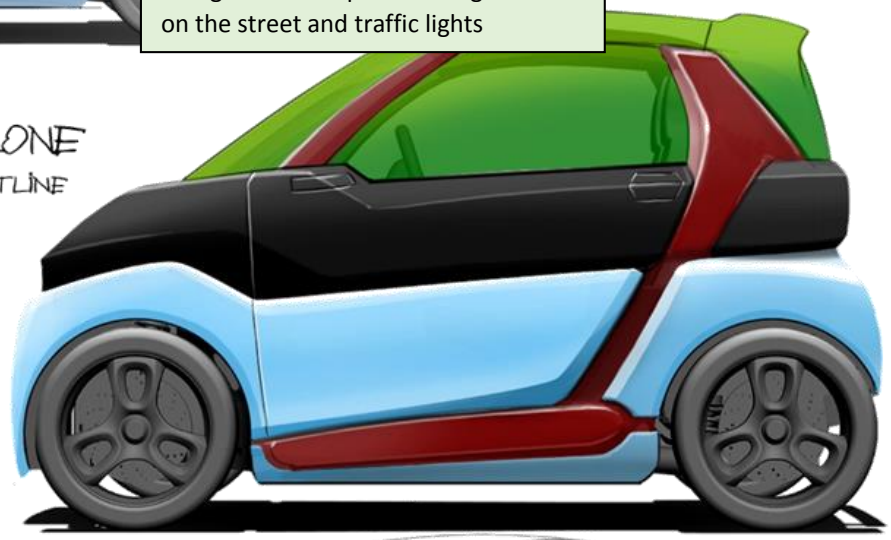




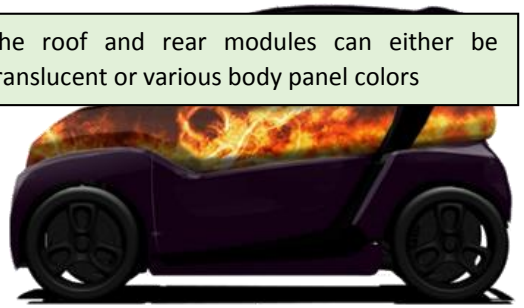


The greenhouse provides a good view on the street and traffic lights

i-ZONE
BELTLINE



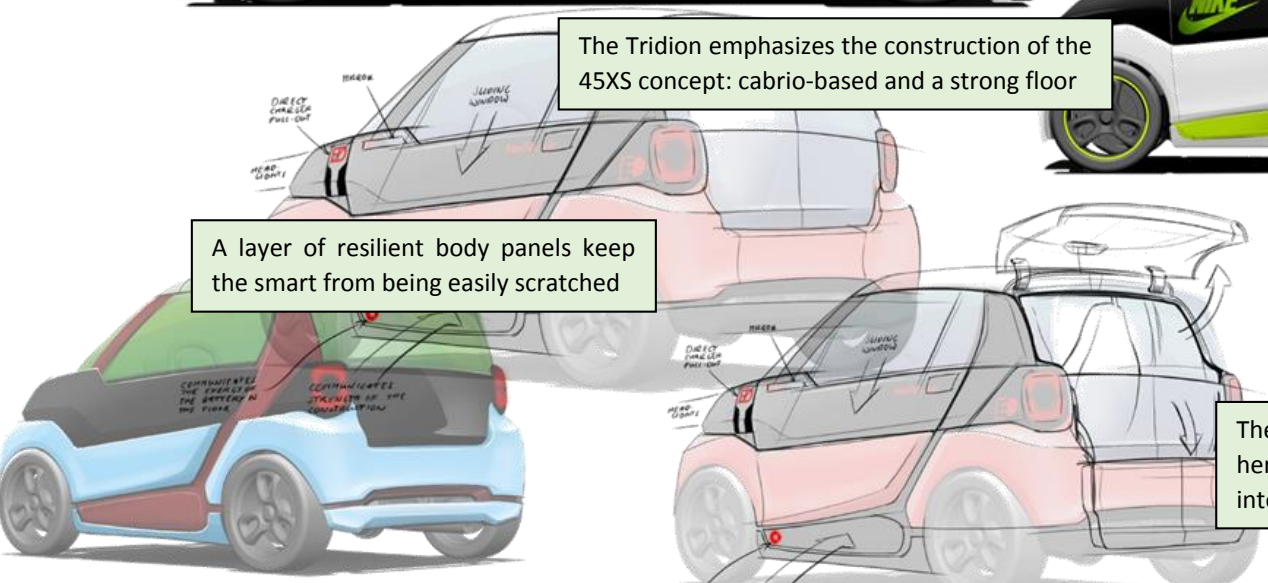
The roof and rear modules can either be translucent or various body panel colors



CAR2GO
MEDITERANA

SMART FOR
SPORTSWARE

The Tridion emphasizes the construction of the 45XS concept: cabrio-based and a strong floor



A layer of resilient body panels keep the smart from being easily scratched

PRESENTATION
MEDIUM

The i-Zones finish the design hierarchy: here you find interactive, individual, intelligent and interesting features

PART IV: SYNTHESIZE

4.1 | The storyline

This part describes how the investigations and decisions within each of the '4S'-pillars – SMART, SAFE, STRATEGY and STYLE – are merged together in order to create a coherent and complete concept.

The core storyline of this project is the strategic approach that the 45XS concept bases on: to provide flexibility and variation based on a basis that carries the main smart qualities. Therewith smart provides each customer with a standardized safe, compact and reliable urban micro car in combination with various functional spaces and a layer of individualizable, intelligent and interactive 'i-zones'. In a nutshell, this is how the '4S'-pillars are merged into one concept.

Building up the 45XS concept from the basis, resulted in a four-step philosophy that describes the concept in a structured manner, emphasizing that the concept has been built from the inside out, focused on the user and technology. Considering the user groups, each step is a way to increase the amount of variations, ultimately being able to serve everyone with a smart that suits them [Figure 4.01]. The four steps are as follows:

STEP 1: TECHNICAL BASIS

The basis of the concept is a fixed platform, which is on its own a drivable, naked car. It includes a fixed construction, the passenger compartment, the necessary safety elements and the complete powertrain.

STEP 2: DERIVATIVE MODULE

The second step is to create various architectures with different technical modules. With a simple roll-over bar, a beach buggy is almost instantly created. Different modules allow to build up either a roadster, a coupé or a micro van architecture.

STEP 3: EXTERIOR CHARACTER

Thirdly, the derived bases are cladded with exterior panels; partly identical, partly unique. Each derivative shows the characteristic metal Tridion, a 'greenhouse', a layer of resilient plastic body panels with an identical leitmotif, and an 'i-zone' belt. The cladding modules are unique for each archetype, and each archetype can be cladded differently.

STEP 4: i-ZONE CONFIGURATION

The last phase is the configuration of the i-zones. The i-zones include everything that has to do with individuality, intelligence, interaction and innovation. They are what keeps the smart interesting and up-to-date: the i-zones are the life-cycle strategy for the 45XS concept.

