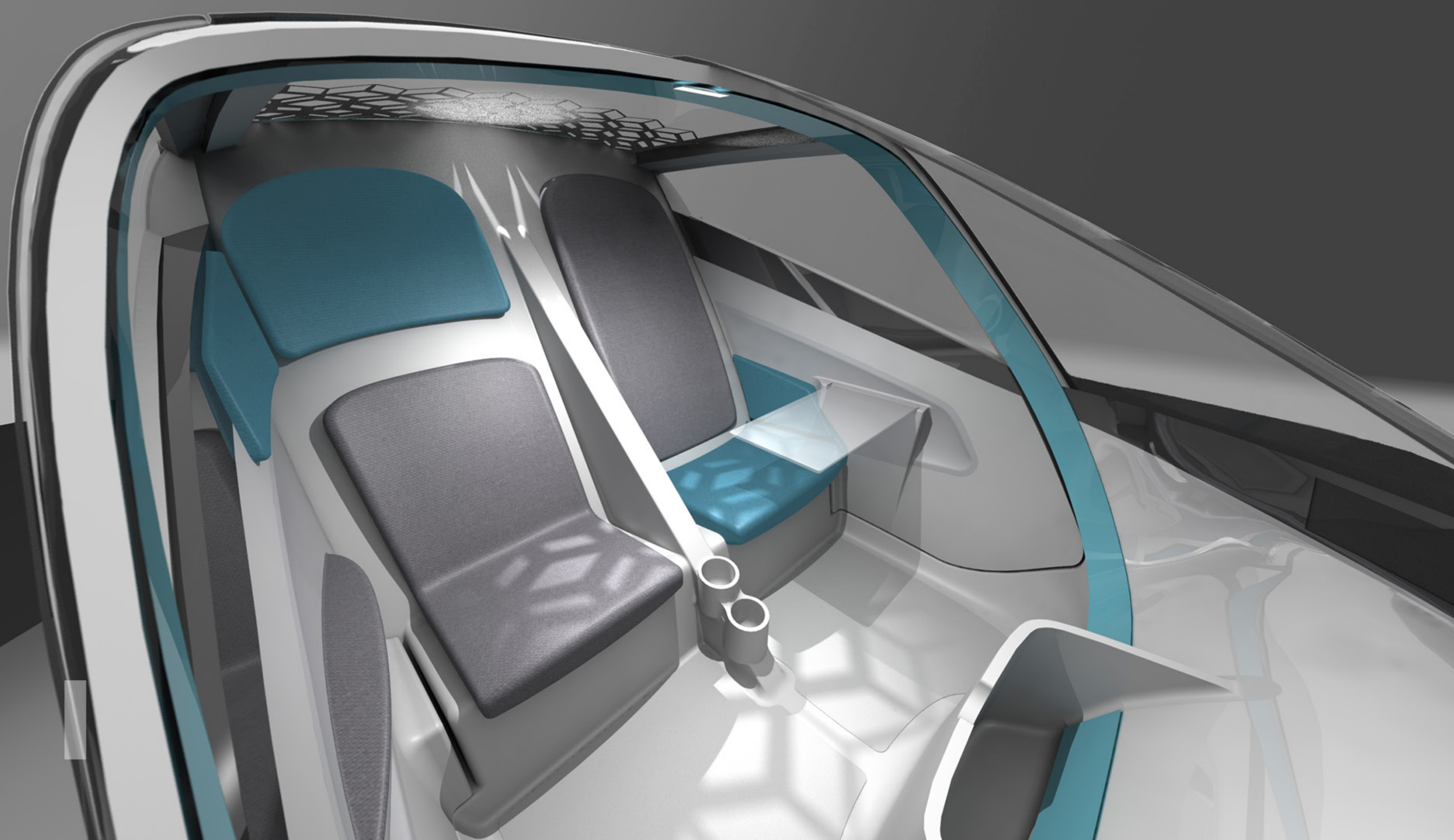
Appendices



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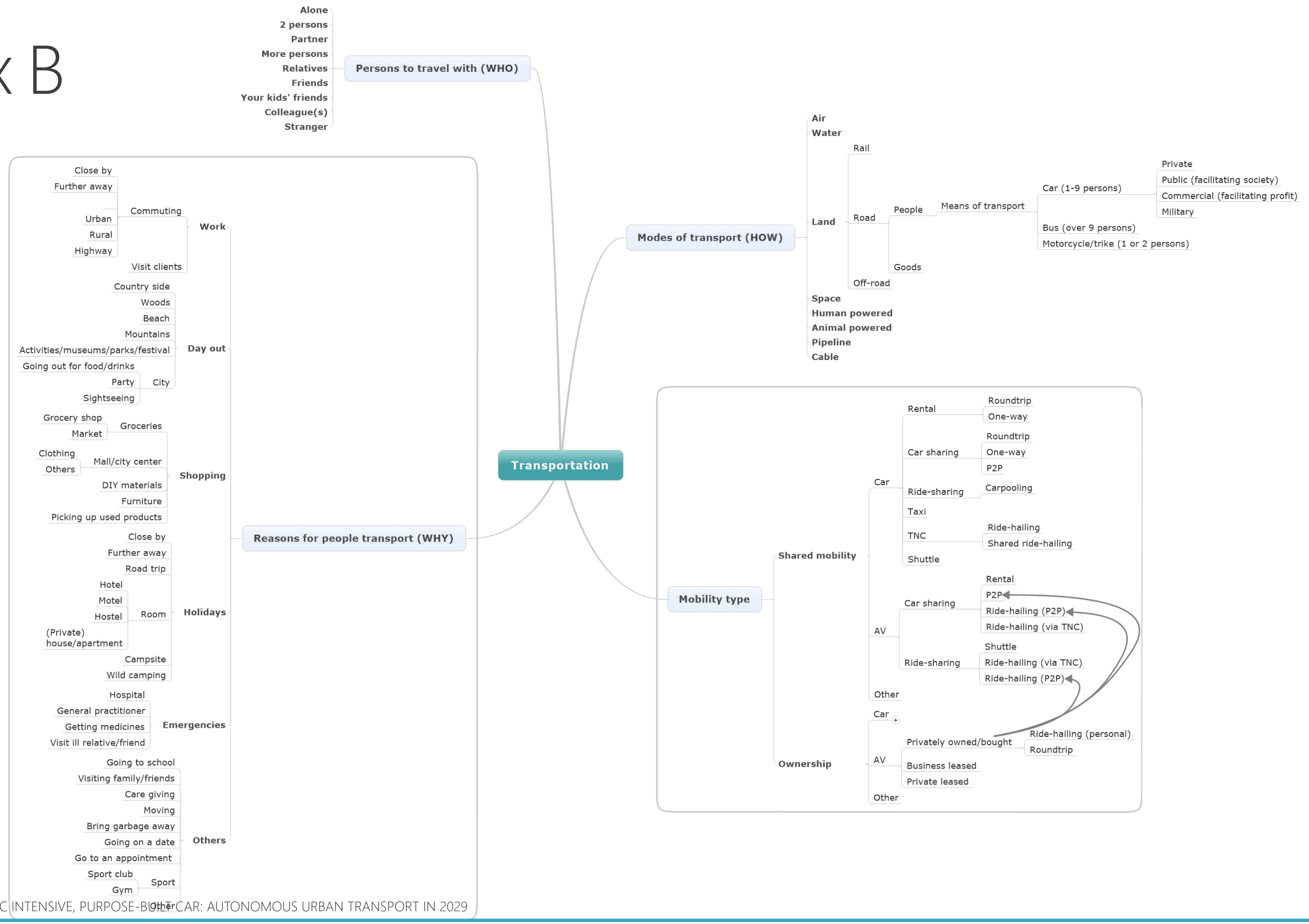
Appendix B

Mindmap on transportation

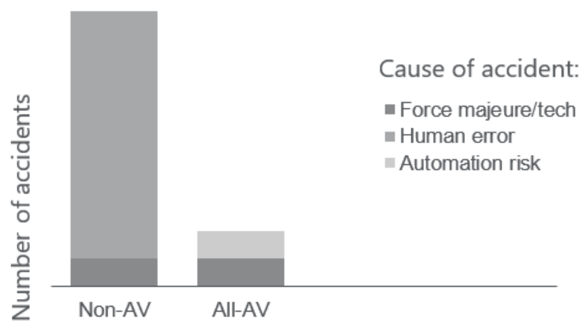


Appendix C

Main research on the backround and possible implications of autonomous driving

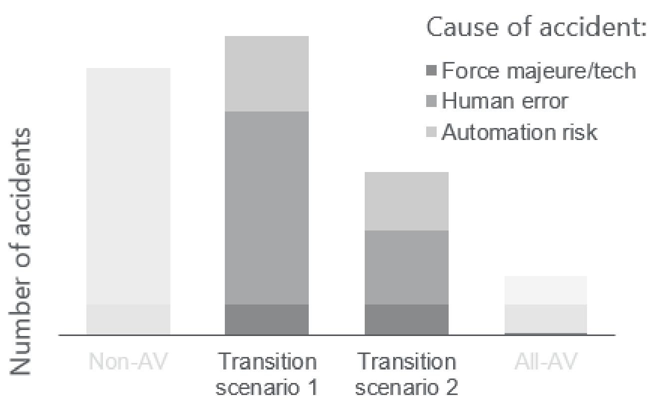
Safety

One of the most prevalent motivation advocating for automation of vehicles is the expectation that the use of autonomous vehicles will reduce the amount of (fatal) casualties, due to the fact that most of the accidents (approximately 90-94 per cent (European Commission, 2018; NHTSA, 2018)) can be linked to human error, most often related to recognition and decision errors (NHTSA, 2018). Annually about 1.35 million traffic deaths are recorded worldwide (WHO, 2018). When the human factor is taken out of the equation, theoretically all of these fatal and non-fatal accidents are zeroed out, assuming that the advanced ADS in dedicated vehicles is indeed able to fully cancel out any accident of this kind. However, this appears to be a too generic statement as some other ADS-related incidents might appear (Gasser et al., 2012), as schematically illustrated in the figure below.



Litman (2018) shows that these accidents can be related to hardware and software failures (technical) and other force majeure (which is currently also the case with non-ADS-DVs), hacking of the ADSs, increased risk-taking by passengers and other road users due to confidence in the ADSs, platooning risks, and possible increased crash involvement because of the increased vehicle distance traveled (VDT).

This optimistic image of reduced accident rates is not taking the transitional period or use of dual mode vehicles into account, where autonomous vehicles and human-driven cars are sharing the road. However, it is found to be extremely difficult to predict what this transitional period means for safety and it is cautiously mentioned that it even might have a negative impact on road safety (Litman, 2018; Sivak & Schoettle, 2015a). This might have to do with the fact that with lower AV market penetration, accidents attributed to human error still exists as depicted in figure 4, where a significant part of the risk of automation is attributed to the interaction between automated and non-automated vehicles.



When looking at safety and bearing in mind the aforementioned 'something everywhere' future development, where expansion of used ADSs in vehicles over the years will lead to higher levels of automation, another potential hazard presents itself. The basis of this hazard is partially rooted in the discrepancy between the mental models of drivers and users and the reality of the capabilities of ADSs (Saffarian, de Winter & Happee, 2012; Llaneras, 2006): from technological point of view, the gradual introduction of more automation features in cars is a logical advancement of technology (Gasser et al., (2012)) and helps gradually increase trust in the system (König & Neumayr, 2017), but overreliance and mental underload causes drivers to be less attentive and more disengaged from their tasks as vigilant driving monitor (DM) (Solís-Marcos, Galvao-Carmona & Kircher, 2017, Banks, Eriksson, O'Donoghue & Stanton, 2018). The names assigned by some OEM's to these systems (cf. Autopilot (Tesla, 2019)) facilitates this misinterpretation, despite the fact that safety features do have warning cues when human intervention is needed. Making a proper human-machine interface (HMI) in order to manage expectations (Gasser, 2012) and communicating the possibilities and limits of these driving automation systems is the key challenge in driving automation systems, where the driver's role is not so much driving as monitoring, and is expected to be capable of intervening in time (Seppelt & Lee, 2015). A combination of engaged level 2 and 3 driving automation systems and failed driver intervention have already been reported to cause several accidents. This is why others are advocating for the more revolutionary 'everything somewhere' approach, in which there is no need for a fallback-ready receptive user for the ADS-DV technology during the automated driving tasks and therefore theoretically the inattention of the user cannot cause any accidents. This would mean that future vehicles will probably leap directly towards a level 4 system and evolve to level 5 autonomy.

Recent research on the attitude of people towards autonomous vehicles showed that they are more uncomfortable than comfortable with AVs (Hudson, Orviska & Hunady, 2019, König & Neumayr, 2017). Differences are discerned looking at nationality, gender, age and education, but the attitude remained predominantly uncomfortable. This attitude might be problematic for the introduction of AVs as human-technology trust -in literature most often defined by expectations, confidence and risk/uncertainty (Schaefer, 2013)- should increase, as the acceptability of ADSs originates in trustworthiness and the state of feeling comfortable being dependent on ADSs (Waytz, Haefner & Epley, 2014, Verberne, Ham & Midden, 2012). There is an opportunity for these attributes for trustworthiness and perceived safety to address in the design of a driverless vehicle in order to increase acceptance. For an optimal result this acceptance should be addressed on two levels; the impact of the characteristics and side-effects of the actual AV, and the concerns considering technology and automation (Hudson, Orviska & Hunady, 2019).
König & Neumayr (2017) conclude that based on respondents' strong desire to be able to take over control of the vehicle at any time due to lack of trust, the vehicle should allow the user to intervene with the driving tasks. This, however, is contradictory with the aforementioned actual (expected) collective safety and therefore not desirable. Therefore other attributes to increase trust than vehicle control should be explored.

Traffic flow

One of the frustrations of car drivers is vehicular queueing and being stuck in a traffic jam (SWOV, 2012, IBM, 2009). Being a counter effect of accessibility, the main reasons for traffic congestion in general are of structural and incidental nature. The former is the case when many people work similar office hours and are therefore going to and from work at similar times, or a road capacity that is too low for the demand at any time. The latter is applicable to accidents, roadworks or other culprits that temporarily lowers the threshold for road saturation (Falcocchio & Levinson, 2015). Over the years many attempts of addressing the road saturation have been made, like changing infrastructure and urban planning (changing supply), but also transportation demand management (TDM) measures has been used in many places to tackle these problems, which includes encouraging drivers to change their behavior like introducing stimuli to start using other mobility types, advocating other working hours and implementing congestion taxes on oversaturated roads (regulating demand) (Ison & Rye, 2016).

Three main future road-use scenarios can be discerned:

- one scenario with partial market penetration where AVs and non-AVs are sharing the road
- another with partial market penetration but where only at certain operational domains only AVs are allowed
- and a scenario where there are only AVs driving around and conventional cars are forbidden on the public roads.

Theoretically, vehicle autonomy should be beneficial for traffic flow: when looking solely at changing the existing vehicles to AVs (scenario 3) it can be assumed that due to smart, anticipating technology and inter-car communication (like V2V and V2I), preliminary anticipation to changing traffic will benefit the traffic flow and reduce the risk of traffic waves and accidents. Moreover, the possible shorter following distances that can be achieved increases the road capacity without increasing the actual road surface area, and combined with more constant vehicle velocities congestion might reduce (Fagnant & Kockelman, 2015). Additionally, Bose & Ioannou (2003) expect that with a 10 per cent AV penetration on highways, traffic waves (one of the causes or amplifiers of slowing traffic) can be smoothed out. As seen in these researches, the expected net changes in traffic flow are only considered in the first and third scenario (respectively AVs and non-AVs share the road and only AV on any road).

However, assuming that the rise of vehicle autonomy will enhance traffic flow, solely based on a limited amount of aspects in these scenarios, seems too superficial. In general the vehicle distance traveled (VDT) increases with population growth, a decline in population density, higher income and higher car ownership rates (Falcocchio & Levinson, 2015), which is still the tendency at the moment. Also, with better vehicle accessibility and increased efficiency (which is the expectation with AVs), the demand for road transportation might not remain the same, but increase (Gruel & Stanford, 2016). Therefore it might not be unimaginable that with certain amounts of AVs on the road the traffic flow might not be influenced that radically. Looking at the V2X technology, especially vehicle to infrastructure and vehicle to vehicle, a higher market penetration or areas with a high share of autonomous vehicles is needed for significant benefits and effects of these systems.