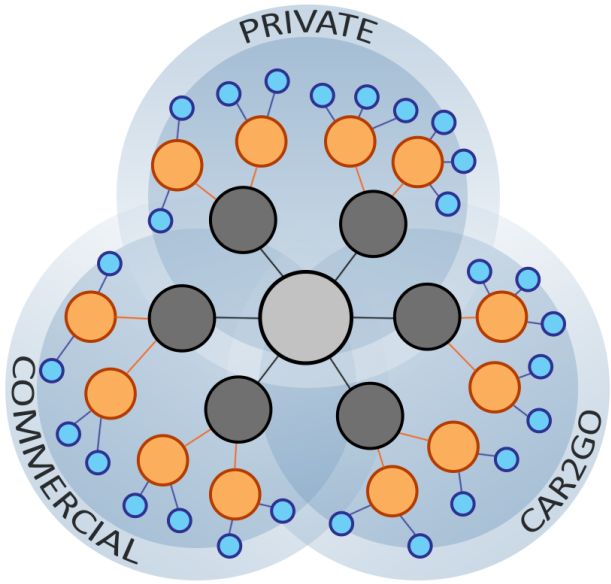


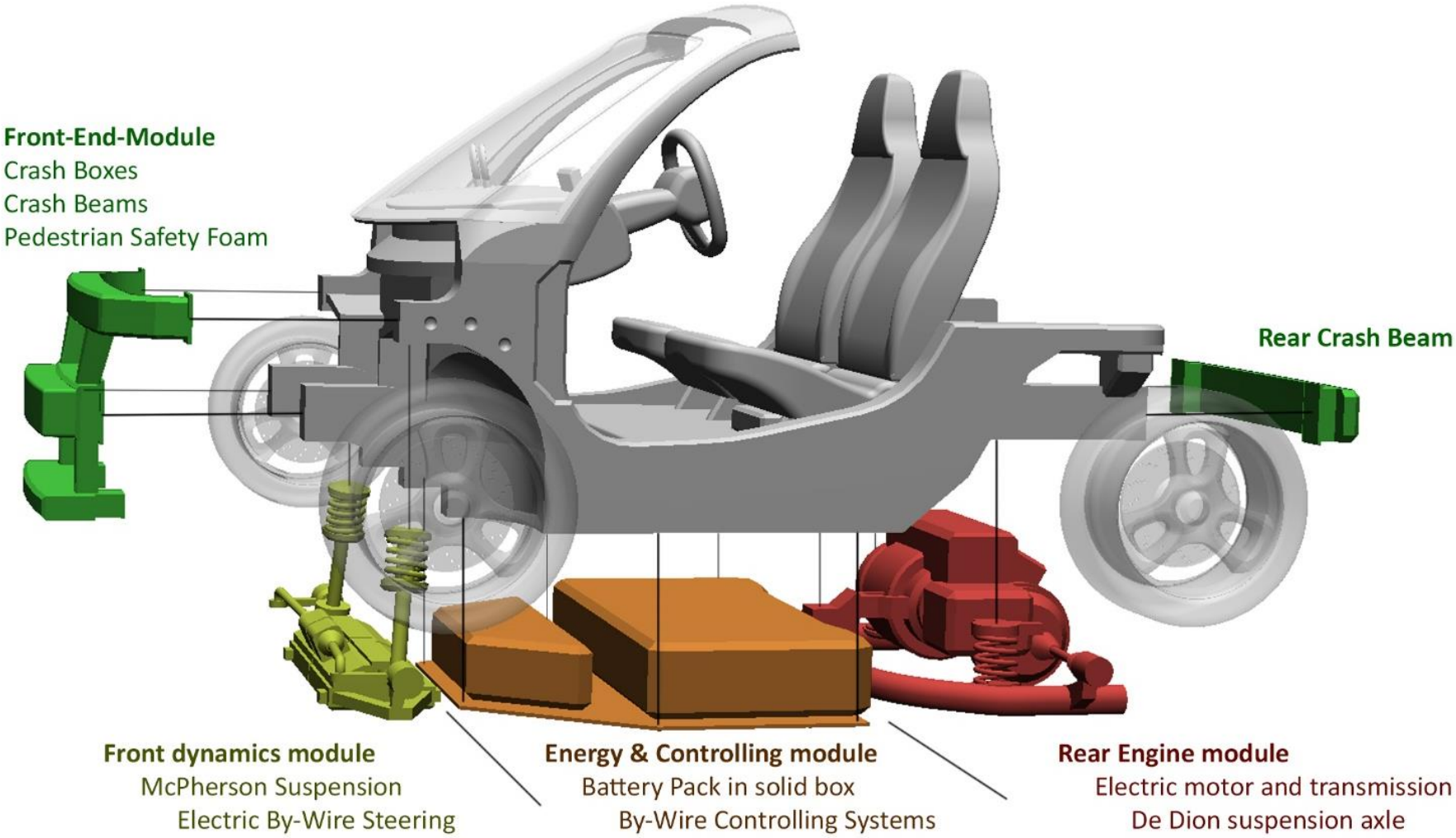
Figure 4.01: fully saturated product placement within the three customer groups

STEP 1: TECHNICAL BASIS

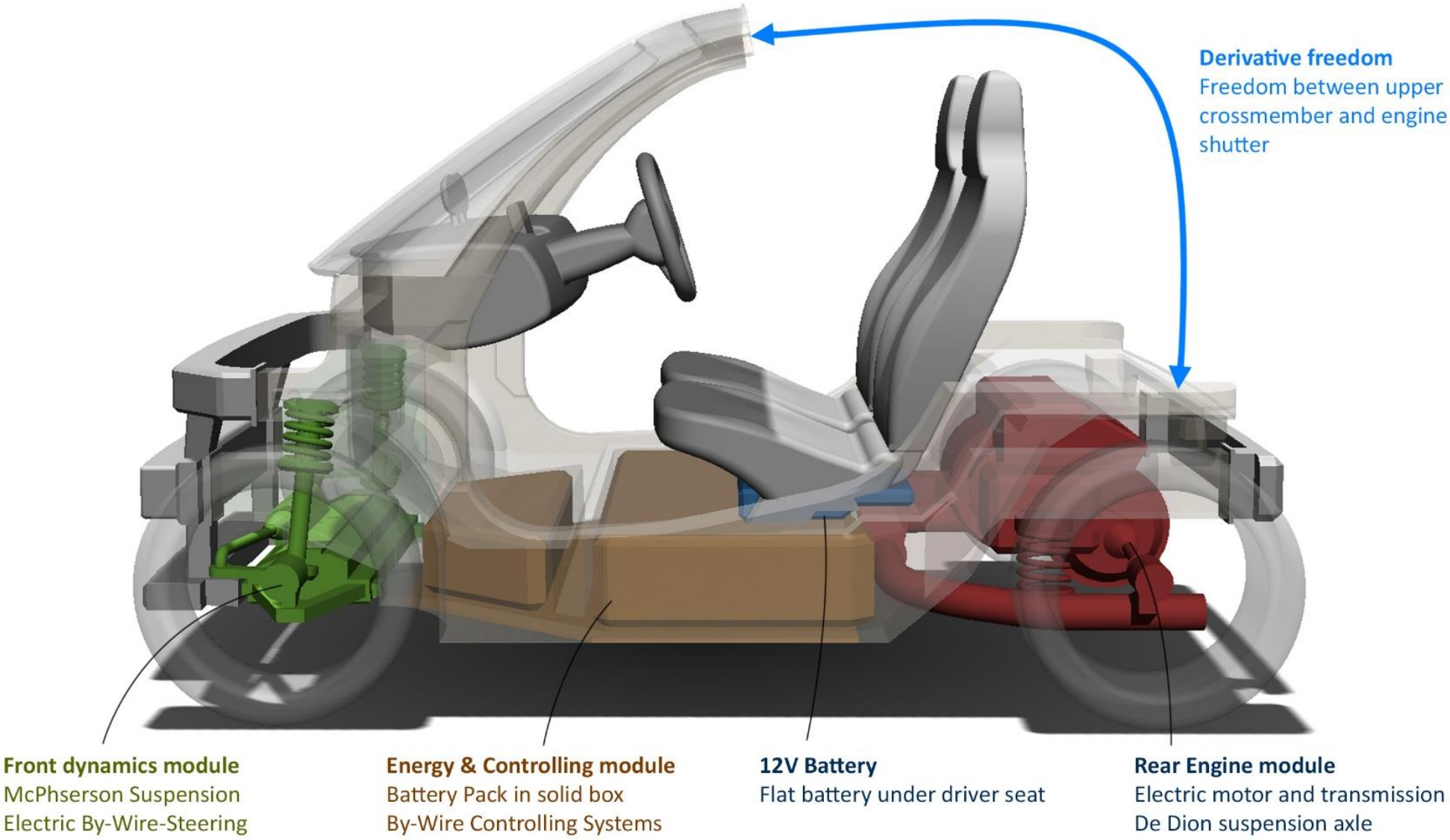
The investigation resulted in a package of under 2.6m that is compact, safe and offers flexibility. The technical basis is fixed for each derivative.

As seen in the illustration below, a cabrio-based package is used that contains various modules. The powertrain modules exist of pure electric systems: the engine, the steering and the brakes are electric and controlled by-wire. The front module is optimized for crash and pedestrian safety and carries the cooling system and head lights.

Two seats fit side-by-side and the cockpit has no mid-console, making sliding over to the other side very easy. The double-hinged door concept that was suggested earlier remains in the concept, but is not technically worked out, due to lack of time and the fact that it the concept has already been researched [44] and can be implemented independently in the 45XS package.