Convenience

The driverless vehicle brings some potential conveniences along with the fact that with an ADS-DV (either single mode or dual mode) there is no need to drive the car yourself and therefore time in the car can be spend differently. As it is often assumed that the implementation of the AV goes hand in hand with a mobility system that is more shared-focused, convenience is also manifested in that the most suitable vehicle option for a particular trip can be chosen.
In order to understand what the potentials of the AV can be for the user in terms of convenience, a mind map has been drawn out, logging all the potential use cases for trip making (Appendix C).
This need or reason for transport can be for example commuting for work, a day out, go shopping, going on holiday, emergency related and more. Some of them require to have a vehicle available for several moments over a longer period of time (such as on a holiday), whereas most of them require a vehicle for just a roundtrip (going to the destination and back). Some of them occur regularly (such as commuting to work, doing grocery shopping, going to school), whereas others are more incidental, like holiday, going out for the day and emergencies.

What differentiates certain means of transport from one another?
- Walking/cycling for shorter distances, preferably with good infrastructure suitable for these means. Bad weather is not preferable.
- Car over public transport, due to freedom of when to leave and door to door transport. Also you can reach remote places.
- Public transport over car, due to per-route payment or prescription and therefore no expenses related to vehicle ownership. It provides good accessibility in dense urban areas and during the trip the user is being a passenger and not the driver.

The (shared) AV is bound to combine these aspects and benefits.

With the absence of the need of human driving tasks, the travel time in the vehicle can be spend doing something else (everyone is a passenger). This change in the way how people behave and approach mobility increases the importance of the vehicle interior (Kilinçsoy, 2018). This can be translated into some use cases and interior functions. This might ask for a different design and project development approach, where the target group is researched and addressed in a more in-depth manner and the interior functions are less restricted by the exterior packaging (Hofmann, 2018).

A lot of research has been conducted to this day on autonomous vehicles and what interior functions they can provide for the users:
- Schoettle & Sivak (2014) have surveyed 3255 persons in several countries and found that the most recurring response to the question what they would think they would do with the time saved in the car by not having to drive, was watching the road (the most heard response), reading, texting or talking with friends and family, sleeping, watching movies, working and playing games.
- Kilinçsoy (2018) observed activities of train users and people in semi-public places in order to get an idea on what people would do naturally in a situation where they are waiting. They have been observed to be sleeping, relaxing, watching around, reading, talking, eating/drinking, and using small and large electronic devices. (difference sleeping public space)
- Kyriakidis, Happee & de Winter (2015) investigated user attitudes towards automated vehicles. They tested 4886 respondent's attitudes towards the following secondary tasks: resting/sleeping, listening to radio, phoning, mailing, watching movies, reading, eating, passenger interaction and nothing. For every tasks except radio listening and doing nothing, the likelihood of people engaging in these tasks increases with a higher level of automation.
- Additionally, all the companies that made the AV concepts that are discussed, have their own vision on what the function of the vehicle could be. These are mainly relaxing (resembling a living space/lounge), working, but also entertaining and creating privacy. Sometimes flexibility of the interior allows users to change between several of these functions.

A downside to the convenience of AVs is that when the cost of time in autonomous car becomes lower, people might choose to live further away from the city. It will increase the total traveled distance (Anderson et al., 2016; Fagnant & Kockelman, 2015). This might have a negative effect on public transportation and increase the dependency on cars (AVs in this case) (Gruel & Stanford, 2016) and will negatively affect the traffic flow.

Comfort

When performing tasks, the brain tries to diminish task-irrelevant stimuli with selective attention (Huang, Kahana & Sekuler, 2009). Still it is found that people have difficulties sustaining attention for a longer period of time (Solís-Marcos, Galvao-Carmona & Kircher, 2017. With the redundancy of the high cognitive workload demanded by the driving tasks and the shift of attention, these former task-irrelevant stimuli become more apparent and makes that this external sensory input is magnified. This might not be the case if the driving tasks are replaced by equally cognitive challenging tasks, but it is imaginable that most of the interior functions might be cognitively less demanding for the users.
Comfort in general, but also in vehicle interiors is a comprehensive indicator and can be divided into visual comfort and physical comfort where the former can be influenced by among others color, shape, smell, tactility, sound, temperature and humidity and the latter by product shape in contact with the body, material softness, sensitivity of the body, and the human-product contact area (Vink, Kamp & Blok, 2005, Vink & Brauer, 2011, Vink & Lips, 2017).
The perceived comfort is more related to the visual aspect of comfort, whereas the perceived discomfort is related to the physical nature of comfort, rather than the absence of comfort and therefore these are two separate discrete states (Zhang et al., 1996).

There is a correlation between comfort level and intention to travel again with the same carrier in the future. This is important to realize for providers of vehicles in a car sharing and ride-hailing service: if the shared mobility type for an intended trip is deployed by different companies with different vehicles, consumers can choose whichever fits them most on different aspects. Consequently, changing carrier after a bad experience might be rather simple when there are several alternatives within the same mobility type. With most of the current public transportation service opting for another carrier within the same mobility type is not possible, as the respective routes are most often deployed by one single company.

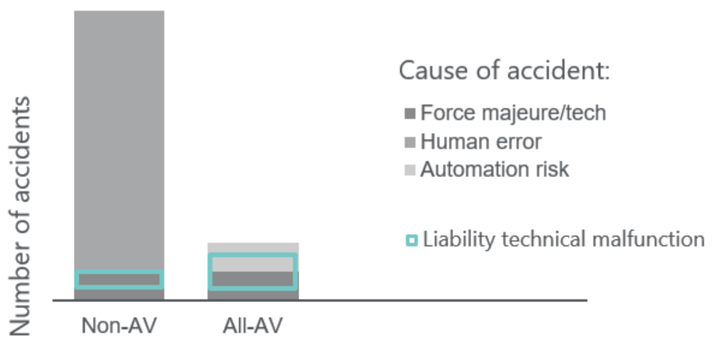
As a company it is always important to know how to create customer loyalty, as it is often considered to be an attribute for positive sales development.
To describe the attachment of a consumer to a service or product, several aspects are considered, namely the intention to reuse and recommend it and general satisfaction, or contentment, where the latter might be a driver for customer loyalty in public transportation (Zhao, Webb & Shah, 2014). These aspects might also be useful in the assessment and development of the autonomous vehicle as a shared mobility type, keeping in mind that the reasoning behind utilization of public transportation is usually driven by necessity (captive rider) or choice (choice rider), but for car-based shared mobility this might not be necessarily the case. Additionally it is researched that personalization in any system is considered to have a positive effect on loyalty directly and through customer satisfaction and trust and can therefore be important in realizing a lucrative service or system (Ball, Coelho & Vilares, 2006).

It can be imagined that a mass produced vehicle cannot be entirely personalized to a particular individual, but with mass customization a certain level of personalization can be achieved.

The perceived comfort of products is correlated to the expectations that the user has of the product (Naddeo, Cappetti, Califano & Vallone, 2015). With a product that is composed of lots of different parts and product (such as a car), the general expected and perceived comfort is based on multiple products and their interaction (for example the seat, the legroom and the material use and appearance of the door panel). Nonetheless, for a vehicle as a whole and the parts, the expected comfort should be congruent with the perceived level of comfort (when it is too low, people are less inclined to use it, which underplay the vehicle's existence, and when it is too high, users might get disappointed, which affects satisfaction and loyalty).

Ethical

In the cases where people are not to blame for accidents, who is? It might be the most straightforward to assume that the OEMs are liable when accidents are traced back to a technical malfunction. This is currently also the case: whenever an OEM or tier supplier is found to be liable for an accident, they can be prosecuted (look at for example the case of Takata airbags, found responsible for 8 deaths and around 100 injuries, GM Chevrolets, responsible for 124 deaths and Ford and Firestone, where over 100 deaths are attributed to faulty tires and the tendency of rollover of SUVs (Levin, 2015)). These lawsuits are most often accompanied with recalls of vehicles of the same category or using the same parts.
Therefore, in the situations where force majeure or technical malfunction is the culprit, nothing is expected to change in terms of liability. However, with more -and more crucial- software modules (ADSs), the potential liability of OEMs and tiers for technical malfunction expends to this new type of accident-category (due to automation risk) as depicted in the figure below.



When looking at the situation where possible new types of accidents due to vehicle automation occur, some might say that it is a trade-off of lives and ethically not preferable (the net safety is reduced, but for certain groups the safety risk might increase). Considering the introduction of safety measures, the focus is on the probability of the consequence of that measure and not on the consequence on its own (Hevelke & Nida-Rümelin, 2014), which counteracts the previous statement. The liability for the remaining portion of accidents due to automation risk might be attributed to another party.

Taking a step back and looking at the maneuvering behavior of the AV, it is clear that decisions have to be made, just as in cars that are driven by humans. But where the decisions of the latter are made directly by the human (driver), for the former the decisions will be made by a machine (albeit programmed by a human). In mixed-traffic situations, the ADS-DV should anticipate human error of non-AVs drivers, but also other road user. In a no-win unavoidable harm situation an AV's system has to opt for the least severe option, but psychologically and morally the right decision is still disputed (Maurer, Gerdes, Lenz & Winner, 2015, Sivak & Schoettle, 2014), as the 'trolley problem' depicts. This thought experiment poses the question whether or not intervention for avoidance of more casualties, but resulting in an other casualty is preferred over no intervention. MIT has conducted a large research globally where they tested people's preferences in how they think self-driving cars should act (Awad et al., 2018). Preferences for sparing human lives, more lives and young lives were reflected in their decisions. Some deviations were found due to the differences in individualistic and collectivist cultures.

People's reservations about the technology is also based on concerns regarding privacy and hacking of the systems (Sivak & Schoettle, 2014, Hudson, Orviska & Hunady, 2019), which is closely associated with a more connected future with increased sharing of information.

Health

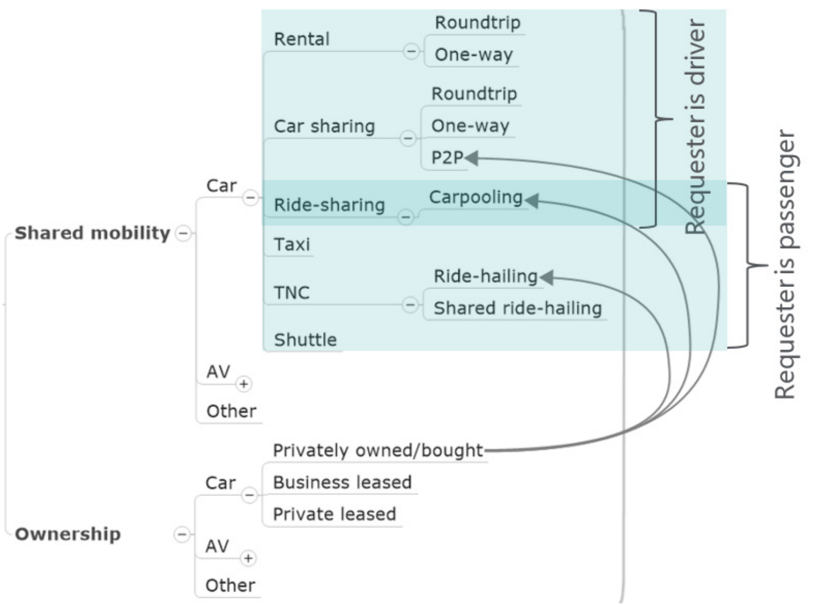
Beside the impact of car accidents on (public) health, other health implications of autonomous vehicles can be considered as well.
One of the most common illnesses found in vehicular movement is motion sickness. The cause being not fully understood, it is most often assumed that the experienced nausea and causes are induced by conflicting input between visual (sight) and vestibular (balance and spatial orientation) systems (Murdin, Golding & Bronstein, 2011). This can be both, actual movement without visual input or visual suggestion of movement without actual motion. Persons that are especially susceptible to car sickness or experience it easily, benefit from measures that reduce the conflicts between sensory inputs. As a driver motion sickness is rather rare, as you are in control of the vehicular movements, but if the user is no longer in control (becoming a passenger) the chances of experiencing motion sickness increase (Diels & Bos, 2016).

Mental health could increase with vehicle autonomy; with little direct involvement with other road users stress related to driving tasks are diminished. However, when involved in other activities other stressors might be introduced. While working in the car, stress related to this work might be unveiled.
Physical health implications of car travel is mainly attributed to sedentary behavior. In general, increased sedentary behavior is associated with increased cardiometabolic risk (which increases the chance of narrowing arteries and development of diabetes) (Knaeps et al., 2016). Additionally, the lower involvement in moderate to vigorous physical activity also showed increased cardiometabolic risk, independently of the sedentary behavior.

Car ownership

Until now, the automotive market has been dominated by personally bought vehicles. But with the rise of private lease, the share of lease vehicles is increasing and with technological advancements and smartphone use being commonplace, shared mobility have entered the mobility sector as well. Looking at the car as a mode for shared mobility, some types are well-known for some time already, such as the taxi, rental car, shuttle and ride-share (carpooling) whereas some other services are relatively underexposed, but gaining a greater market-share, especially in cities, such as car sharing and ride-hailing (facilitated by a transportation network company (TNC)) (Clewlow & Mishra, 2017). Sometimes some of the aforementioned terms are used interchangeably, but there are distinct differences between them, which are explained next. The enumerated shared mobility types are schematically depicted in the figure at teh right.

- The rental car is requested by a rental company for a fixed amount of time. Depending on the service of the rental company, it is possible to either rent it as a roundtrip service, where you return the vehicle to the destination where it was rented from, or as a one-way service, where the company enables you to return it to another location than where it was picked up. As you are renting the vehicle without a driver, you are expected to drive the vehicle yourself.
- The car sharing service is similar to the rental service on the aspects of the requester of the service being the driver as well and the possibility to opt for a roundtrip and one-way service. Additionally, the peer-to-peer (P2P) service provides the requester the possibility to get a car that is not part of the fleet of a car-sharing company, but rented out by an individual. Usually the shared car is paid by the hour or minute, as opposed to the prepaid and fixed period of use of rental vehicles.
- Ride-sharing, often referred to as carpooling, is a mobility type that originated as a solution for commuters that traveled similar routes. Within the 'pool' you could either be the driver or the passenger and you share the costs of travel with the other participants. In several countries ride-sharing has been promoted by companies and government in order to reduce the amount of vehicles on the road that are occupied by only one user.
- A taxi is a rather traditional service where professional drivers are driving around and can be hailed at the roadside or on designated taxi stands. The requester of the service will be a passenger and not a driver as opposed to the previous shared mobility types. The fair is depending on a combination of the traveled distance and amount of time spend in the taxi. With the smartphone it is often also possible to hail a taxi in advance and taxi companies are introducing apps as well to attract more customers for their service.
- Ride-hailing (and shared ride-hailing) is a service provided by a TNC that can be joined by both professional and part-time drivers. It compares to a taxi in the way it operates (the driver picks the requester up at a location and is dropped off at the desired location), but it differs in the way that it is hailed and paid for. This is all conducted via a subscription-based mobile platform that matches the customer with a nearby driver. The drivers of the vehicles are contractors for the TNC and not employees as is the case with a taxi company and are therefore free to choose how much and when to work. Due to the integration of recent technological advancement in this shared mobility type, it can be considered as an evolution of the taxi.
- The shuttle service is usually deployed on fixed routes to connect different transportation hubs with each other, or as a service of a company to transport their consumers or employees locally. Within this mobility type the user is likely to share the vehicle with others and has no say in this.
- A car that is owned by the user in the sense that the vehicle is either bought or paid for in fixed terms for a prolonged period of time, might be offered for shared mobility as well (if the insurance allows it). Platforms where car owners can offer their car for sharing (P2P), carpooling systems and ride-hailing services are being introduced over the years.



In some countries and large cities the taxi sector is regulated and the regulations do not yet consider ride-hailing (enough) (Hall, Palsson & Price, 2018), resulting in adjusting regulations or even banning of the system at all (Clewlow & Mishra, 2017). However, the adoption of this service and variation on it (shared ride-hailing) is rapidly increasing worldwide.

Initially it was thought that ride-hailing services would affect the use and development of public transportation negatively, but research argue that ride-hailing might be a complementary option to alternatives of using your own car, like public transportation. It has an effect on car-ownership and use and public transport use and its attribution depends on personal motivations: it might be an alternative and used as a substitute for public transport or complementary in the sense that it will provide the user with more flexibility (reachable locations and also time-wise) when using a combination of public transport and ride-hailing for first and last mile (Hall, Palsson & Price, 2018).

In prospects, vision and concepts, AVs are often envisioned to be privately owned (luxurious) vehicles, AV car shared (and ride-hailing based) or (fixed route) ride-sharing shuttle services (see chapter X). There are some advantages and disadvantages to any of these ownership models, as mentioned by Litman (2018):

- For a personally owned AV, the (dis)advantages are similar to the current situation of vehicle ownership: the advantage of having a car available at any given time, you can take it to a broad variety of locations and you can leave your belongings in your car.