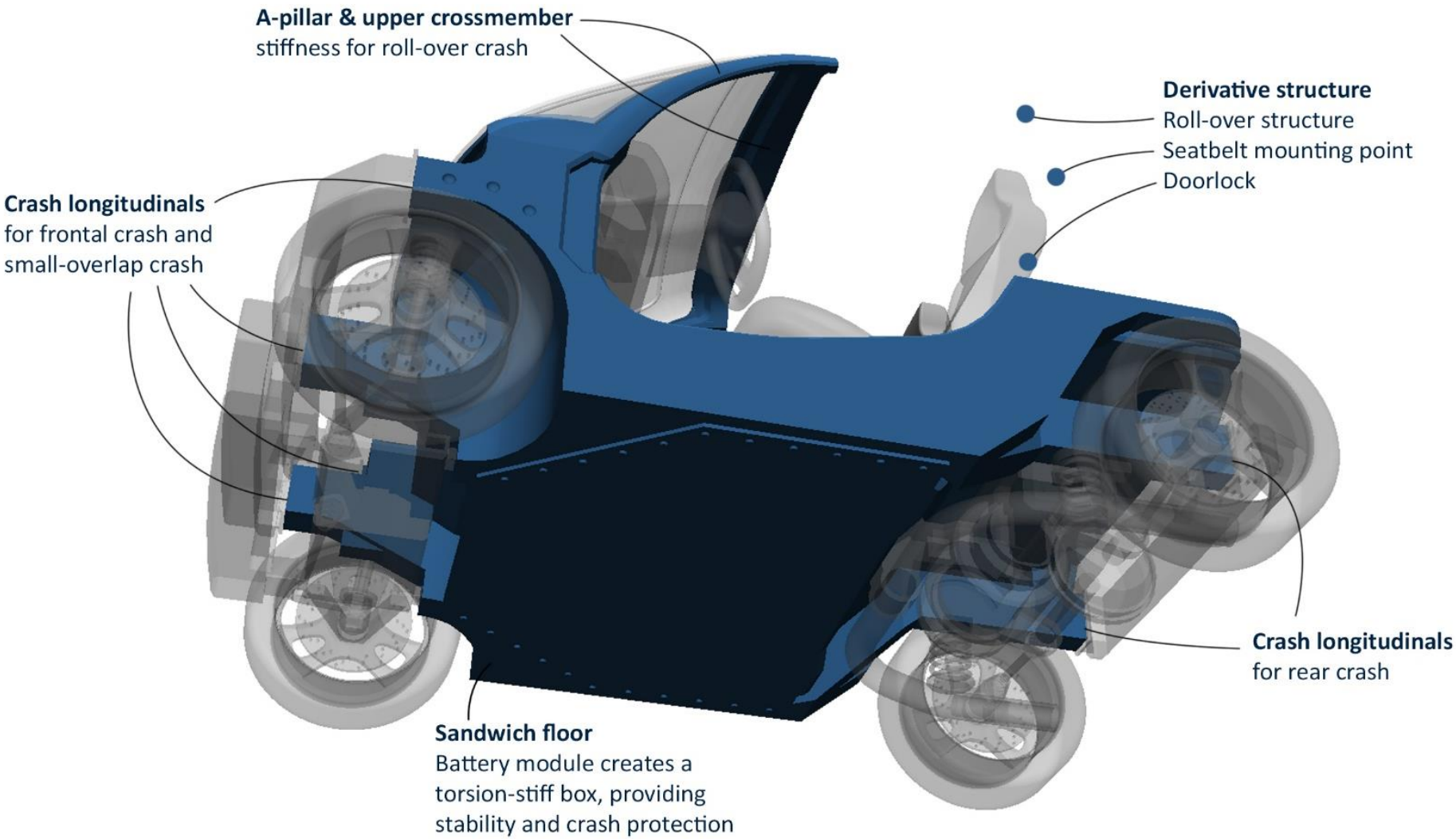


The package provides freedom for the next step between the side panel that runs over the wheels and the upper crossmember that holds the 3PS windshield.



The structure, since it is based as a cabrio, needs to have a very strong floor. This is provided by the rigid box that is created when the battery module is mounted to the frame. The combination of the solid double floor, the short wheel base, the relatively voluminous cross beams and the use of high-strength steel provides enough rigidity for a safe and dynamic car. Experts from the Body in White department at smart [38] [47] confirmed that this structure is sufficient and enables the use of plastic roof modules. Besides the use of better steel and relatively voluminous cross beams also enables to save weight in relation to the current EV cabrio-model.

The A-pillar (positioned according to 3PS) must be very stiff, yet compact, and therefore needs a thick and heavy structure. Investigation is still ongoing within smart in order to see if the use of the 3PS pillar is feasible. [39] In this project it is assumed that it is strong and stiff enough.



The materials and/or components that are used are described below.

Body-in-White

In order to keep the weight low, yet provide the necessary stiffness in the construction, a new type of steel is used. So called hot-formed MS-steel [Figure 4.02], which has a very high tensile strength [40] enables the structure to be thinner and therewith lighter than currently used steel [38].

In combination with the rigid floor structure, the new steel BiW provides the rigidity and reduces the weight of the structure with 10 to 15% [38].

Powertrain

The engine is a successor of the current electric engine, built by EM-motive (Daimler + Bosch), and the battery is the successor of ACCUmotive's (Daimler + Evonik) current battery. The engine will be configured to allow one-pedal driving, meaning that the engine automatically regenerates energy when throttle is released.

The steering and braking are electric and by-wire, which is assumed to be fully allowed in production car implementation by then. The automatic emergency braking systems, that are required for safety, are included in the electric systems, meaning that no additional actuator systems are needed.

The front suspension is a lighter McPherson subframe made from aluminium. The rear suspension is a De Dion axle which is an integral part of the engine module.

Specifications

Dimensions [details: Figure 4.03]	
Length	2555mm
Width	1700mm
Height	1510mm
Wheelbase	1820mm
Wheels	
Front diameter	580mm
Front width	175mm
Front track	1475mm
Rear diameter	580mm
Rear width	225mm
Rear track	1475mm
Weight	
Weight*	850kg [Appendix 4]
Performance	
Top speed	140km/h
Range	200km
Turning circle	7.5m

*based on cabrio complete car.

Figure 4.02: types of steel. Source: worldautosteel.org

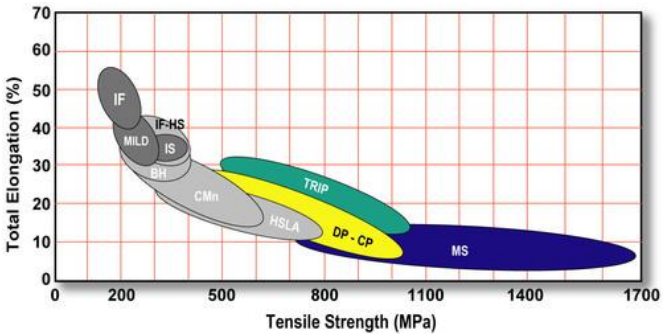
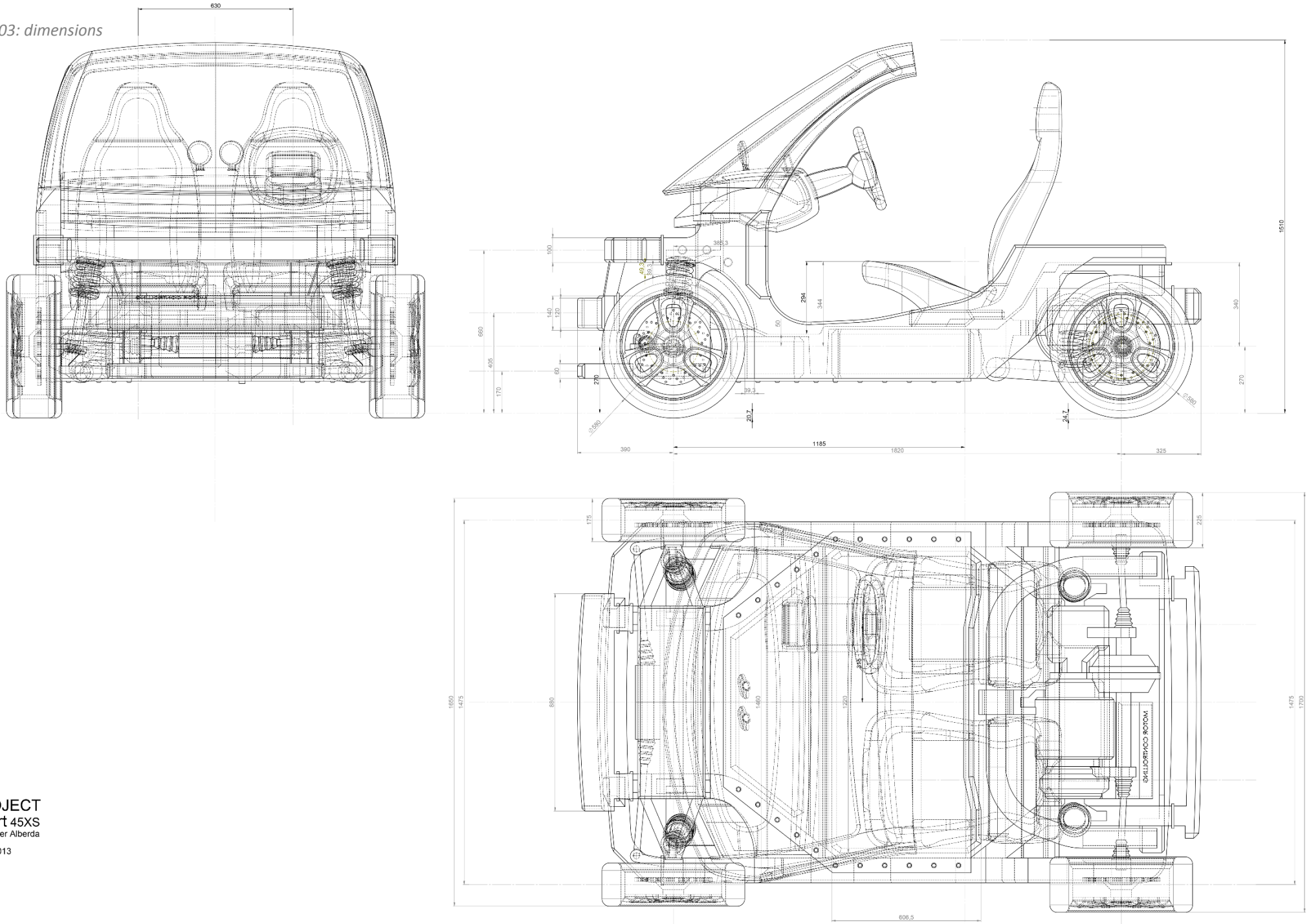


Figure 4.03: dimensions



STEP 2: DERIVATIVE MODULE

Since the basis is torsion stiff, a roll-bar mounted on the rear will create a 100% safe naked smart. For the 45XS concept, four architectures will be available: buggy, coupé/convertible, roadster/cabrio and micro van. The next paragraphs describes how a couple of modules are combined and mounted.

Buggy

An extremely fun vehicle, ideal for warm environments, is created by mounting a roll-over construction. This derivative shows how with minimal elements and features, a fun outdoor concept is created.

The roll-bar, made from steel tubes, is welded on to the BiW at four points, creating a rigid structure (1A).

Roadster/cabrio

A true cabrio experience means heaving as little roof as possible. Therefore an aesthetic roll-over construction is used, that is exposed when the roof is folded or removed.

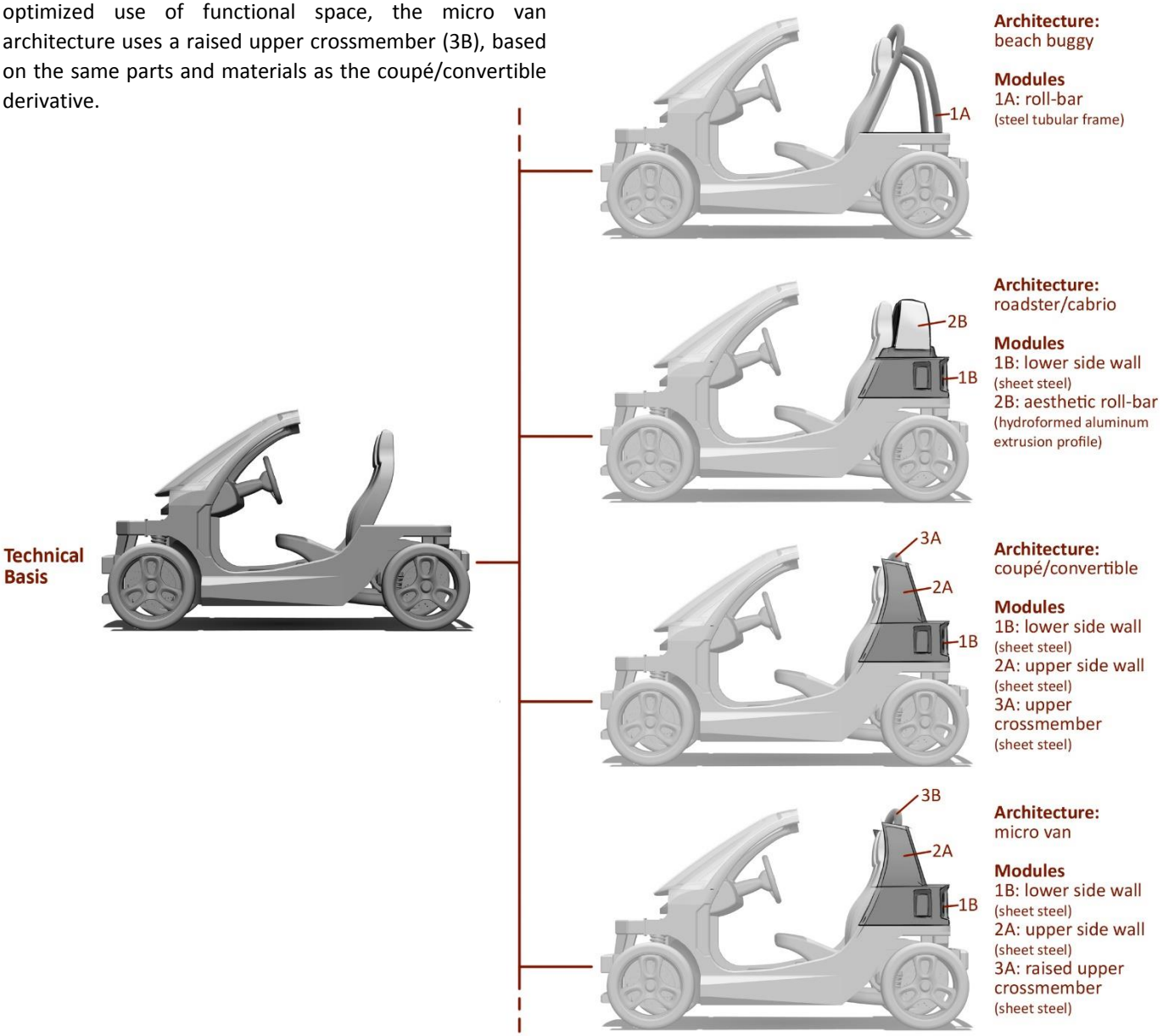
The first panel that is placed on the BiW, made from sheet steel elements, contains the door lock, charger and rear lights montage positions (1B). On top of that a hydro-formed aluminium extrusion profile is bolted (2B).

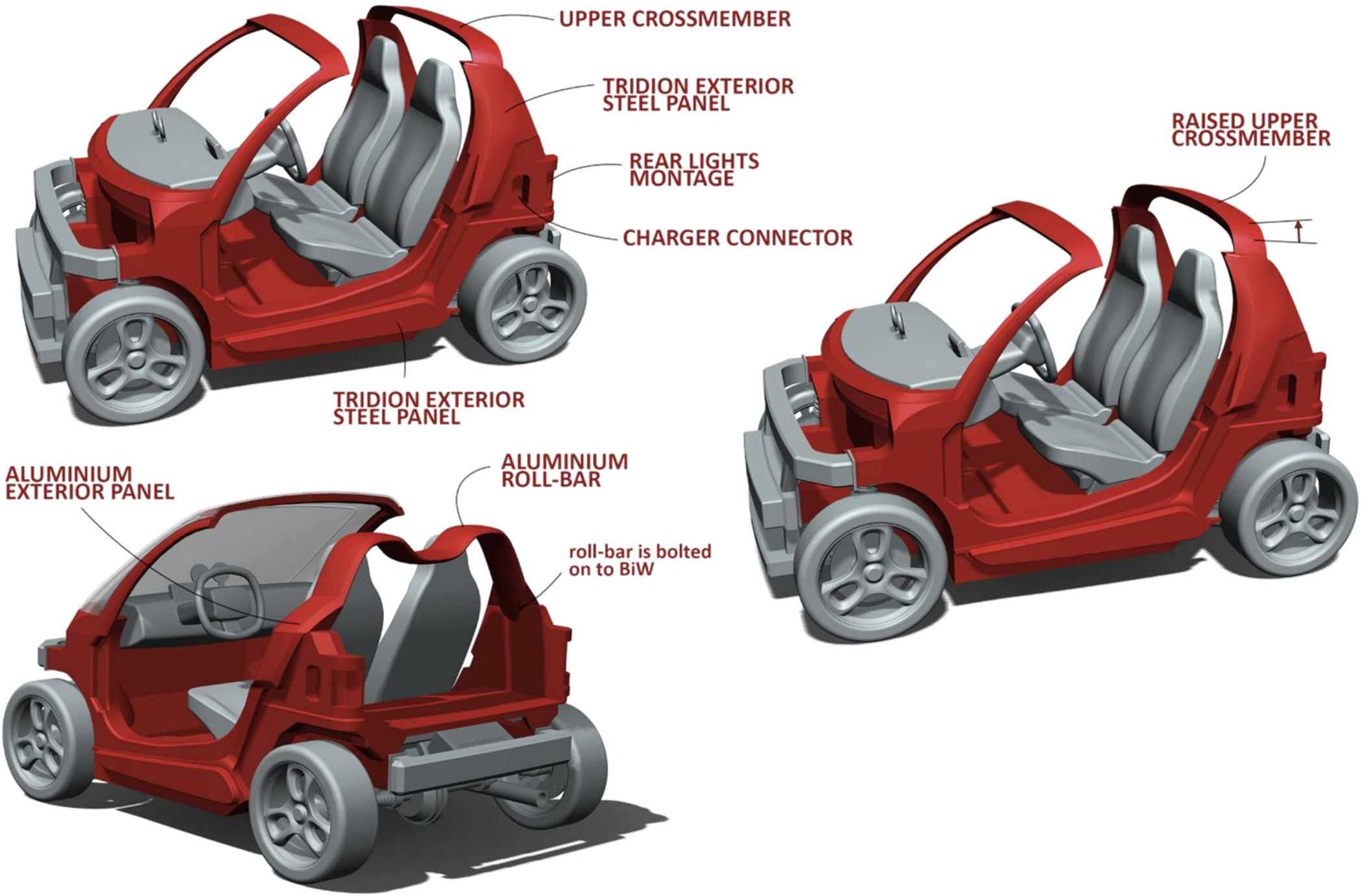
Coupé/Convertible

This architecture includes a sheet steel upper wall (2A) and an upper crossmember, also made from sheet steel (3A). these create a rigid structure and allow various exterior modules to be bolted onto. These exterior modules are made from plastic and metal elements with connection points and hinges etc. (STEP 3). These modules do not need to complement to the main structure for stability and safety; the coupé/convertible architecture provides enough stiffness and rigidity [38].

Micro van

In order to create a more functional derivative with optimized use of functional space, the micro van architecture uses a raised upper crossmember (3B), based on the same parts and materials as the coupé/convertible derivative.