But the ownership comes with a higher price, especially considering you pay for it even when you don't use it. Additionally, the car that is bought, might not fit every scenario optimally.

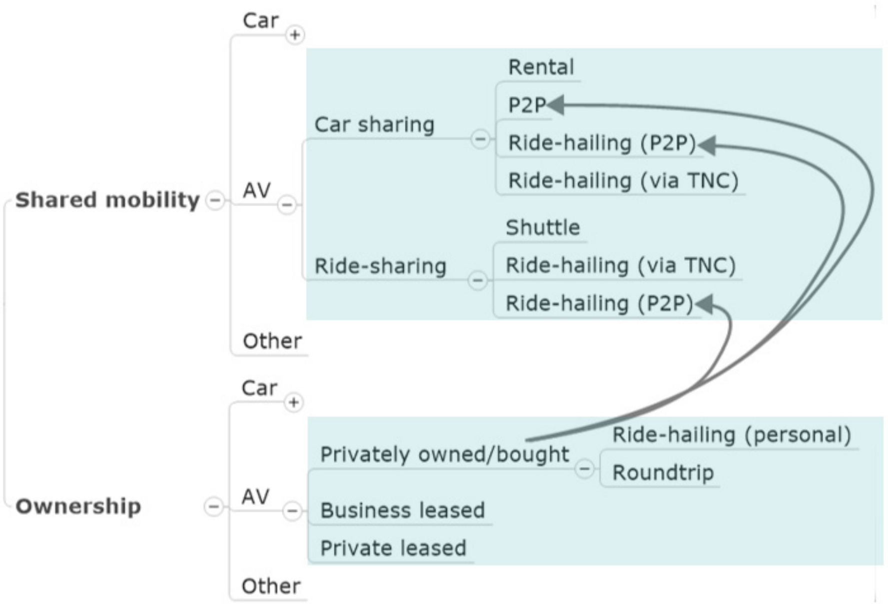
- Accompanied with a little more effort, a shared AV can be hailed by the user and pick them up and drop them off at the locations of their choice. The vehicle choice can be tailored to their specific needs at that time. The absence of the high initial vehicular cost does not need to be carried one-to-one by the user. Whereas a chauffeur might assist the customer, that might not be the case anymore when a chauffeur is rendered obsolete. Other aspects of public (shared-vehicle) transportation might be applicable here as well, such as having no control over the status of the vehicle in terms of for example cleanliness.
- The AV ride-sharing vehicle would be expected to be the most affordable, as faring is based on multi-person use and is currently used for short distances at low-speed. These shuttles are often less comfortable to drive, might be fixed-route based (but not necessarily) and the disadvantages of the aforementioned mobility type would apply here as well (Litman, 2018).

The terminology of mobility types within the context of AVs can be similar to that of the situation of conventional vehicles, but due to the redundancy of a driver, there are some slight differences within these proposed overarching categories, as depicted in the figure at the right and explained below:

- Within the AV car sharing system, a car can be rented from a company (AV rental) or an individual (AV P2P) and within the rental period be used (and hailed) by the renter only. Another option might be the subscription based

Additionally the AV in this mobility type can be hailed via TNCs or individuals. In this case, however, the vehicle is hailed from the spot and can be used for one trip and after that be hailed by someone else.

- The ride-sharing AV can be envisioned as a shuttle service between fixed points with several stops in between (that is how it deployed at the moment as well). Another option is to hail a vehicle from a TNC or an individual. People that have proximate destinations can be coupled to share the same ride.
- If an AV is personally owned, it could be bought or leased. Especially in the early years when the prices of these vehicles will be significantly higher than conventional vehicles, due to the not yet available economies of scale, leasing might be the more attractive alternative when ownership is preferred. This has been seen in the rise of (battery) electric vehicles ((B)EV) as well, where most of the vehicles are being leased as well, due to the higher prices than comparable vehicles with internal combustion engines (ICE) but also because of the long term risks (battery degradation and vehicles with better range developing rapidly).



Pollution

A lot of changes in regulations and approaches for problems in general are partially rooted in environmental awareness and reduction of harmful emissions. This is also the case with car mobility: ever since the California Air Resources Board (CARB) passed a mandate in the nineties that enforced OEMs to start developing less polluting vehicles, the development of electric vehicles, (plug-in) hybrids and other alternatives for the ICE started to take off (Shaheen, Wright & Sperling, 2002). The reasons behind the introduction of AVs is line with the measures for the reduction of emissions, as a more shared mobility system, the use of the electric drivetrain and a better traffic flow should be beneficial.

But with better vehicle accessibility and increased efficiency, the demand for road transportation might not remain the same, but increase (Gruel & Stanford, 2016, Pakusch, Stevens, Boden & Bossauer, 2018). This phenomenon in general, labelled as the Jevons paradox, is seen in a lot of different disciplines and is expected to be applicable to the future of autonomous vehicles as well. The rebound effect, explaining that the actual achieved reduction is diminished (or neutralized or even negative) by e.g. increased trip-making, results in a less positive image as the reduction will be lower when using a more holistic approach in understanding traffic demand instead of only looking at vehicle efficiency (Pakusch, Stevens, Boden & Bossauer, 2018). Additionally, besides the increased trip-making of users due to the attractiveness of the mode of transport, AVs are expected to make trips without passengers in order to go to another consumer, or a parking spot, charging or cleaning point, increasing the VDT even more.

Sorrell, Gatersleben & Druckman (2018) discerned seven types of rebound effects related to efficiency of vehicles:

- Direct effects, where efficiency translates into lower costs and higher vehicle usage rates and distance travelled
- Indirect effects, where efficiency induced cost savings are used to finance other goods or services
- Embodied effects, describing that technological advancements to ensure efficiency put extra strain on the production part of the life cycle
- Service quality effects, describing that technical improvements induces the demand for e.g. larger or more powerful cars instead of more efficient ones.
- Energy market effects, which explains encouraged increased energy consumption due to lower prices as a result of the initial lower demand
- Secondary effects, which explains changes in prices investment, production and trade, affecting energy consumption
- Transformational effects, indicating that efficiency increases attractiveness of the vehicle as transportation mode and consequently increasing the strain on the car-related infrastructure

The rebound could be regulated on some of these levels by for example increasing costs of travel, increasing travel time, limiting comfort, enhancing attractiveness of alternative modes of transport (Gruel & Stanford, 2016). But some of these measures might conflict with interest of involved parties.

Yet, improving vehicle efficiency is still a rather self-evident way of improving vehicles. In any case it will have positive effects; either for the environment (due to decreased pollution) or for the users (cheaper or ability to travel further). To increase efficiency, the drivetrain and propulsion plays a key role, but also the aerodynamics of the vehicle (drag coefficient, affected by frontal drag area and airflow to the back), rolling resistance, and the used materials (for weight reductions or substitution for more environmentally friendly alternatives) (Cerdas, Egede & Herrmann, 2018). The holistic approach of a life cycle assessment (LCA) shows that when electric vehicles (as long as the energy they used does not come solely from coal) are implemented, that their overall CO2 emissions after some period of use are below that of an ICE vehicle (with breakeven points between 40.000 and 100.000 driven kilometers, depending on the used ICE, battery technology and energy mix of charging the EV battery) (Hawkins, Singh, Majeau-Bettez & Strømman, 2012).

EQUAL MOBILITY

When being able to dive a car is not a requisite anymore, anyone should be enabled to make use of a car. Societal groups that might not have been able to drive themselves, but can use an AV on their own include people that don't have a driver's license, children that are too young to drive, people that are disabled to drive due to physical or mental reasons and elderly who don't have the motor skills it takes to drive (anymore). People that are unfit to drive are also enabled to use a vehicle themselves (think of people that are under the influence of alcohol, drugs or medicines or too tired to drive).

The only aspect that might be of influence is accessibility, in terms of affordability, but moreover physical accessibility (think about people that have difficulties getting in a car, due to physical limitations).

Appendix D

Reference material and derived values for the autonomous concept, as found on the respective companies' websites

Adient

AI17 (dual mode, LV4)

Privately owned, comfort, functions, space
https://www.adient.com/advancements/ai17

AI18 (single mode, LV4)

Ride-sharing, safety, comfort,
https://www.adient.com/advancements/ai18

AEV robotics

MVS (dual mode and single mode)

Modular, ride sharing, pods, goods and people
https://aevrobotics.com/

Aston Martin

Lagonda Vision Concept (dual mode, LV4)

Luxury, rotate seats, space, comfort, material
https://www.astonmartin.com/en/live/news/2018/03/06/lagonda-vision-concept---a-new-kind-of-luxury-mobility

Audi

Aicon (single mode, LV5, ride-hailing)

Luxury, premium, relaxation, lounge, function, intercity"
https://audi-dialoge.de/en/audi-aicon

BMW

Next 100 (dual mode)

Personalized, driving pleasure, mono-materials,
https://www.bmwgroup.com/en/next100/brandvisions.html

iNEXT (dual mode)

Comfort, relaxation,
https://www.bmwgroup.com/BMW-Vision-iNEXT

Chrysler

Portal (dual mode, LV3, upgrade LV4)

Millennials, family, flexibility, inside out
https://www.fcagroup.com/en-US/media_center/insights/Pages/chrysler_portal_concept.aspx
https://iimediaevents.com/chryslerportalconcept/downloads/press-releases/pdfs/CH_Portal_Concept_Overview.pdf

Honda

NeuV (dual mode)

Car sharing, facial recognition, learning, urban
https://global.honda/products/motorshow/Tokyo2017/003.html

Icona

Nucleus (IV5)

Living space, shared, versatile
http://www.icona-designgroup.com/en/portfolio/nucleus-exterior/

Italdesign

Pop.Up Next (single mode)

Multi-modal, drone, modular,
https://www.italdesign.it/press/?ps=pop.up

GEA (dual mode)

Lounge, work, relax, gym
https://www.italdesign.it/project/gea/

Mercedes

F015 Luxury in Motion (dual mode)
Space, comfort, lounge, luxury, safety, privacy
https://media.daimler.com/marsMediaSite/en/instance/

ko/Overview-Mercedes-Benz-F-015-Luxury-in-Motion.xhtml?oid=9904624

Vision Tokyo (dual mode)

https://www.mercedes-benz.com/en/mercedes-benz/vehicles/passenger-cars/mercedes-benz-concept-cars/mercedes-benz-vision-tokyo-connected-lounge/

Vision Urbanetic (single mode)

Modular, ride-sharing, goods, people, urban
https://www.mercedes-benz.com/en/mercedes-benz/vehicles/transporter/vision-urbanetic-the-mobility-of-the-future/

Mini

Vision next 100 (dual mode)

Urban, car sharing, personalisation
https://www.mini.com/en_MS/home/automotive/concept-vehicles/next-100.html

NIO

EVE (dual mode)

Living environment, stress relief, flexibility
https://www.nio.io/visioncar-experience

Nissan

IMX Kuro (dual mode)

Open space, privacy, driving, juxtaposition
https://www.nissan.com.sg/experience-nissan-refresh/design/imx-kuro.html

Nuro

(single mode)

Goods, low speed, errands
https://nuro.ai/product

Peugeot

e-LEGEND (dual mode)

Excitement, desire, dynamic, heritage
https://int-media.peugeot.com/en/peugeot-e-legend-concept

Renault

SYMBIOZ (dual mode, LV4)

Living room, space, activities,
https://group.renault.com/en/news/blog-renault/renault-symbioz-demo-car-an-innovative-people-focused-design/

EZ-GO (single mode, LV4)

Ride-sharing, hailing, urban
https://media.group.renault.com/global/en-gb/renault/media/pressreleases/21205140/renault-ez-go-premiere-mondiale-du-robot-vehicule-concu-pour-la-mobilite-urbaine-partagee

EZ-PRO (single mode)

(last-mile) delivery, car sharing, customizable, productivity, skateboard platform
https://media.group.renault.com/global/en-gb/renault/media/pressreleases/21215529/renault-ez-pro-un-robot-vehicule-et-un-concierge-pour-la-livraison-du-dernier-kilometre

EZ-ULTIMO (single mode, LV4)

Premium, luxury, car sharing, privacy, living room, space, juxtaposition
https://group.renault.com/en/news/blog-renault/renault-ez-ultimo-inspired-by-french-design/

Rinspeed

Snap

Skateboard platform, modularity, urban
https://www.rinspeed.eu/en/Snap_48_concept-car.html#mehrlesen

Microsnap

Skateboard platform, modularity, urban
https://www.rinspeed.eu/en/microSNAP_50_concept-car.html#mehrlesen

Rolls Royce

103EX (single mode)

Luxury, personalized, unique
https://www.rolls-roycemotorcars.com/en-GB/103ex.html#

Smart

Vision EQ fortwo (single mode)
Car sharing, hailing, urban
https://www.mercedes-benz.com/en/eq/concept-cars/smart-vision-eq-fortwo/

Toyota

Concept-i (dual mode)
Driving, inside out, experience
https://www.toyota.com/concept-i/

E-palette (single mode)

Goods delivery, service, ride-sharing, flexible
https://newsroom.toyota.co.jp/en/corporate/20546438.html

Volkswagen

Sedric (single mode, LV5)
Car sharing, ride sharing, mobility for all, lounge, space
https://www.discover-sedric.com/en/

I.D. Buzz

Rail system, flexible, space, lights, lounge
https://media.vw.com/en-us/releases/826

I.D. Vizzion (LV5)

Luxury, lounge, customize, comfort,
http://inside.volkswagen.com/world-premiere-in-geneva-the-ID-vizzion.html

I.D. Crozz (dual mode)

Lounge,
http://inside.volkswagen.com/ID-Crozz-IAA.html

Volvo

360c (single mode)

Travel, sleeping, comfort, car sharing, versatile
https://www.volvocars.com/intl/cars/concepts/360c

Yanfeng

XiM18 (dual mode)

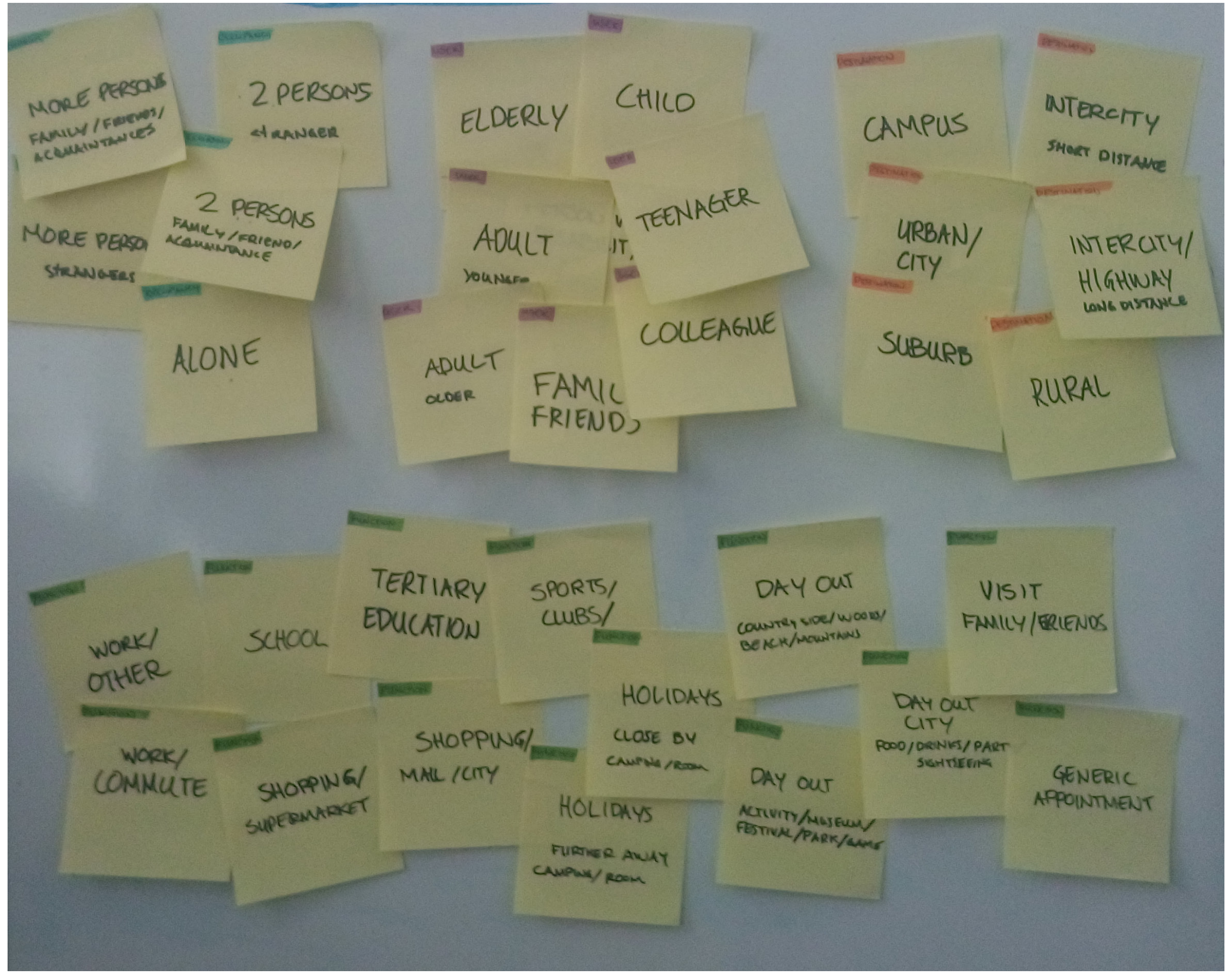
Functions, moving arrangement, comfort, lounge, work
https://www.yfai.com/en/yanfeng-automotive-interiors-xim18-makes-european-premiere-iaa-2017

XiM20 (single mode)

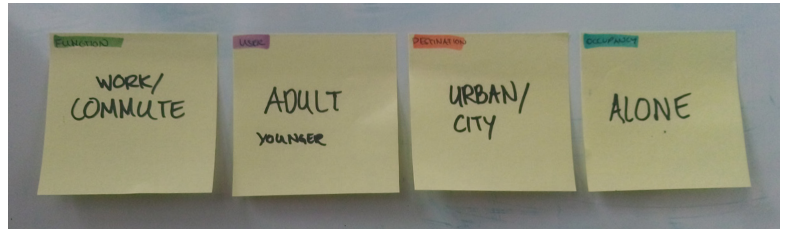
Ride-sharing, comfort, flexibility, clean
https://www.yfai.com/en/yanfeng-automotive-interiors-unveils-xim20-autonomous-rideshare-vehicle-interior

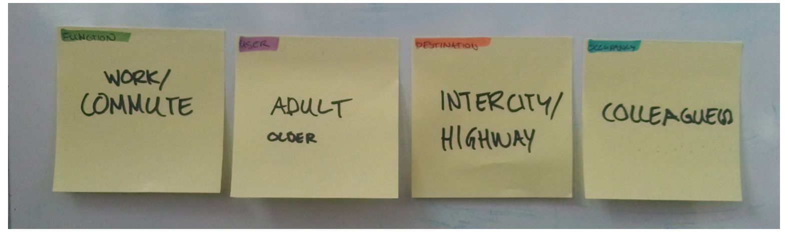
APPENDIX E

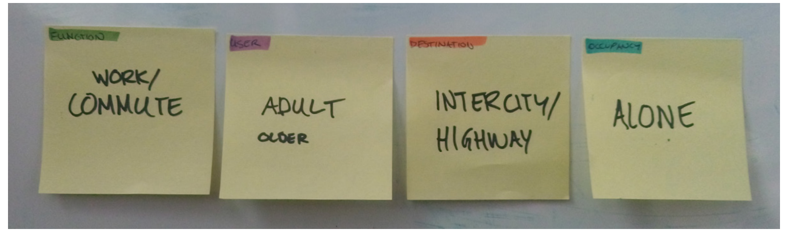
Scenario ideation and combination

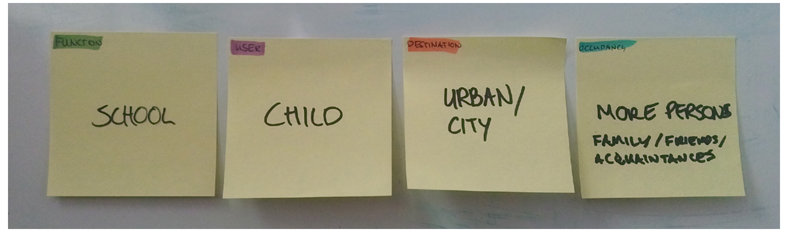


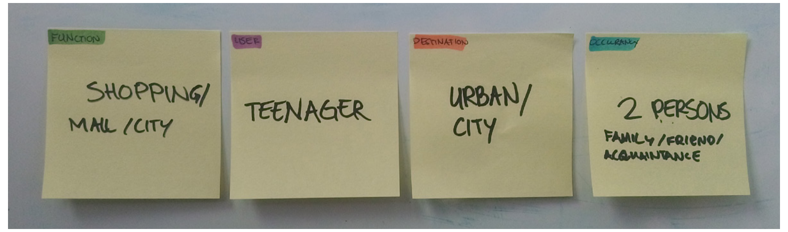
- vehicle occupancy
- user type
- environment
- function of vehicle use

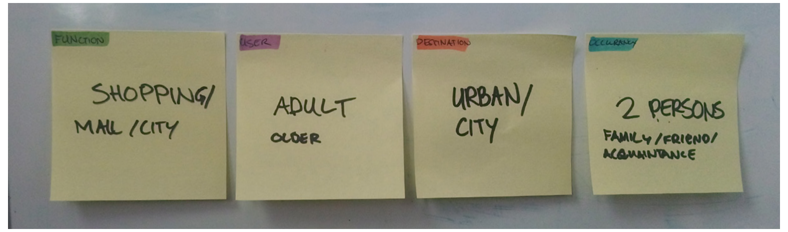


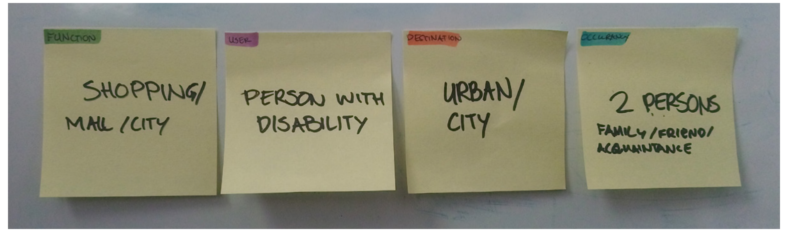


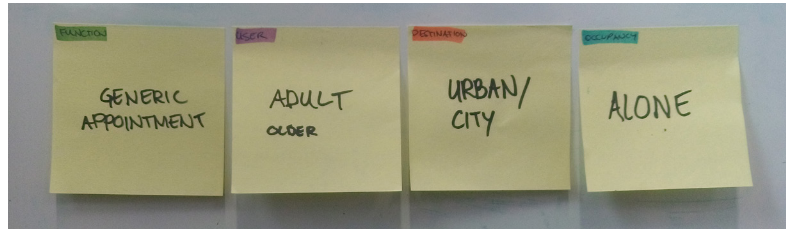


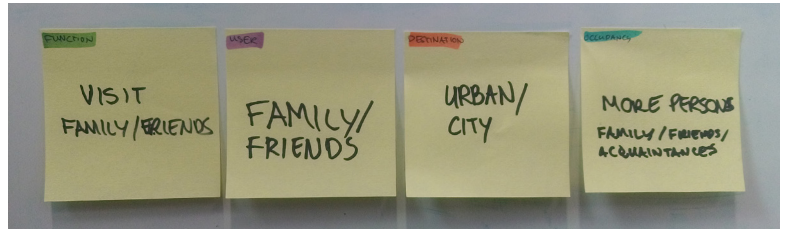


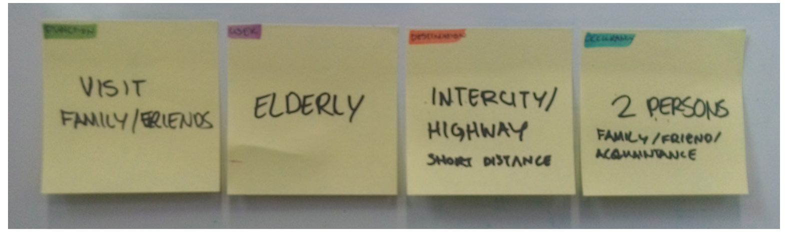


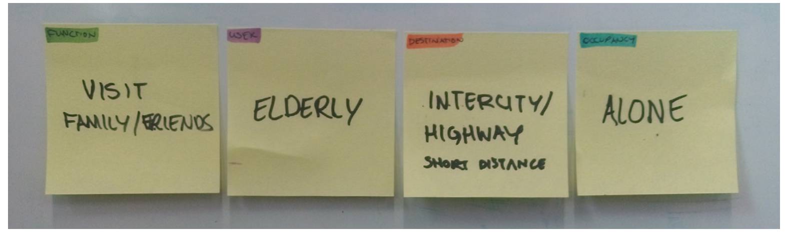


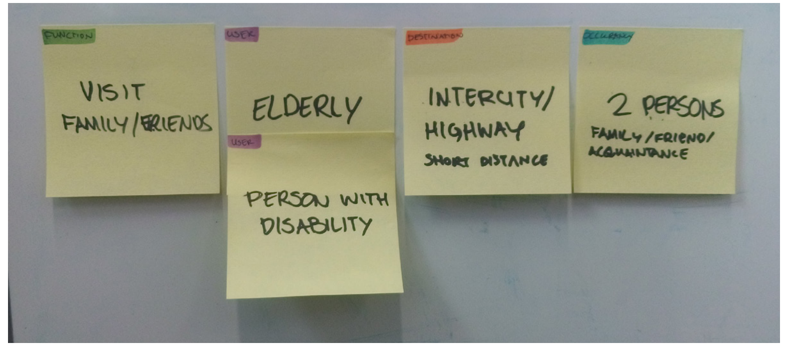


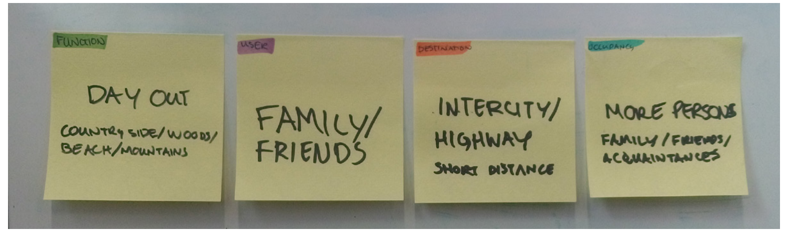


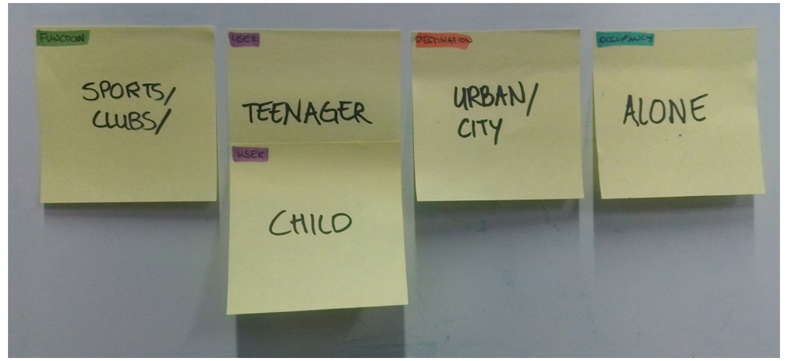

VISIT FAMILY/FRIENDS
FAMILY/ FRIENDS
URBAN/ CITY
MORE PERSONS FAMILY/FRIENDS/ ACQUAINTANCES

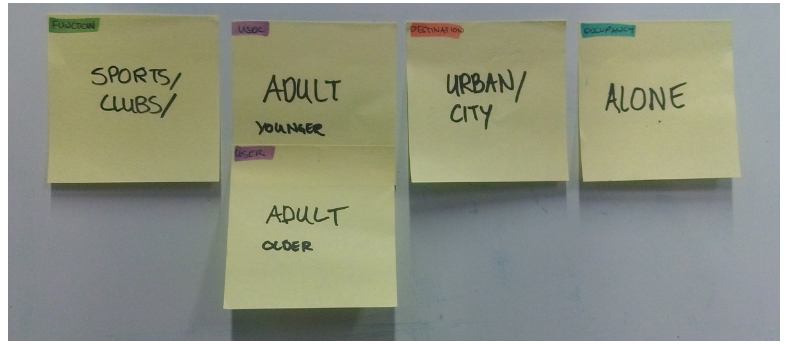

VISIT FAMILY/FRIENDS
ELDERLY
INTERCITY/ HIGHWAY SHORT DISTANCE
2 PERSONS FAMILY/FRIEND/ ACQUAINTANCE

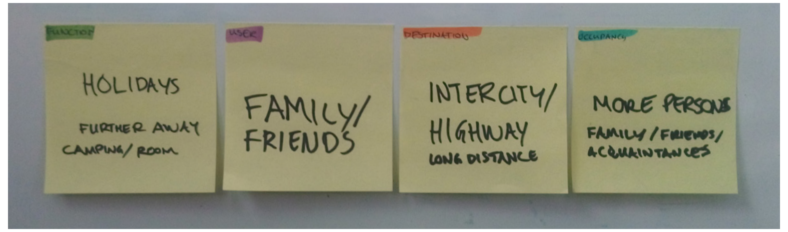

VISIT FAMILY/FRIENDS
ELDERLY
INTERCITY/ HIGHWAY SHORT DISTANCE
ALONE

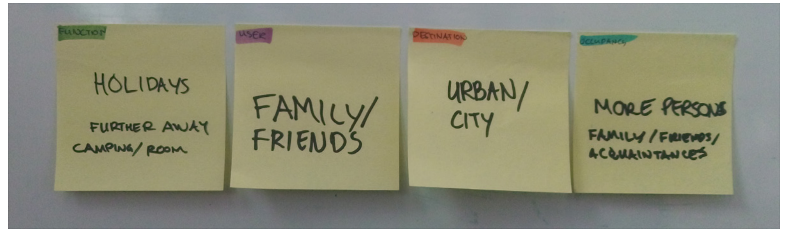

VISIT FAMILY/FRIENDS
ELDERLY
PERSON WITH DISABILITY
INTERCITY/ HIGHWAY SHORT DISTANCE
2 PERSONS FAMILY/FRIEND/ ACQUAINTANCE

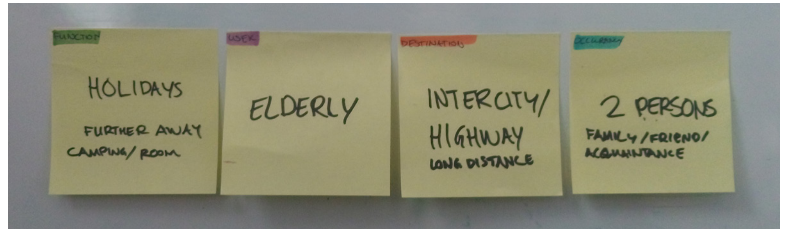

DAY OUT COUNTRYSIDE/WOODS/ BEACH/MOUNTAINS
FAMILY/ FRIENDS
INTERCITY/ HIGHWAY SHORT DISTANCE
MORE PERSONS FAMILY/FRIENDS/ ACQUAINTANCES

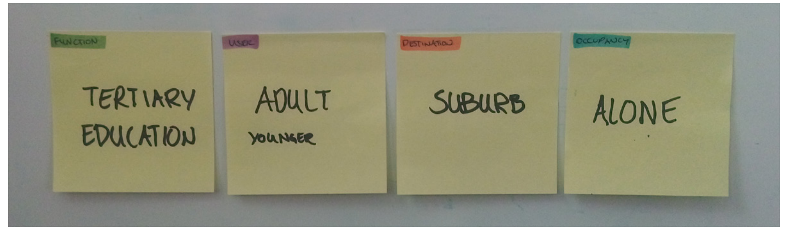

SPORTS/ CLUBS/
TEENAGER
CHILD
URBAN/ CITY
ALONE

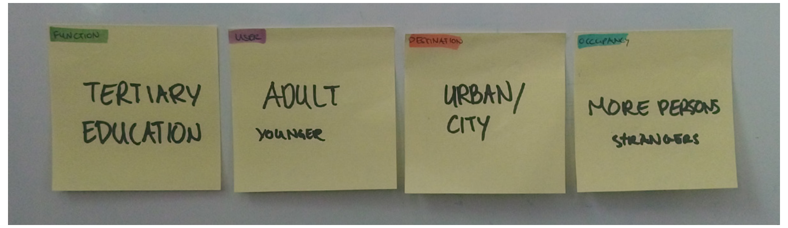

SPORTS/ CLUBS/
ADULT YOUNGER
ADULT OLDER
URBAN/ CITY
ALONE

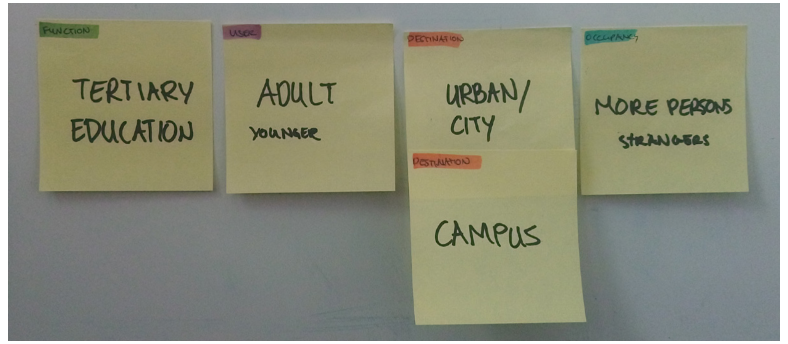

HOLIDAYS FURTHER AWAY CAMPING/ ROOM
FAMILY/ FRIENDS
INTERCITY/ HIGHWAY LONG DISTANCE
MORE PERSONS FAMILY/FRIENDS/ ACQUAINTANCES