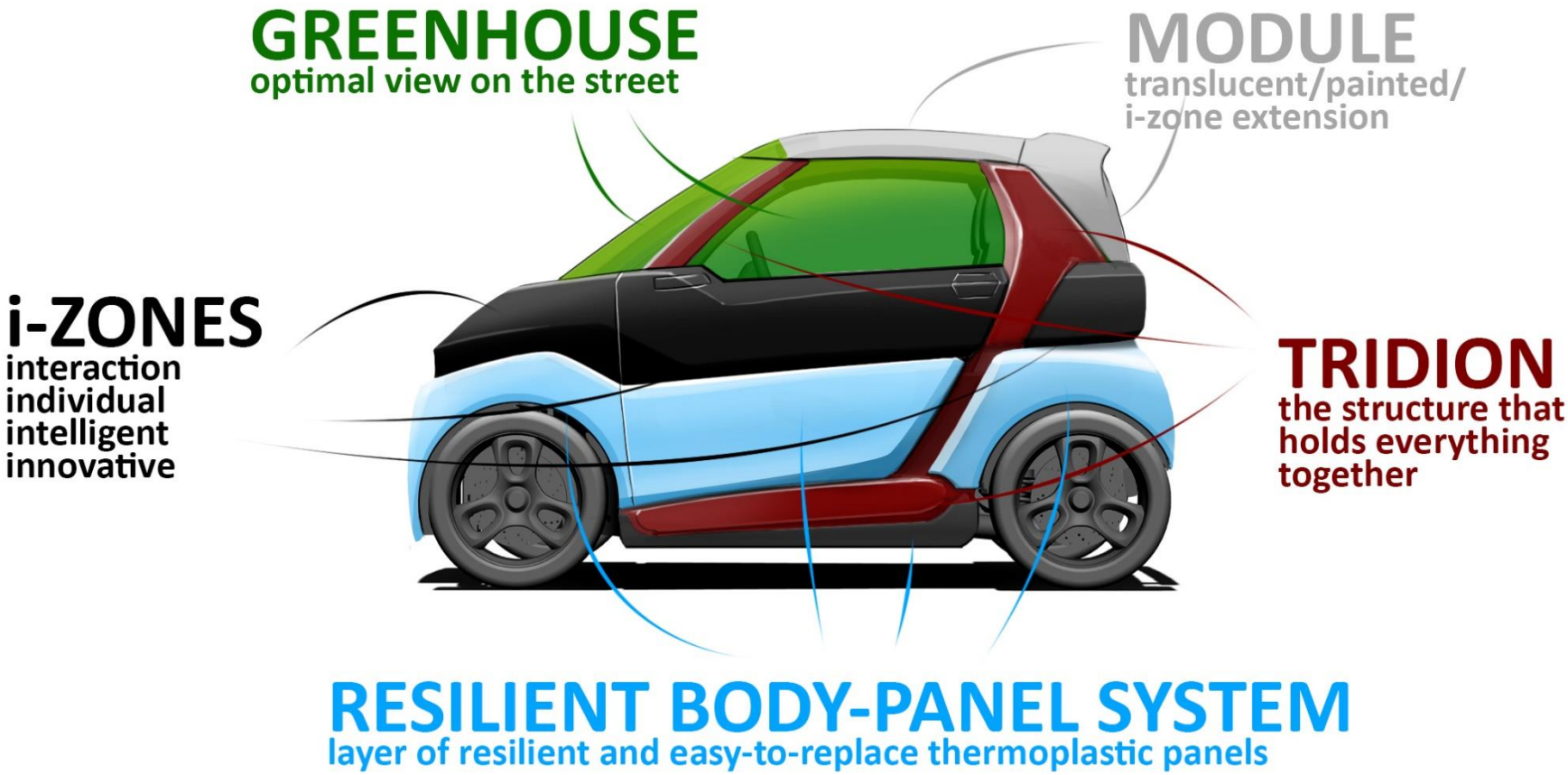

UPPER CROSSMEMBER
TRIDION EXTERIOR STEEL PANEL
REAR LIGHTS MONTAGE
CHARGER CONNECTOR
TRIDION EXTERIOR STEEL PANEL
RAISED UPPER CROSSMEMBER
ALUMINIUM EXTERIOR PANEL
ALUMINIUM ROLL-BAR
roll-bar is bolted on to BiW

STEP 3: EXTERIOR CHARACTER

To create ready-to-go product, the various derivatives are cladded with exterior panels and modules. Based on the new design language, each one has identical and unique elements.

Design Language

The design language of the 45XS concept is the result of reinterpreting the smart design qualities and creating a link between technology, usage and aesthetics.



Tridion

The Tridion, which emphasizes three core elements of the structure: the rigid floor, the strong A-pillar and the derivative module structure. They are made from steel panels (in case of the roadster also partly aluminium profile), so people can see and feel the strength of the Tridion. The floor and derivative elements are connected, creating the recognizable Tridion shape that smart has had in its design.

Greenhouse

The greenhouse or glazing provides good sight on the street and makes it easy to oversee the smart's dimensions when parking in tight spots. The windshield is made from glass, the 3PS windshield frame, side windows and optional translucent roof and tail gate are made from Polycarbonate.

Resilient Body-panel System (RBS)

The body panels are 'down-graded' if it comes to A-class surfacing; they are the resilient layer around the car, making it more resistant to dents and scratches. The Polypropylene thermoplastic parts will be standard fit with basic coating layers, showing the colour of the raw plastic. This saves costs and puts more focus on the i-zones.

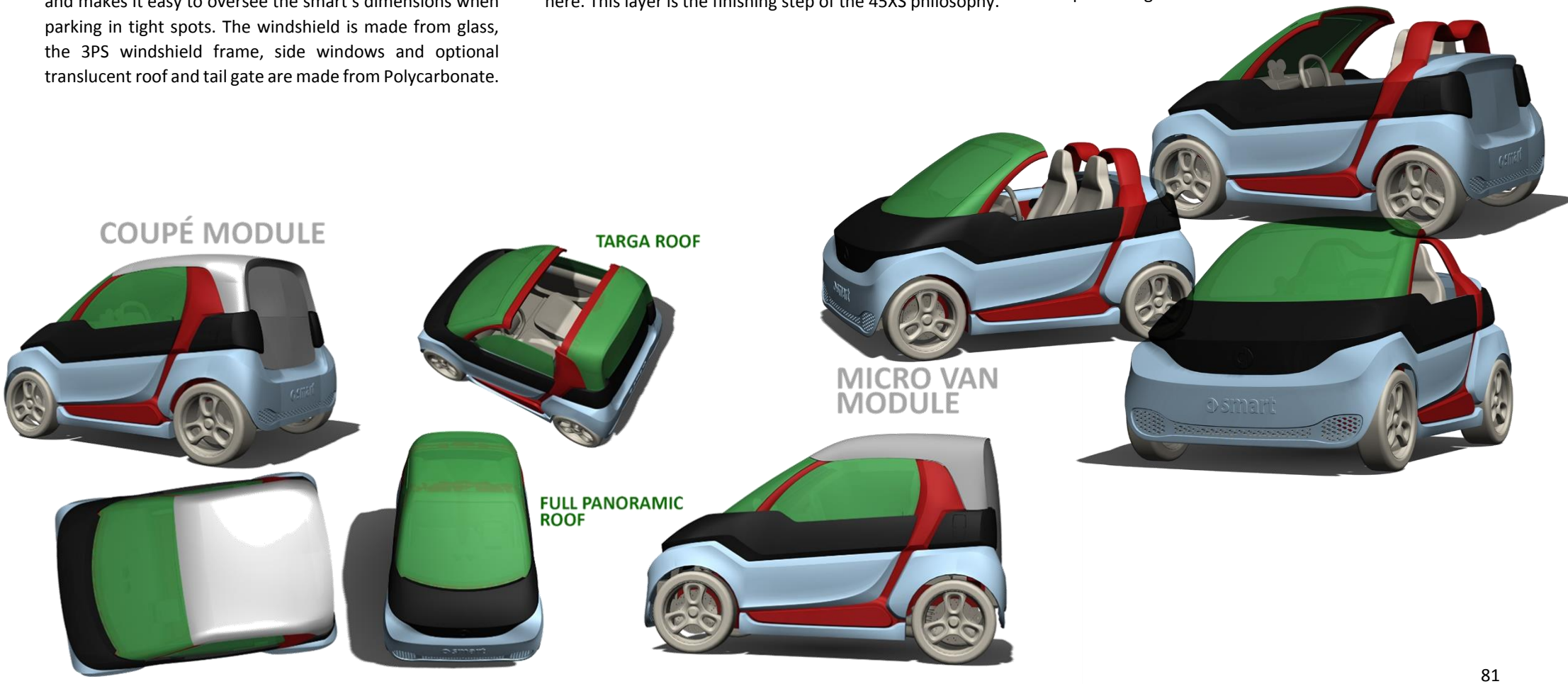
i-Zones

These zones are the addition to the smart design language: this is where the car comes to life. All elements of interaction, individualization and intelligence are integrated here. This layer is the finishing step of the 45XS philosophy.

Module

The module is dependent of the architecture that is being cladded. Various module create difference in the derivatives too. For example, the roadster architecture can have a removable hard top roof or a foldable textile roof. The coupé/convertible can have a fixed translucent panoramic roof, a removable Targa roof, a tri-top roof, a two-part tailgate or single tail gate, etc.