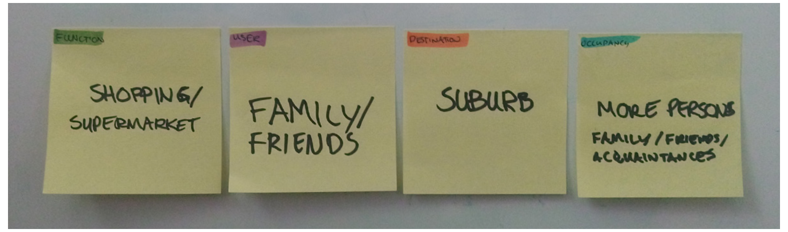

HOLIDAYS FURTHER AWAY CAMPING/ ROOM
FAMILY/ FRIENDS
URBAN/ CITY
MORE PERSONS FAMILY/FRIENDS/ ACQUAINTANCES

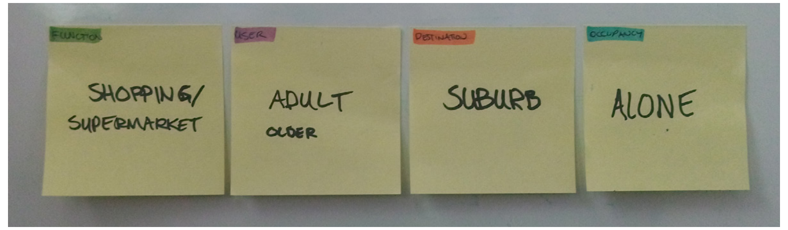

HOLIDAYS FURTHER AWAY CAMPING/ ROOM
ELDERLY
INTERCITY/ HIGHWAY LONG DISTANCE
2 PERSONS FAMILY/FRIEND/ ACQUAINTANCE

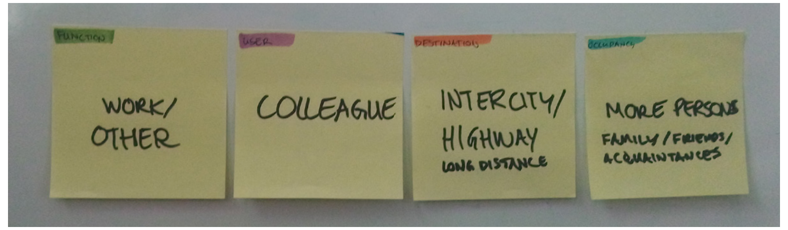

TERTIARY EDUCATION
ADULT YOUNGER
SUBURB
ALONE

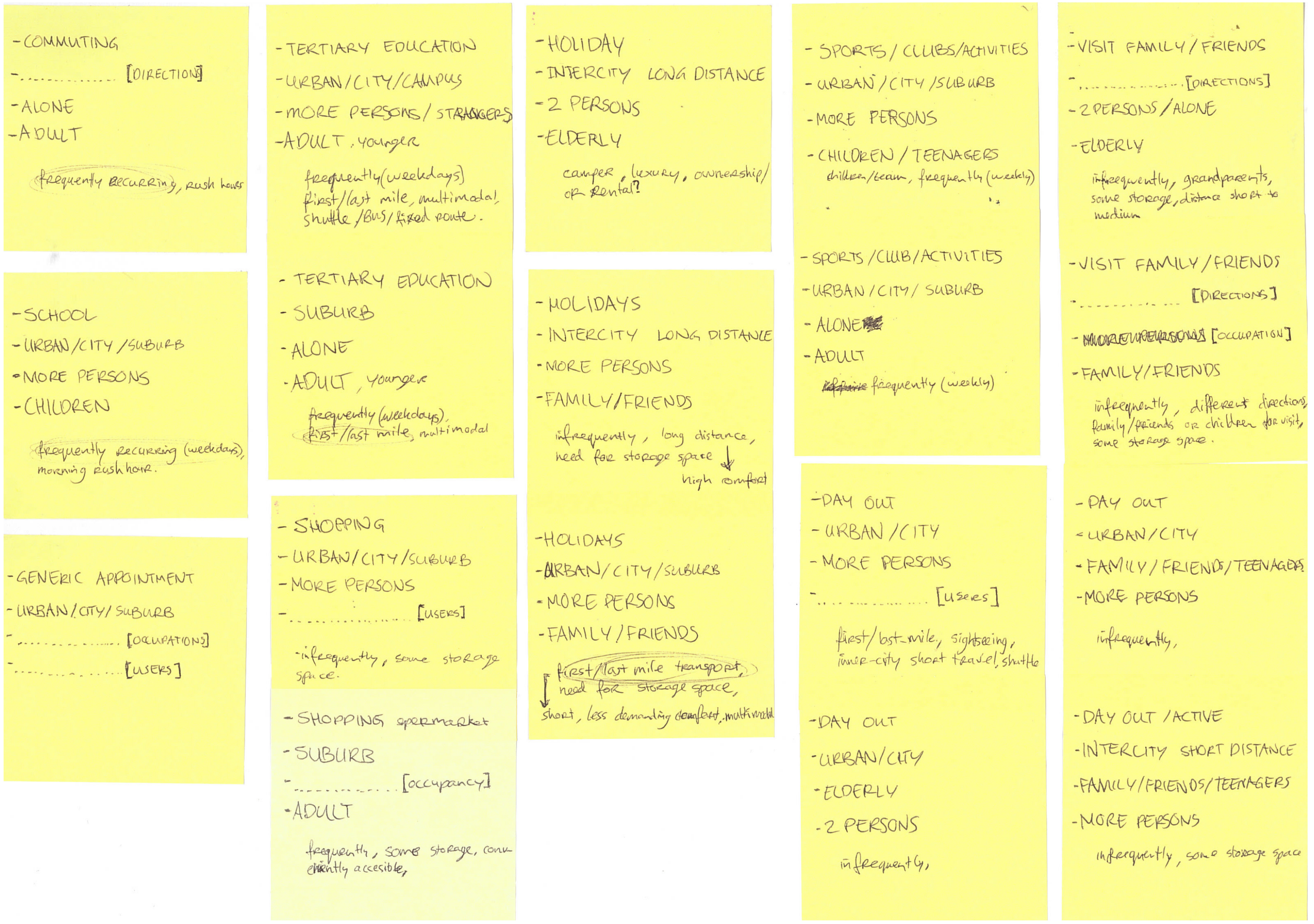

TERTIARY EDUCATION
ADULT YOUNGER
URBAN/ CITY
MORE PERSONS STRANGERS


TERTIARY EDUCATION
ADULT YOUNGER
URBAN/ CITY
CAMPUS
MORE PERSONS STRANGERS

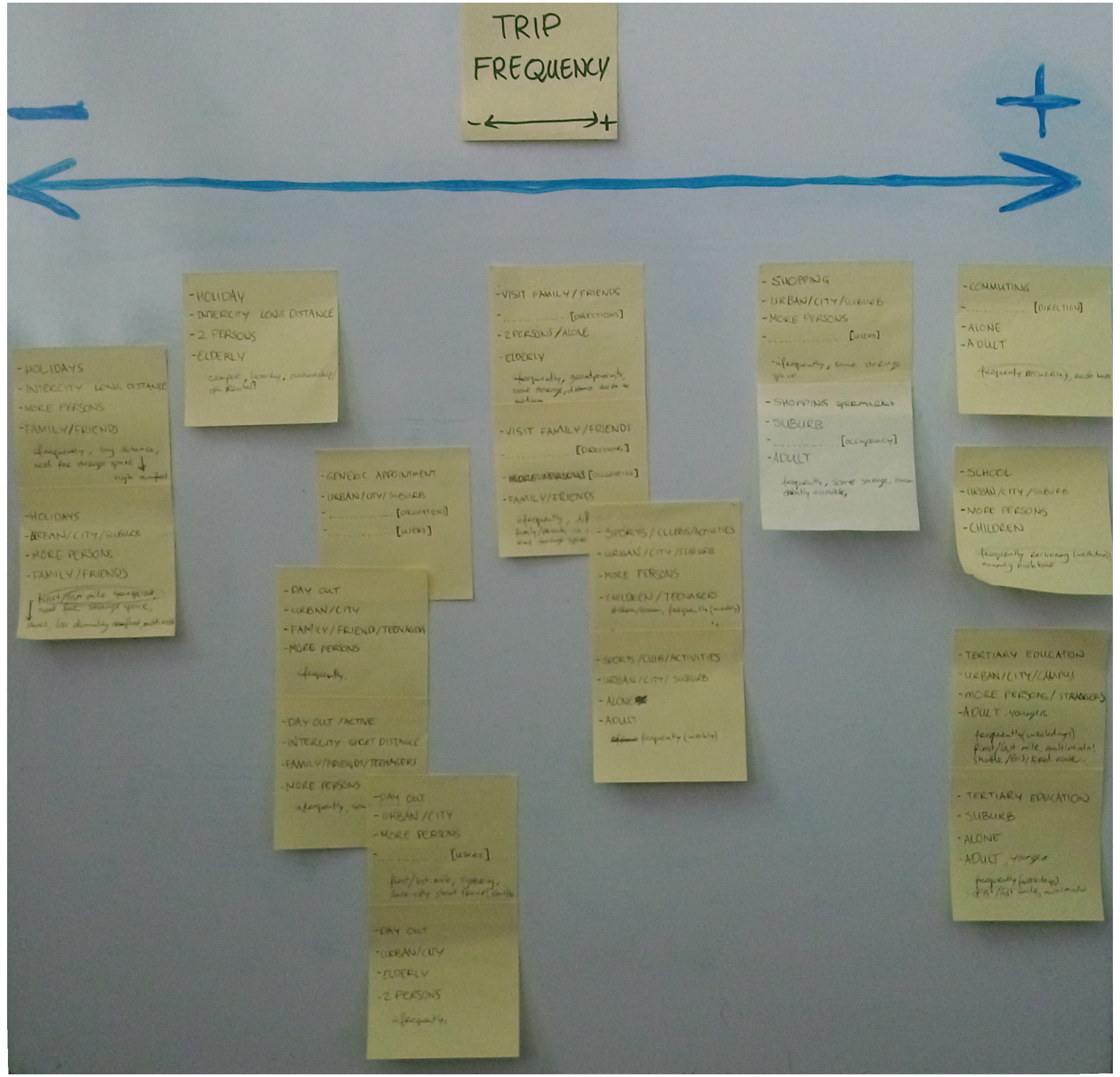

SHOPPING/ SUPERMARKET
FAMILY/ FRIENDS
SUBURB
MORE PERSONS FAMILY/FRIENDS/ ACQUAINTANCES


SHOPPING/ SUPERMARKET
ADULT OLDER
SUBURB
ALONE

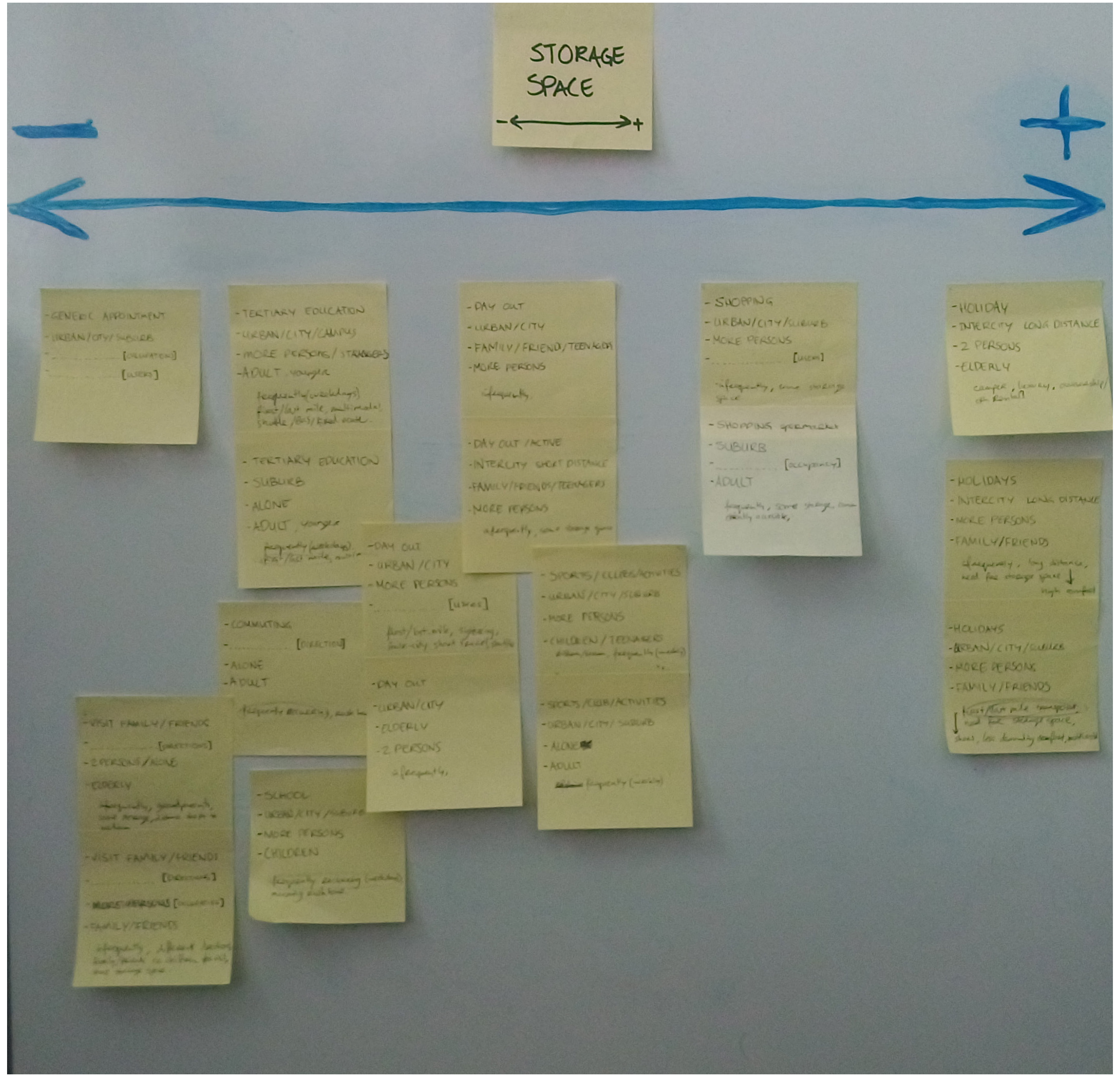

WORK/ OTHER
COLLEAGUE
INTERCITY/ HIGHWAY LONG DISTANCE
MORE PERSONS FAMILY/FRIENDS/ ACQUAINTANCES

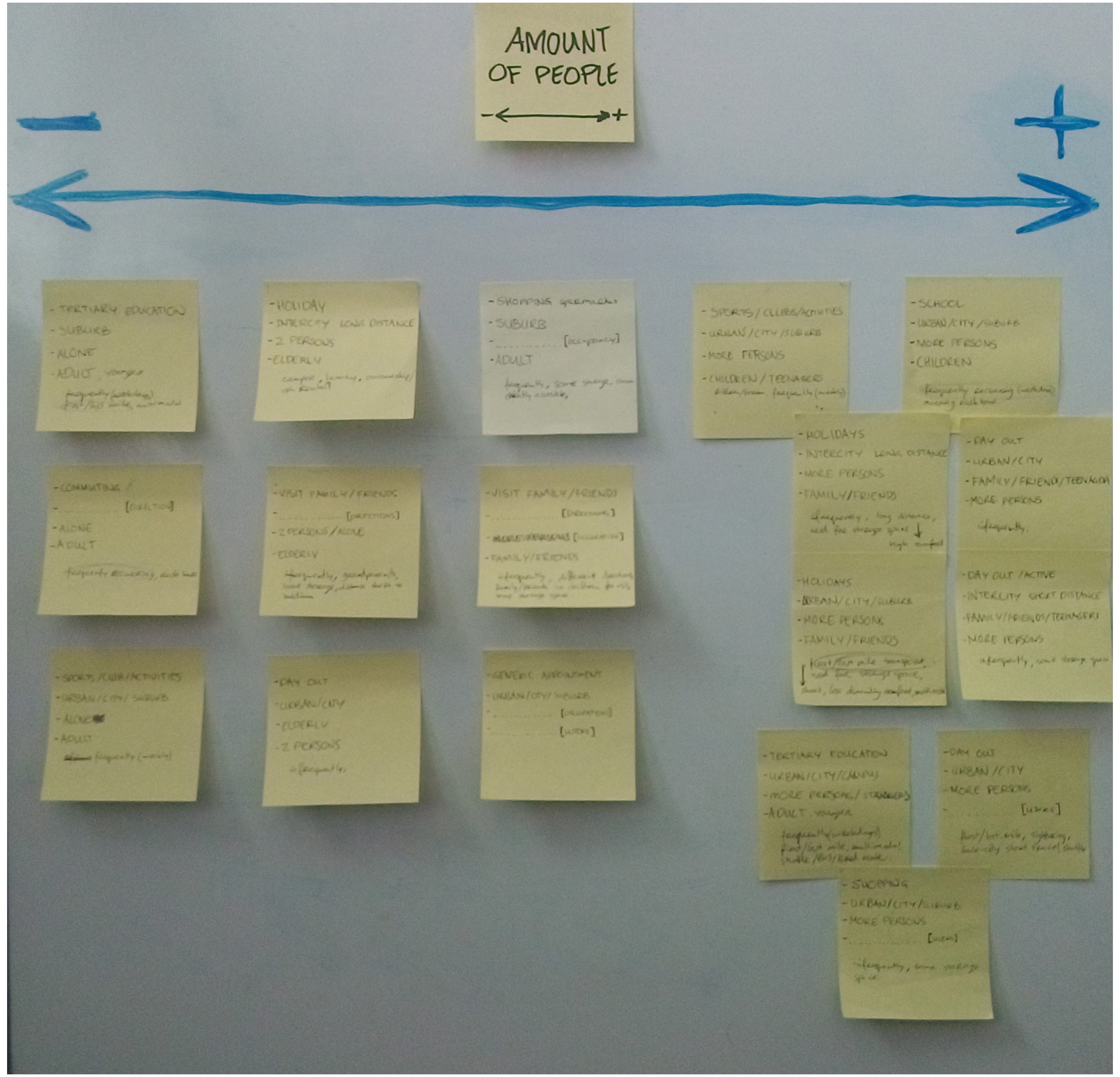


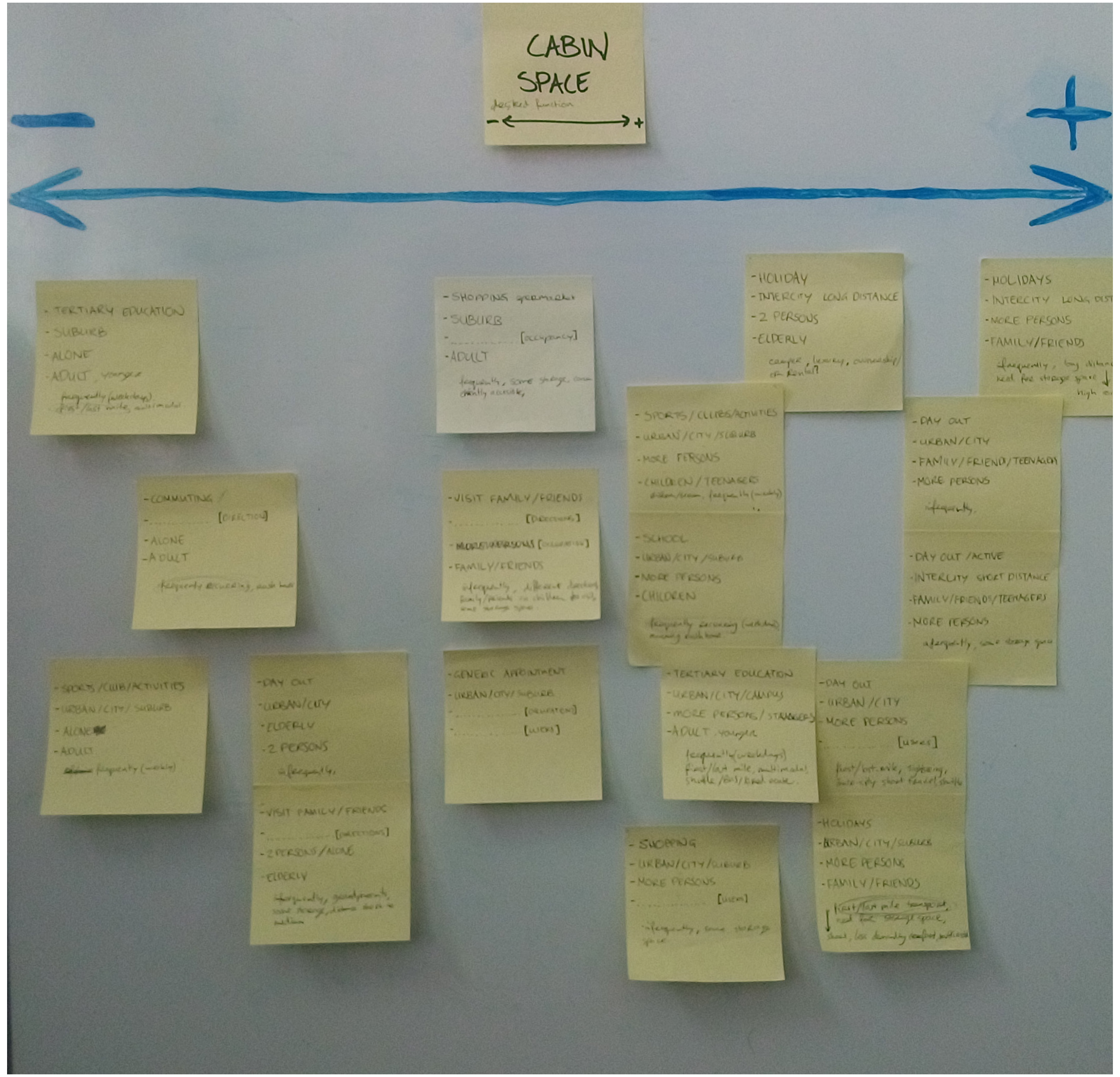
- COMMUTING
- .... [DIRECTION]
- ALONE
- ADULT
frequently recurring, rush hour
- SCHOOL
- URBAN/CITY/SUBURB
- MORE PERSONS
- CHILDREN
frequently recurring (weekdays), morning rush hour.
- GENERIC APPOINTMENT
- URBAN/CITY/SUBURB
- .... [OCCUPATION]
- .... [USERS]
- TERTIARY EDUCATION
- URBAN/CITY/CAMPUS
- MORE PERSONS/STRANGERS
- ADULT, younger
frequently (weekdays), first/last mile, multimodal, shuttle/bus/fixed route.
- TERTIARY EDUCATION
- SUBURB
- ALONE
- ADULT, younger
frequently (weekdays), first/last mile, multimodal
- SHOPPING
- URBAN/CITY/SUBURB
- MORE PERSONS
- .... [USERS]
infrequently, some storage space
- SHOPPING supermarket
- SUBURB
- .... [occupancy]
- ADULT
frequently, some storage, conveniently accesible,
- HOLIDAY
- INTERCITY LONG DISTANCE
- 2 PERSONS
- ELDERLY
camper, luxury, ownership/or rental?
- HOLIDAYS
- INTERCITY LONG DISTANCE
- MORE PERSONS
- FAMILY/FRIENDS
infrequently, long distance, need for storage space, high comfort
- HOLIDAYS
- URBAN/CITY/SUBURB
- MORE PERSONS
- FAMILY/FRIENDS
first/last mile transport, need for storage space, short, less demanding comfort, multimodal
- SPORTS/CLUBS/ACTIVITIES
- URBAN/CITY/SUBURB
- MORE PERSONS
- CHILDREN/TEENAGERS
children/team, frequently (weekly)
- SPORTS/CLUB/ACTIVITIES
- URBAN/CITY/SUBURB
- ALONE
- ADULT
frequently (weekly)
- DAY OUT
- URBAN/CITY
- MORE PERSONS
- .... [USERS]
first/last mile, sightseeing, inner-city short travel, shuttle
- DAY OUT
- URBAN/CITY
- ELDERLY
- 2 PERSONS
infrequently,
- VISIT FAMILY/FRIENDS
- .... [DIRECTIONS]
- 2 PERSONS/ALONE
- ELDERLY
infrequently, grandparents, some storage, distance short to medium
- VISIT FAMILY/FRIENDS
- .... [DIRECTIONS]
- [OCCUPATION]
- FAMILY/FRIENDS
infrequently, different directions, family/friends or children to visit, some storage space.
- DAY OUT
- URBAN/CITY
- FAMILY/FRIENDS/TEENAGERS
- MORE PERSONS
infrequently,
- DAY OUT/ACTIVE
- INTERCITY SHORT DISTANCE
- FAMILY/FRIENDS/TEENAGERS
- MORE PERSONS
infrequently, some storage space