As said before, these modules have no structural purpose, but might need simple frames for montage and hinges etc. Other than that, they are made from plastic, in order to keep the weight down.

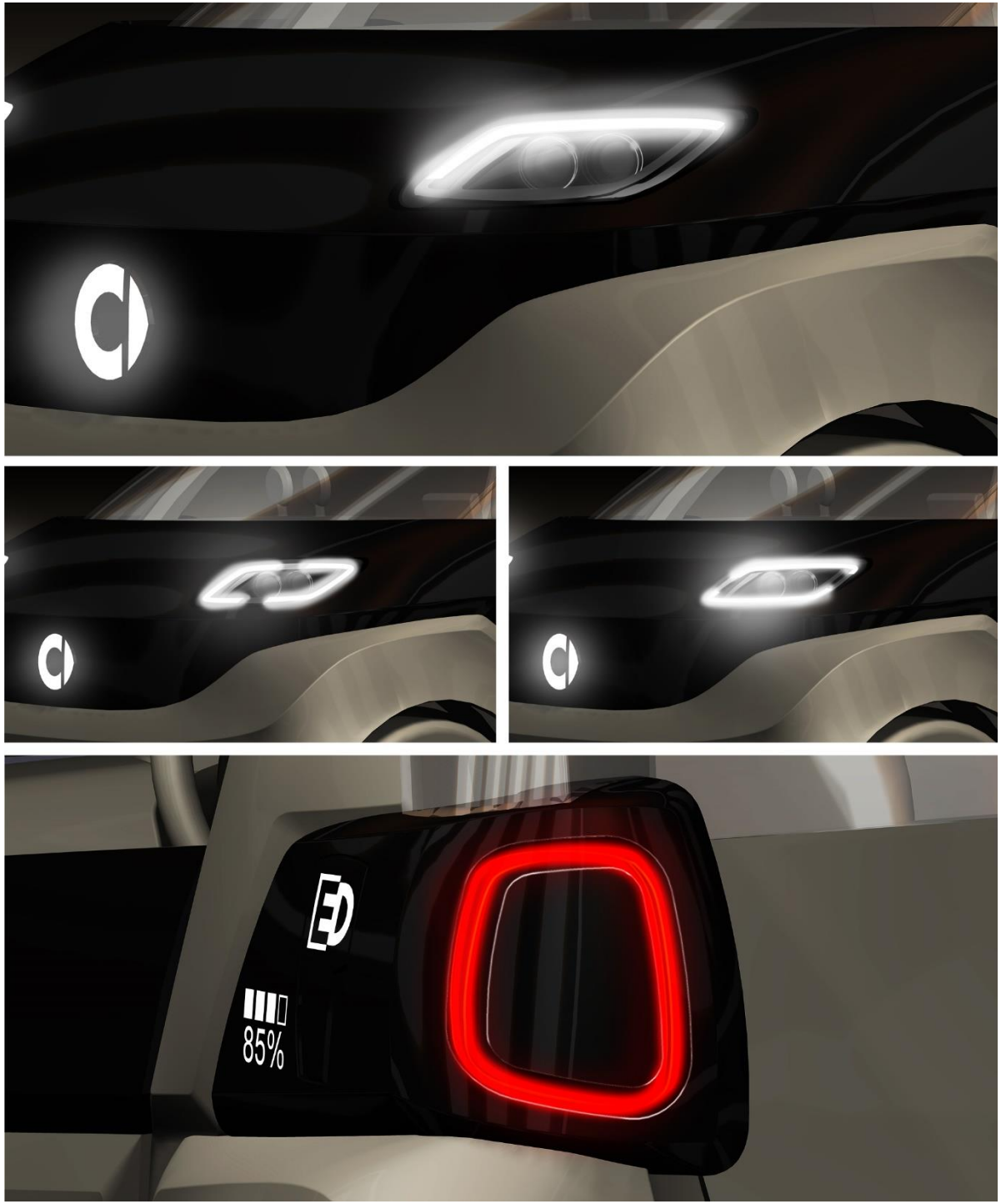


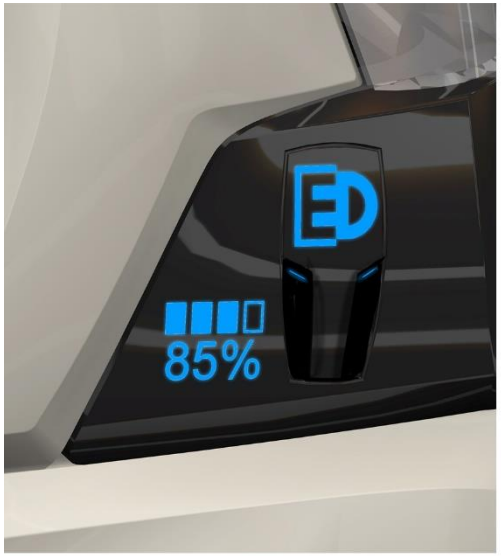
STEP 4: i-ZONE CONFIGURATION

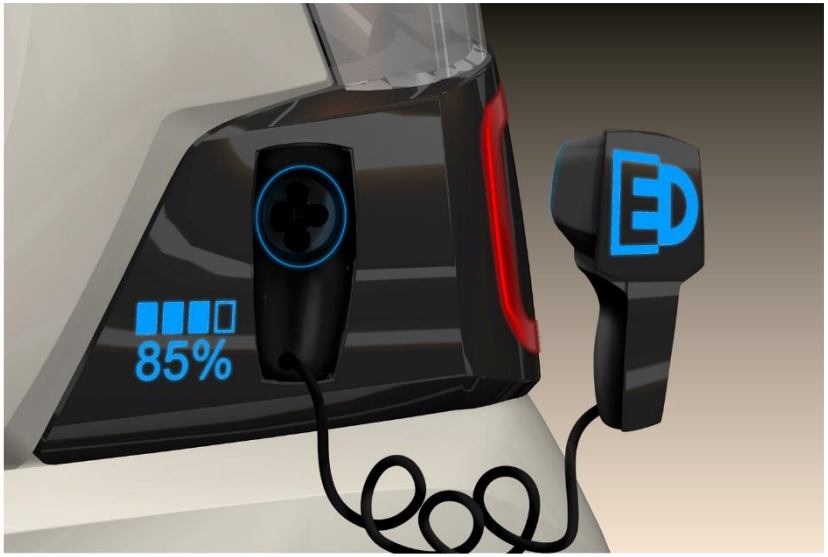
The final step is to configure the i-zones. Interactive elements, individual features and aesthetics, intelligent systems; in other words everything that makes the car interesting and interactive happens are in the i-zones. They are so to say, the cherry on top of the pie; the jewellery; the eye-candy.

Identical parts such as the safety assist sensors, head light and tail light unit, mirrors, door locks and charger unit have fixed places within the i-zones and the rest is configurable by the customer.

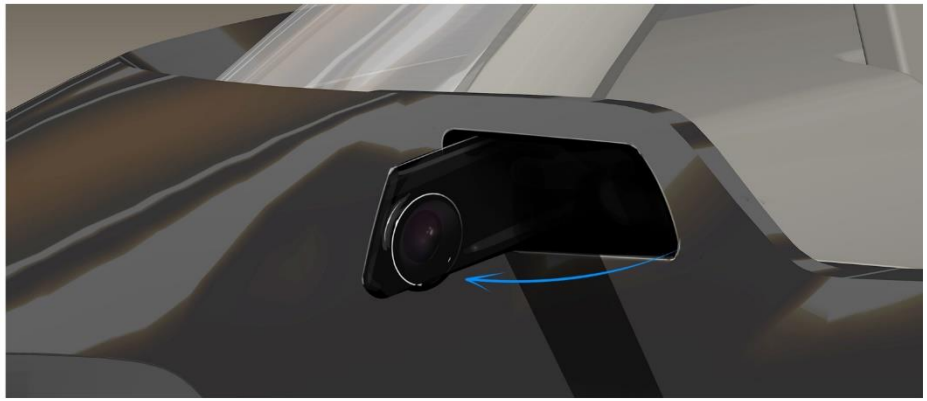
Customers can adapt the DRL (daytime running lamps) to their preference and mood. The light emitting logo emphasizes the car's active senses; it's eyes on the road.



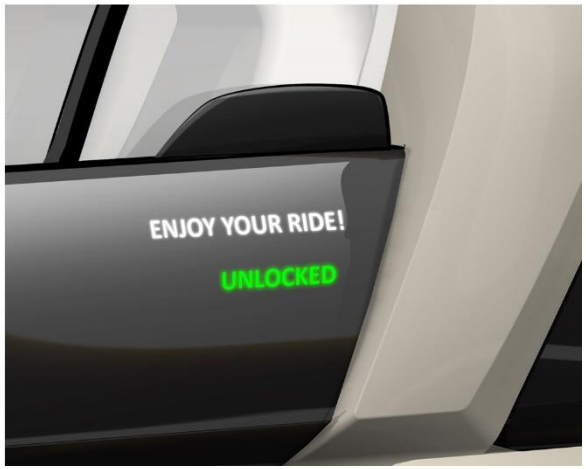




The charger unit is directly retractable from the rear i-zone element. The blue ring confirms that the cable is completely rolled out (to avoid overheating) and ready to be connected with a charger pole. A display indicates the battery status.