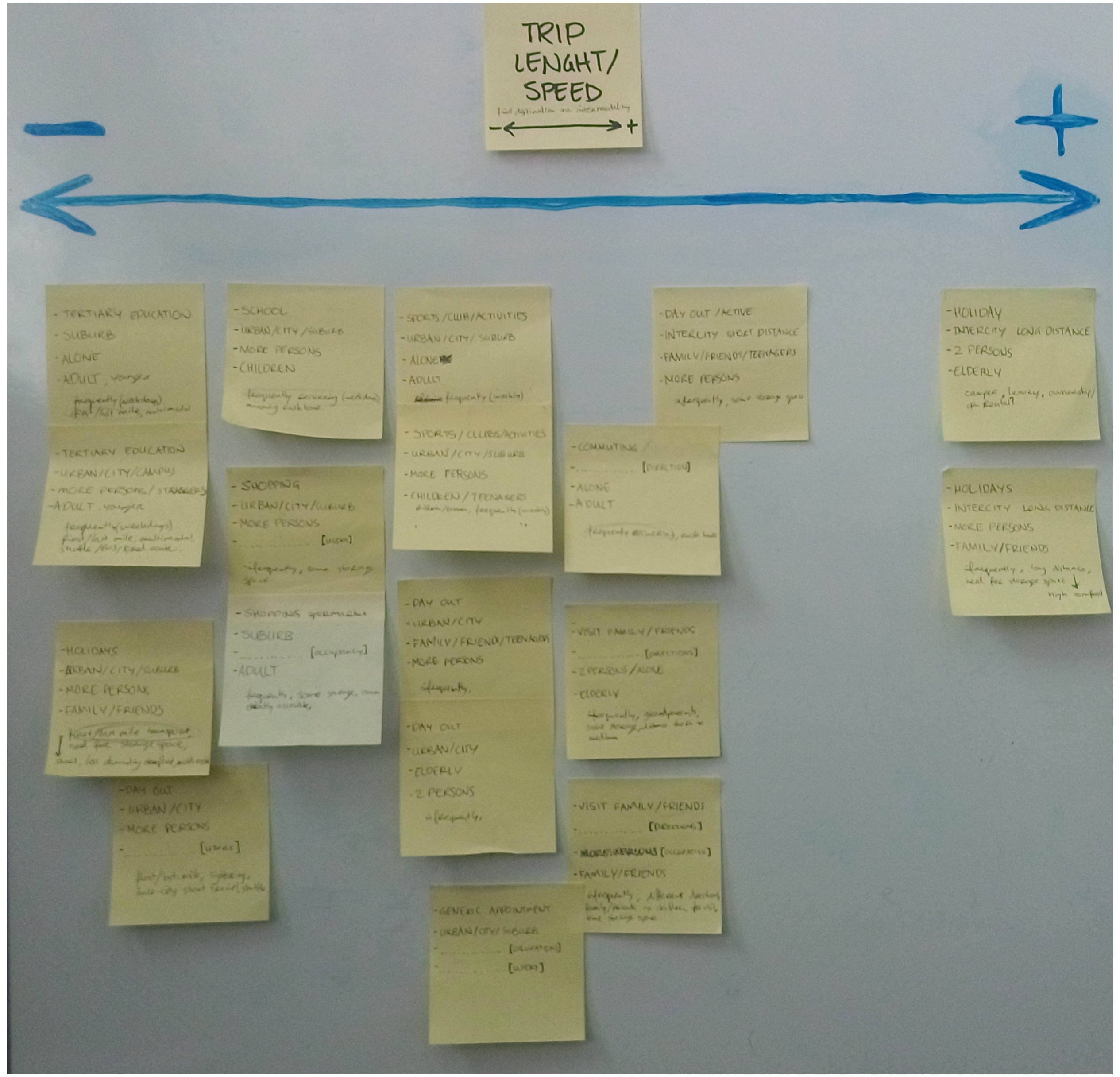


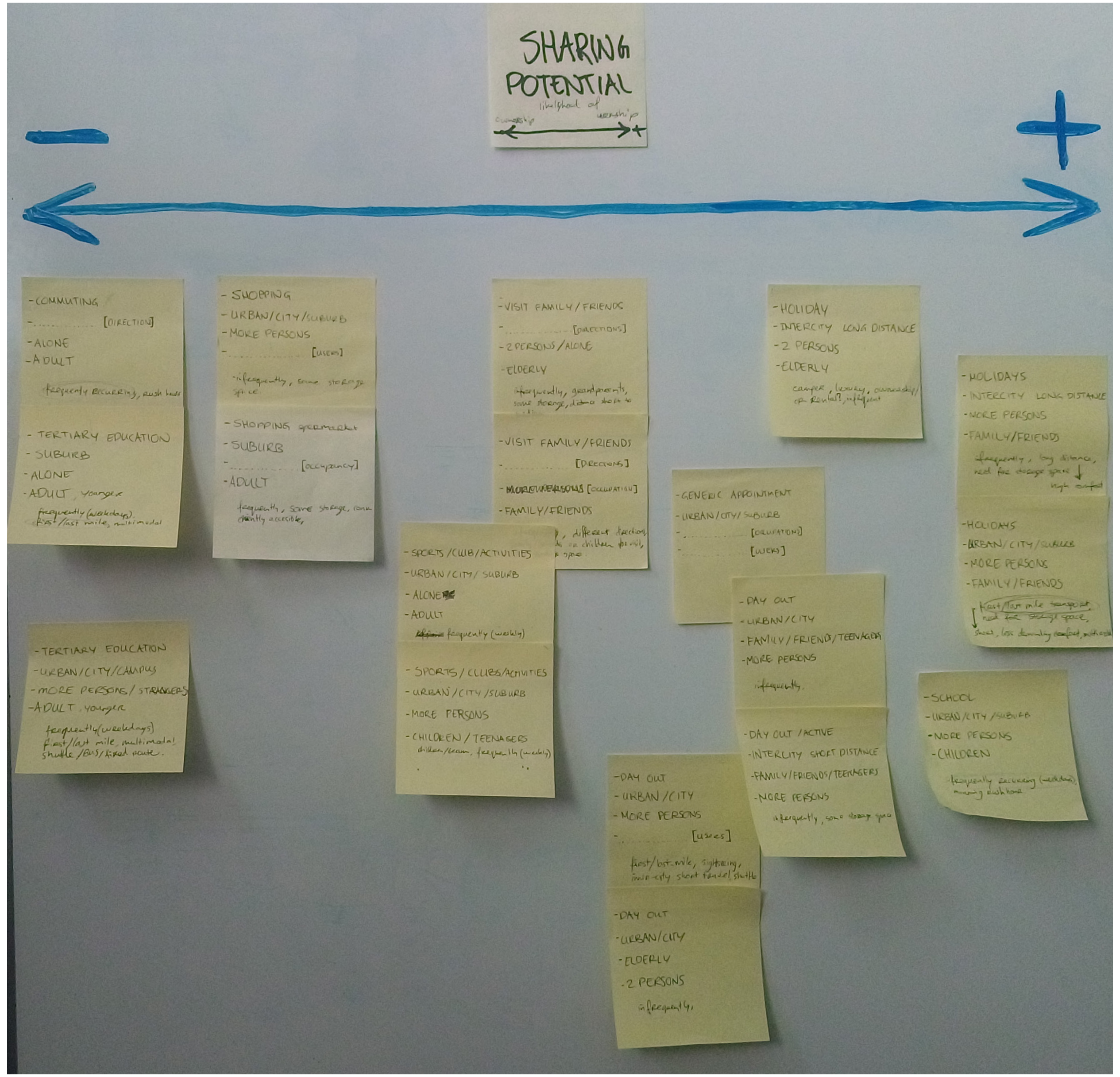
TRIP FREQUENCY
-
+

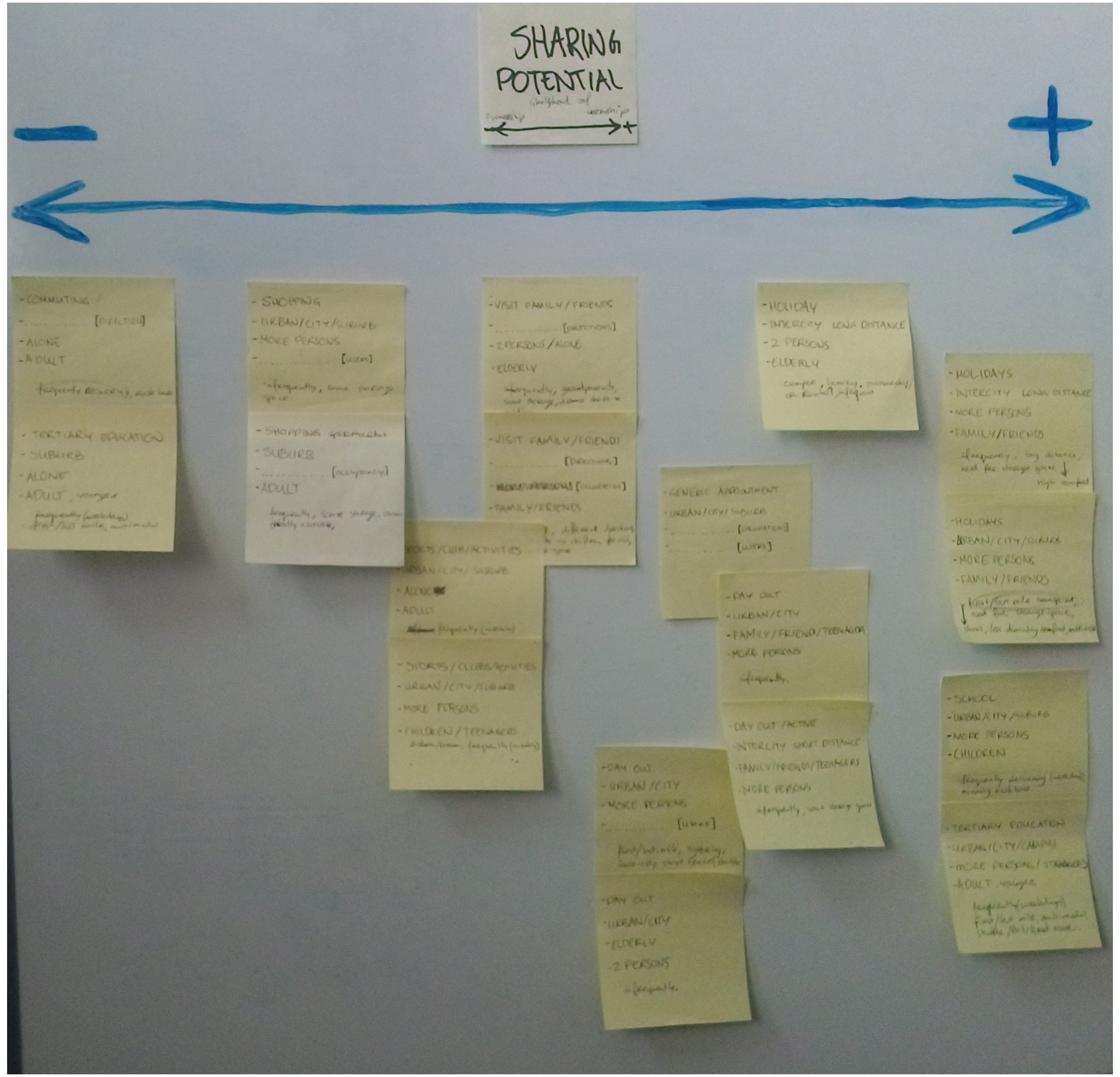

STORAGE SPACE


AMOUNT OF PEOPLE


CABIN SPACE

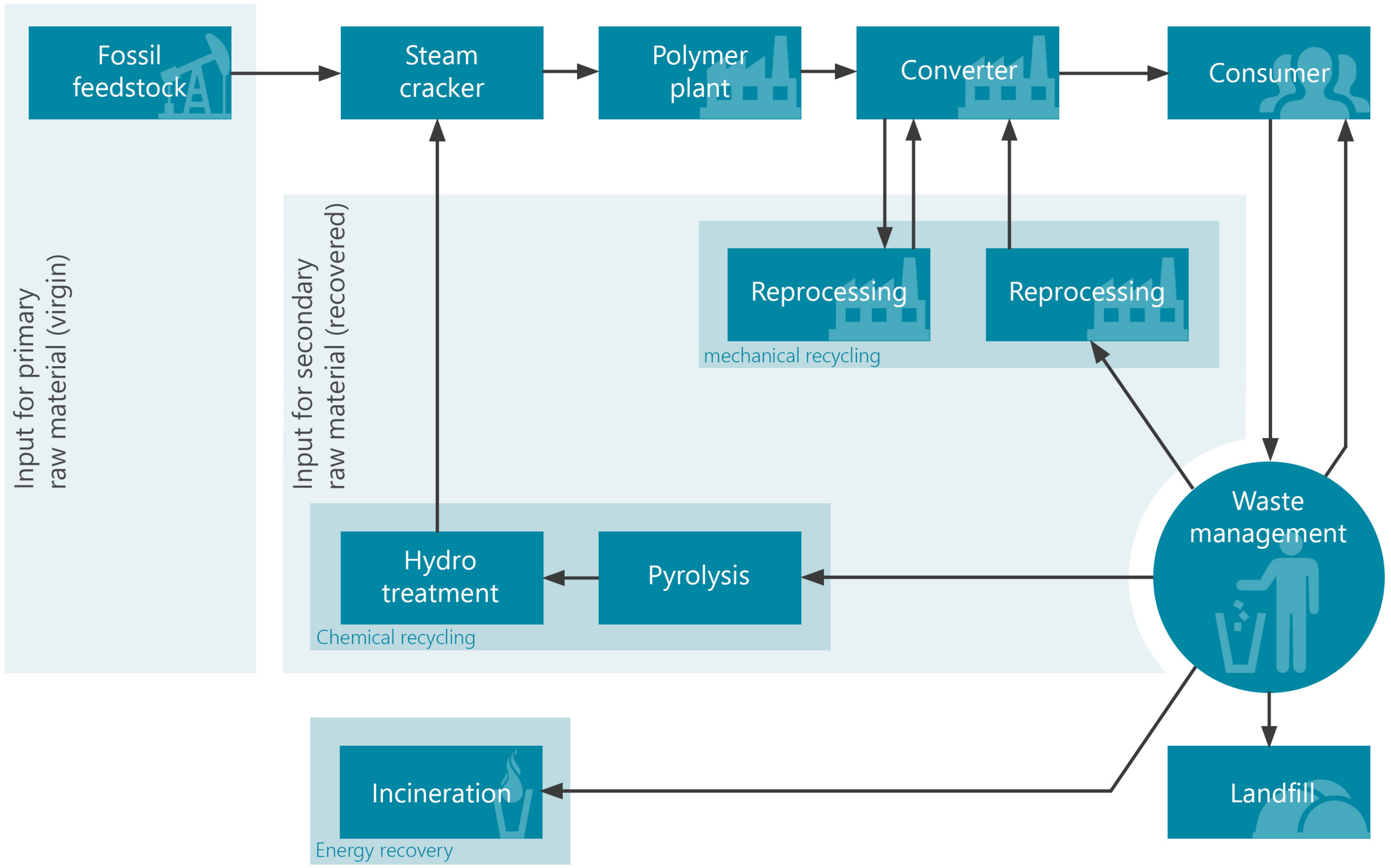

TRIP LENGHT/ SPEED


SHARING POTENTIAL


SHARING POTENTIAL

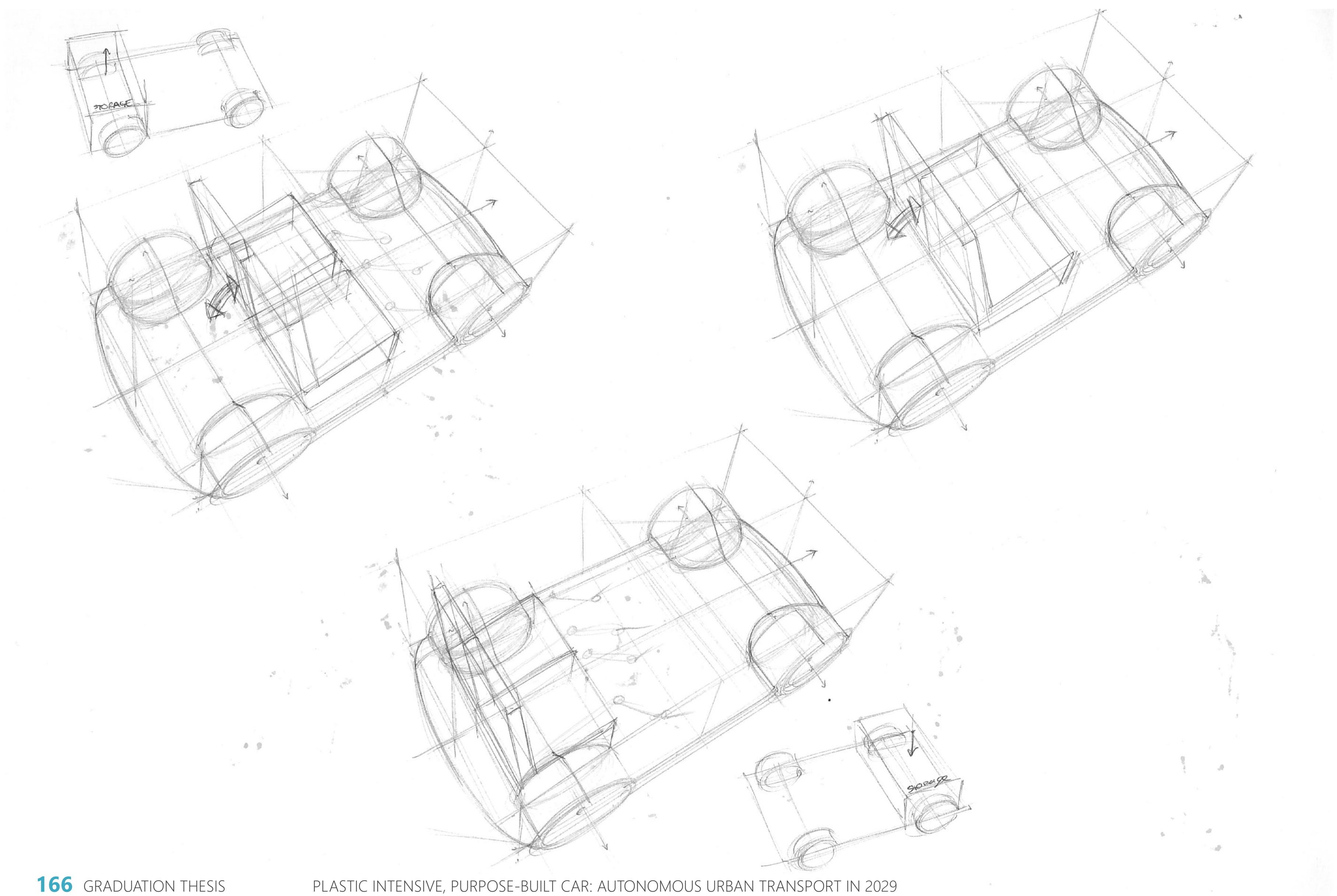
Appendix F

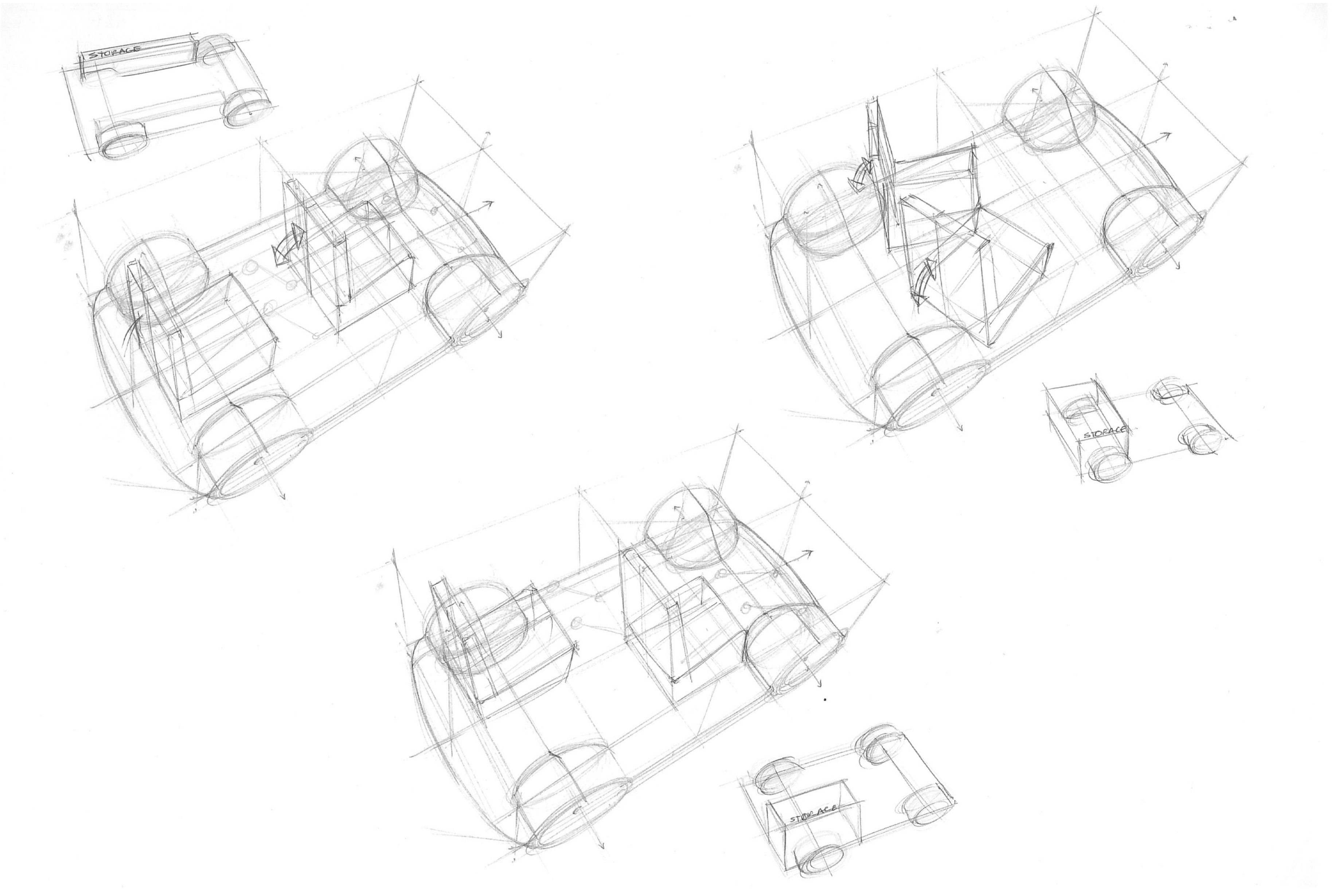
Recycling systems



Appendix G

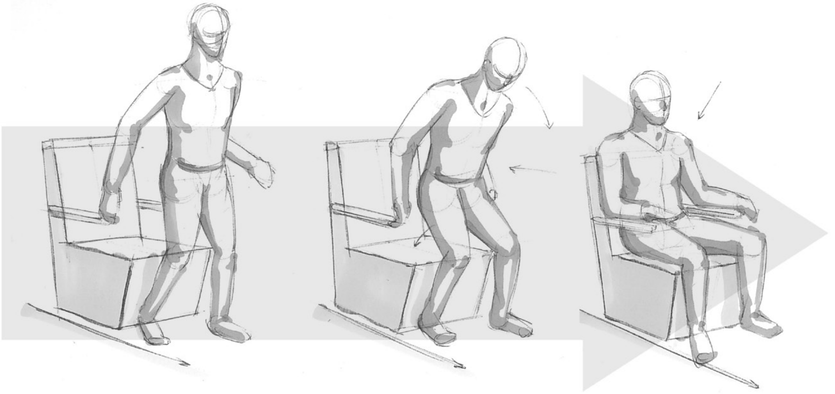
Package development: seat and storage position