The smart 45XS uses camera mirrors that are folded away when parked or in autonomous driving lanes.

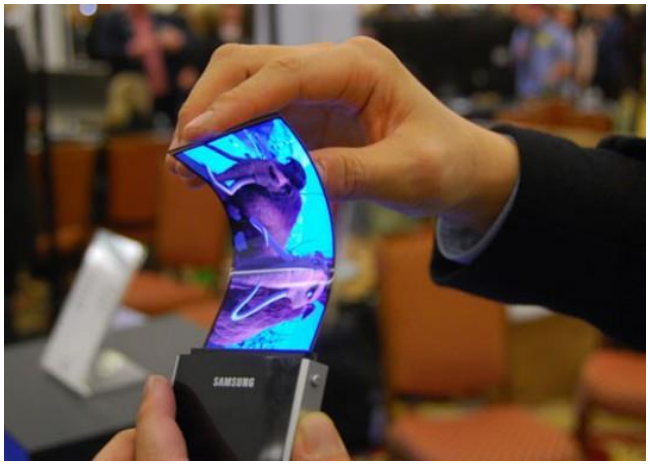


Each smart is unlocked keyless at the door lock panel. The CAR2GO cars are unlocked with the user's member card. Private cars are easily unlocked with fingerprint recognition or RFID.

The i-zones can be used differently by each customer. A private car has features and widgets or apps that match the user's preferences and identity, a commercial car shows company details and advertisements, while a CAR2GO car shows its status has features on the outside that everyone can use, such as digital shopping.

The standard material for the i-zones is black tinted polycarbonate, allowing displays to be placed behind it while maintaining a smooth and monotone surface. The i-zones however, are not meant to be the same on each smart. Changing the information on integrated displays or changing the appearance or material; the idea of the i-zones is that the customer can release its creativity.

The i-zones are also the lifecycle strategy of the 45XS concept. Since it is so hard to predict how and how fast the world of digital devices changes, the i-zones are a platform that can be updated with newer technologies during the lifecycle. For instance, the first version has OLED screens with touch-functionality, but later it could be fitted with full 3D OLED foils, creating a fully digital and operable surface.



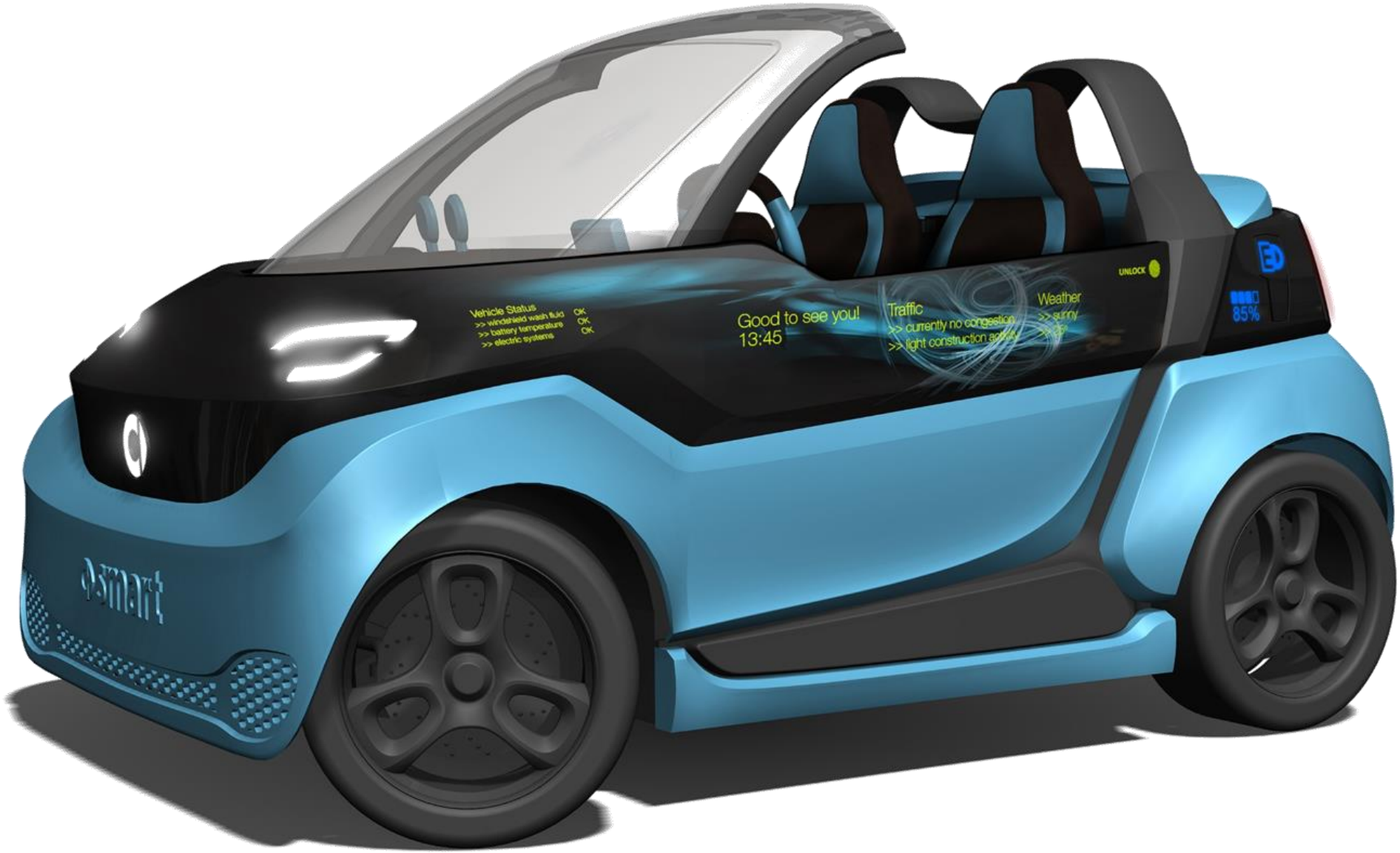
Digital technologies develop quicker than we can imagine


UNLOCK
Good to see you!
13:45
Traffic
>> currently no congestion
>> light construction activity
Weather
>> sunny
>> 25°
85%
CAR 2GO
I'M AVAILABLE
SIMPLY. ALWAYS. EVERYWHERE.
PLEASE SCAN YOUR MEMBER CARD

4.6 | smart 45XS preview

These illustrations show three examples of fully configured models, one for each user group. They preview how using the four steps of the 45XS concept result in customer-specific, individual smart cars.

This privately owned fortwo roadster is configured so that the owner easily enters his or her smart with a touch of the finger. Before entering, the smart informs the owner about the traffic and weather circumstances before taking off.



This micro van smart is part of a delivery service fleet, providing people with fresh meals. The small smart is ideal to quickly drive from door to door. With one seat and a customized storage system, the smart offers plenty of space for the delivered goods.

This CAR2GO smart coupé emphasizes the transparency and openness of the car-sharing system. It for instance shows when it is available and at the same time entices other people to try and experience CAR2GO too.

PART V: REVIEW

5.1 | Verification

The 45XS concept and its four-step philosophy makes it possible to continue with creating derivatives. In this project three variations, one for each customer group, were eventually shown, but many more ideas came up among the process.

Derivative study

A brief side project of an intern in the team [46] was to create a fun derivative for a warm summer day. The basic package was provided and the freedom was left to create a functional space and a matching exterior. The result, a 'smart forbeach' [Figure 5.01] showed that the technical basis provided plenty of design freedom.

Figure 5.01: smart forbeach by Matthias Krentz

Team workshop

In order to verify the usability of the 45XS concept, a workshop was done with the team. Three teams were asked to briefly brainstorm about the use of either a private, commercial or CAR2GO car, and describe functionality that is desired [Appendix 5].

The conclusion was that the concepts are mostly dependent on the functionality of the exterior module and the interior functionality. Many practical interior features were addressed, such as dedicated grocery basket racks, hooks to attach clothing or bags and an instrument panel with proper navigation system and practical compartments. Also, the functionality of the rear hatch was seen as important for practicality, such as an extendible drawer with dedicated compartments for tools and a down-foldable hatch to sit and relax on.

It was also addressed that in the private user category, a part of the customers would prefer a high-performance variation, comparable with current BRABUS models. It was noted that for that, an improved dynamic system with e.g. a larger wheelbase, could create an interesting derivative. Due to the limitation of the fixed basis that was created, this would not be possible with the 45XS concept. Also, although it was discussed that in the commercial category, many customers would be dependent of a larger cargo space, meaning that a longer variation would be needed.

The use of the i-zones came to interesting findings that show that it stimulates rethinking the function of the car's exterior. For example, a delivery service car, which would often make short stops, can show clear warning signals to other road users, and allow hands-free locking and unlocking of the doors and cargo space (for when the service guy has its hands full).

Another interesting discussion came from brainstorming specifically about CAR2GO use. Since people often leave stuff behind (including grandchildren…) or forget to properly close the rear hatch, it would be nice when the car visually or vocally informs the user about this, therewith preventing inconvenient situations. The i-zones are therefore the ideal platform to integrate intelligent and interactive features.

Overall, the discussions and brainstorm-talks during the final phase of the project indicated that many creative ideas can be fit within the 4-STEP concept smart 45XS. It even took the minds of some away from the drowsy November weather and to a sunny summer's day in a Mediterranean environment, driving top-down with the joyful and agile smart.

5.2 | Conclusions

During the project, the 4S-pillars eventually became the 45XS concept line. To conclude the design project, this chapter looks back at the 4S challenges and the goals that needed to be achieved. Were the goals achieved? And what was sacrificed for that? This chapter describes once again per pillar what the conclusions at the end of the project are.

SMART

Although the goal at the beginning that was set by smart was to achieve an under 2.6m package, the ultimate goal is the 2.5m that smart once had and matches the width of a parking place. The reason for the 2.6 goal was that, based on experience, smart realizes that this is already a huge challenge when it comes to the production car. Also, under 2.6m (meaning 2.5 and two more digits) would be a great marketing reference for the brand, therewith securing its 'unschlagbar parkbar' quality.

After the package analysis, it was clear that an under 2.6m could be achieved, while using feasible technology. The push was actually already given by the 453: shrinking the passenger cell in length and grow in width. By holding on to this width and returning to a smaller engine and front end package, the goal was achieved. Besides, the width is compensated with a double-hinged door concept, therewith making egression and ingression easier.

The use of by-wire systems decreased packaging space and created the option to lower the occupant's heel position (equal to the 453). Besides, the electric by-wire systems simplify the implementation of active safety systems, which will undoubtedly become mandatory features. The choice to use smaller wheels again (max. 580mm diameter) resulted in a lower car, making the overall stance look stable and sporty, addressing to the fun character of the rear-engine smart.

Because the current market is not yet ready for a pure electric brand, smart would also consider combustion and/or hybrid drivetrains. Considering the choice to optimize the engine compartment for an electric motor, it cannot be guaranteed that a 2.6m package is maintained with the 45XS basis, if this engines are fitted in it. The reason however, that the smart keeps on growing, was that more conventional choices are made and in that way, the 45XS concept proved that when making these choices, the goal is achieved.

SAFE

Meeting worldwide safety requirements was the goal set at the beginning. Investigating the context of safety, showed that safety is more of a strategic theme than one would think. Complying with regulations is one thing, but achieving a high safety rating from different institutes is different. For example the system that Euro NCAP uses, continuously changes and intensifies. Being tested one year may earn you 5 stars, the next year only 4. In order to keep it less complicated, it was assumed that the rules for occupant protection remain equal, that pedestrian safety will stabilize after a few years and most innovations will come in the field of active safety assists, consisting of sensors, algorithms and feedback to the user or car.

Within this project, the three aforementioned factors were dealt with as follows: occupant protection by a rigid construction and relocating/removing 'blockbuilders'; pedestrian protection by the solutions that were designed by M. Ravestein's 3PS graduation project and safety assists by including dedicated space for sensors in the front end package.

Regarding the assumptions that were made, the 45XS concept meets the requirements and has all facets of safety integrated. With the input and feedback from experts in the fields of safety and structure it was ensured that the knowledge and skills smart has is implemented in a way that challenges the brand to get the most out of it.

STRATEGY

The driving challenge for this project was to create an interesting concept that is interesting for smart's business. The desire to create flexibility therefor helped in making important decisions. Characteristic for the concept is that the technology is cabrio-based, meaning that all the stiffness and safety facets needed to be integrated in an open structure. The freedom that this provided, was necessary for the overall vision, which included creating open vehicles like a buggy and roadster.

To strengthen the concept of using a cabrio base, it was designed in a way that for a coupé type, no roof structure was needed. The roof module (which could be different variations) therefore has no structural elements, other than what is needed for hinges and montage.

The concept was discussed with Body in white experts and the conclusion was that this was possible, since high quality steel in combination with the short and rigid floor creates a very strong and torsion stiff structure, without gaining weight.

With the four step philosophy, which resulted from the strategy investigation, smart truly creates maximum flexibility while conserving the core smart qualities for each one. The use of modules allow to make relatively small series (e.g. 10,000) without many investment costs, yet creating valuable derivatives, that altogether potentially raise production numbers towards 200,000 in the first years after introduction. Therefore it can be said that the strategic goal was met within this project.

STYLE

The new exterior styling hierarchy is a combination of smart design qualities (e.g. the overall stance, the frisky look, the Tridion, the resilient body panels etc.) with newly introduced elements (the modules and the i-zones). Therewith recognizable smart design was created, yet newly interpreted.

The goal to reinterpret the CBS resulted in a split of RBS (Resilient Body-panel System) and i-Zones, where all the elements of individualization, interaction and intelligence are integrated. The i-zones also include a life-cycle strategy, meaning that features within can be updated in facelifts or with limited editions. This was based on providing a platform for rapidly developing media technologies, such as touch displays, 3D displays, sensors, LEDs etc.

The overall appearance and the design hierarchy therefore were satisfactory and achieved the goal of the project.

Concept 45XS

Merging the 4S-pillars into a 4-STEP philosophy led to a very usable and well-arranged concept. It made sense that the four pillars would not result into one car, but in a gradual system in which each step increases the variety of the smart car. On one hand this allowed showing in a structured way how the smart 45XS concept is an integral design based on the four pillars. On the other hand it stimulates and inspires other designers and engineers to continue filling in the four steps themselves.

The four steps are very easy to oversee and clearly tell the story of what the concept is about: providing the various customers with unique and well-fitted products, all based on the core idea of the smart car.

With the i-zones, the smart 45XS concept shows that it is ready for the future and ready to serve each customer independently, even when it considers a shared car. This is the key element that creates the emotional bond between the user and the car, making it desirable.

This project presented the philosophy and vision for the fourth generation and enticed the company with three concept cars resulting from it. Hopefully, this project stimulates and inspires the company further to look at the development the same way as was done in this project.

5.3 | Recommendations

The results of this project are satisfying and reached the goals that were set. Not every detail was of course worked out, therefore some elements that are important to the continuation of this project need further investigation.

First of all, it has to be calculated which forces occur on the platform in order to determine the amount of tension that is created in the roof modules. Since the concept is designed in a way that the roof module has no structural function, it needs to deal with the dynamic torsion forces that occur while driving. Also, it needs to be ensured that these relatively soft modules, cause no hazardous situations when the car rolls over in a crash.

Crash management is very complicated and takes many experts to deal with. Ground rules were used in this project to create space for good crash performance, but it requires more experts to verify the crashworthiness of the design. For example the suspension linkage and rims, which are also a 'blockbuilders', could be improved in order to absorb forces better too.

During the project, the idea of extended wheelbase (30-80cm) derivatives was discarded, since it did not fit the concept of providing the core smart qualities in each derivative. It is however strategically interesting for smart to consider flexibility in this direction, especially because of the 'joy of life' related concepts forus and forstars. An important element of this further investigation is testing whether the cabrio-based structure is still sufficient in this case.

The double-hinged door concept, which is a solution for compact parking, needs to be further investigated too. The idea is fully based on the car's footprint, rather than comfortable ingression/egression space. Although some research backed up the positive result (especially more space to put your foot), this is a rather complicated case and needs to be tested with mock-ups.

It is also recommended that a project is done that uses the philosophy of this project (flexibility, i-zones) and transfers it to the interior design. This is particularly interesting, since the interior is just as important for the interaction, individuality and intelligence of the car as it is on the outside.

5.4 | Evaluation

Looking back at the project makes me realize how much I've learned and tried to implement in the project. I have also learned a lot about managing a personal project, and making decisions rather than rethinking every step over and over again, which I sometimes tend to do.

Making choices was most challenging during this graduation project, since I wanted to include everything that I thought fitted within the four pillars. Keeping many options open, showed that it was more difficult to communicate the core storyline, making it weaker. When these choices were made, and clear distinguishes were made between what was and what wasn't included, the storyline became much stronger and defendable.

The fact that this project was done abroad and within a huge company like Daimler, was a great experience. Although the 'Schwaben' are not known for their openness for doing things differently, the people who were involved in this project were more than helpful and open to new ideas. The team I worked in has also been great and provided a lot of support, not the least by my mentor, Alexander Pothoven, who initially provided the assignment and challenged and supported me along the way.

At the beginning of the project the main focus was to learn about engineering, safety and design, of which the Overall Package and Design team has lots of know-how. Within the first months of analysis and 'lessons learned', I redefined the assignment into the 4S challenges, which relate to the four separate (and of course also interconnected) investigations that were done. This provided structure in order to determine where I stood in the project and what still needed to be done.

Along the way it became clear that the 4S themes would together form a concept based on a four step philosophy, rather than one single concept. So the fact that the strategy pillar was included, has had a huge influence on the project, making it fare more interesting and valuable for smart, but also more complex and sometimes difficult to stay focused.

The four steps however, were the ideal way to interconnect the work that has been done considering the four pillars, and to show that a TU Delft student knows more than just engineering, or just design, but knows a just what is needed about everything to create an integral product.

Conclusively, to me the results of the project and the amount of knowledge and experience that I've gained are more than satisfactory. As the last project of the Industrial Design Engineering study it has been the ultimate challenge, which I could recommend any other student to accept.

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