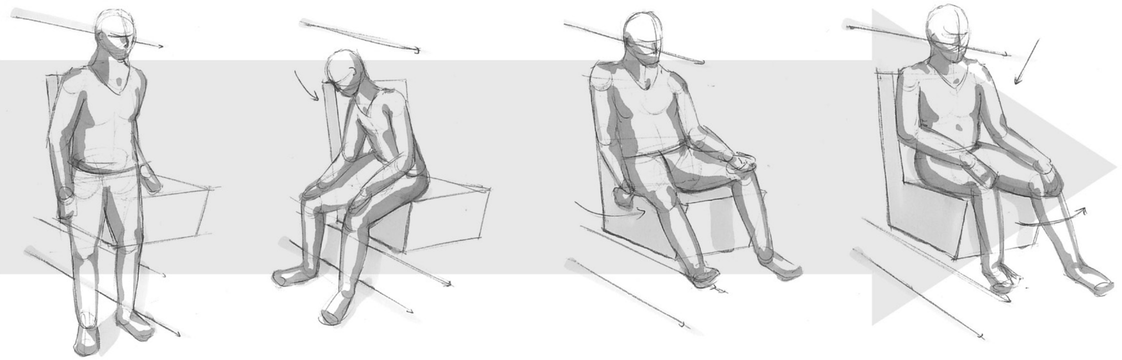


Appendix H

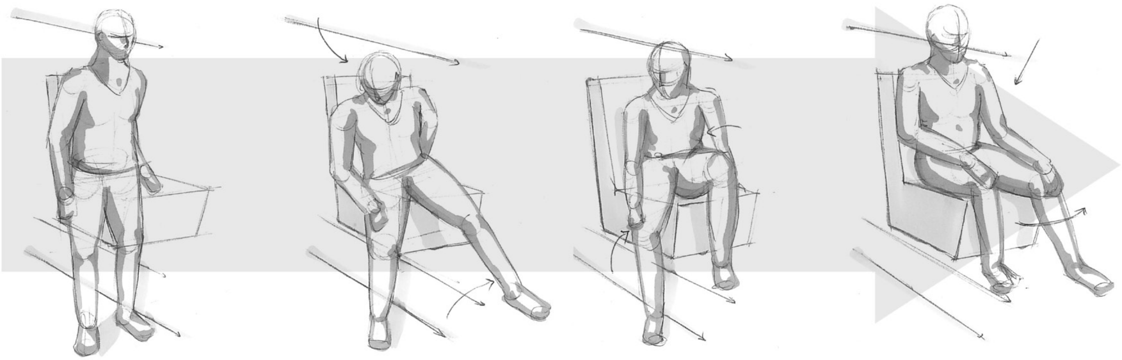
seating ritual and door lay-out



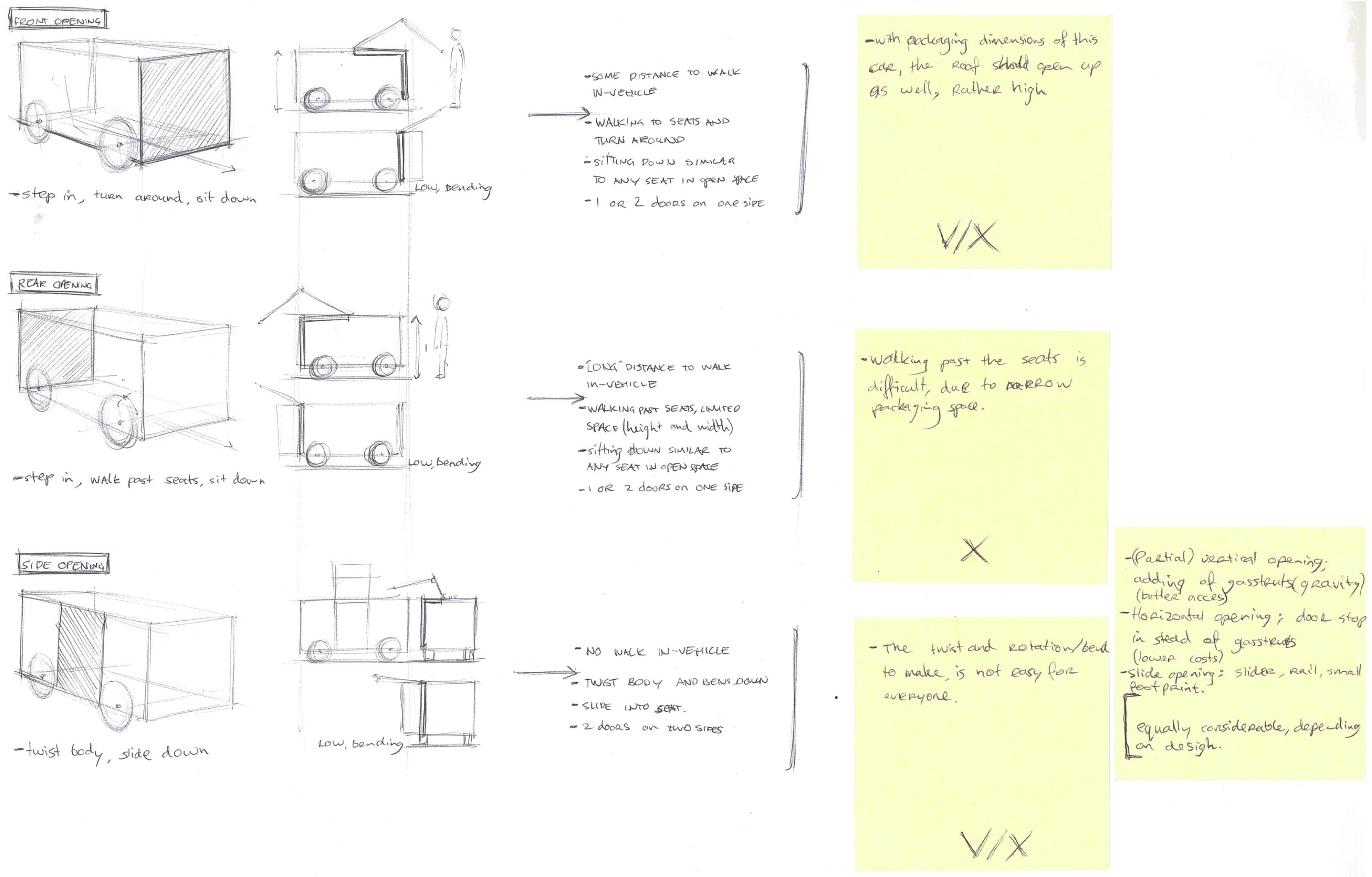
Approaching from the front of the seat

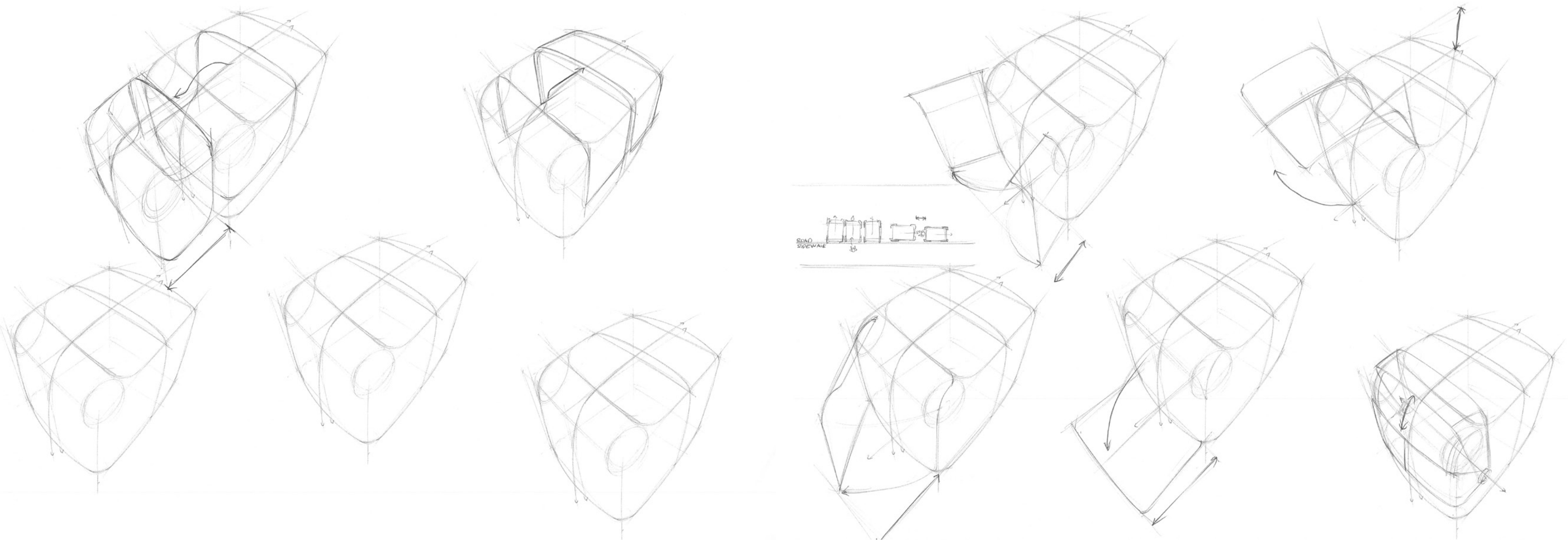


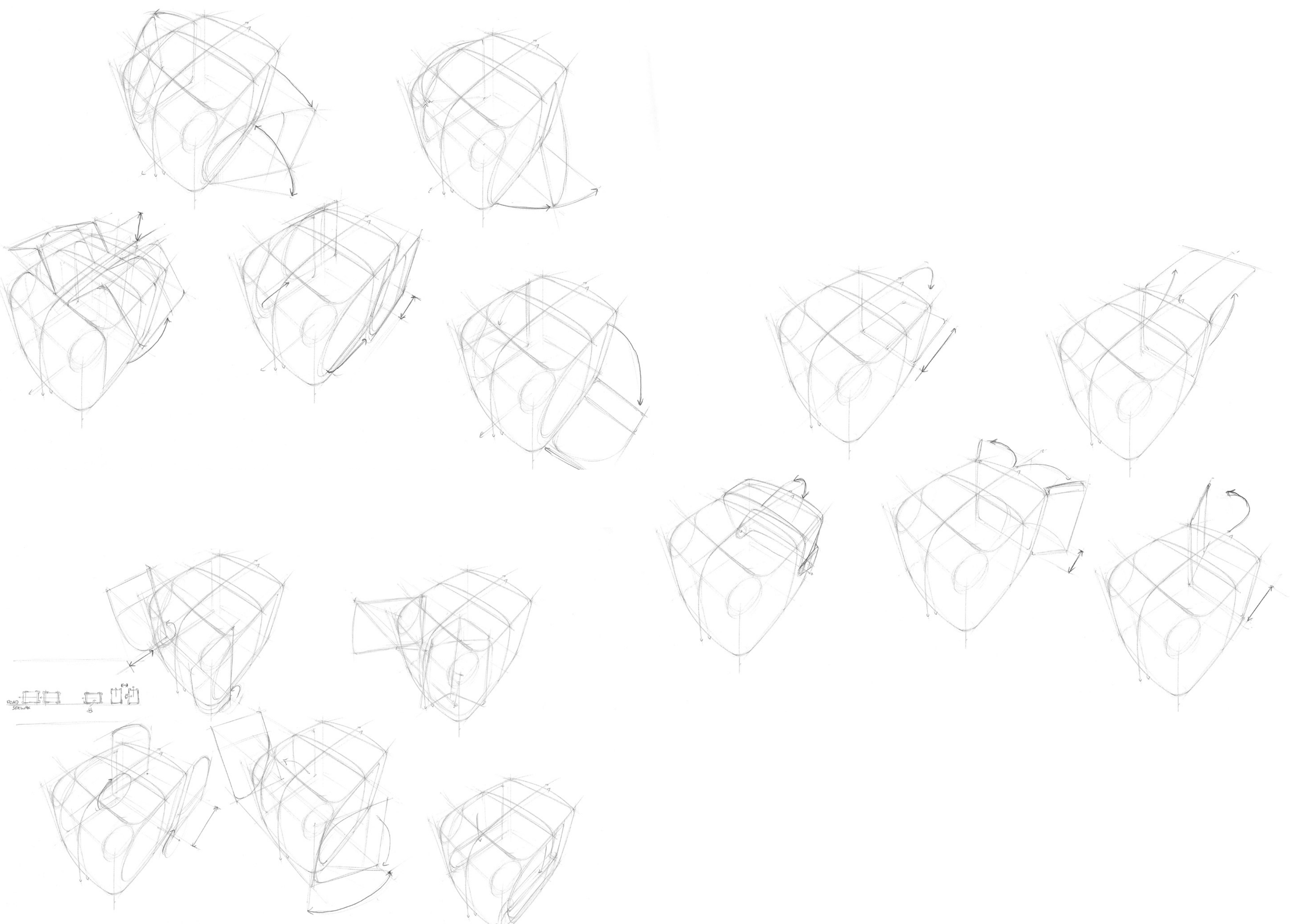
Approaching from the side (with limited head room) 1



Approaching from the side (with limited head room) 2

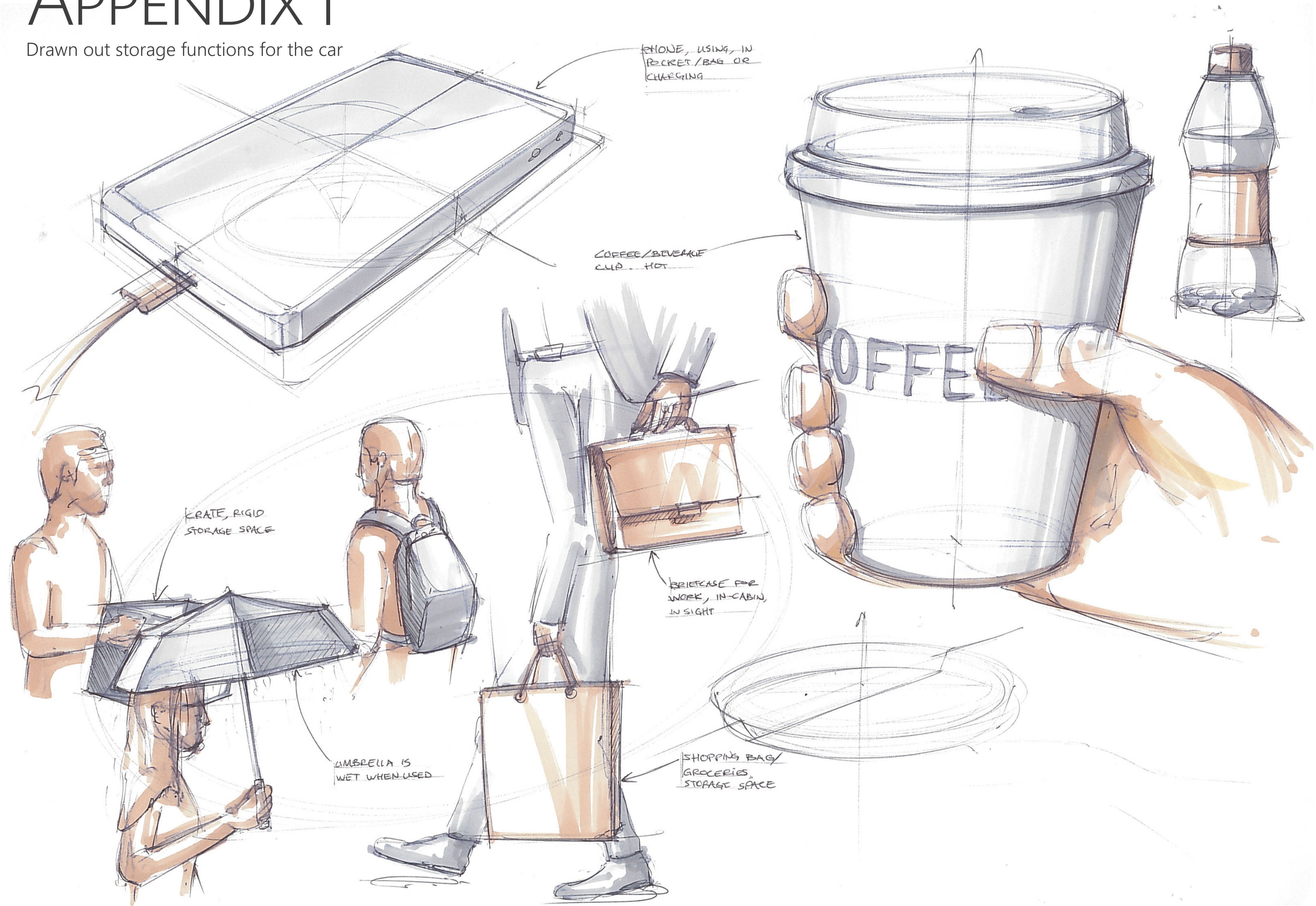






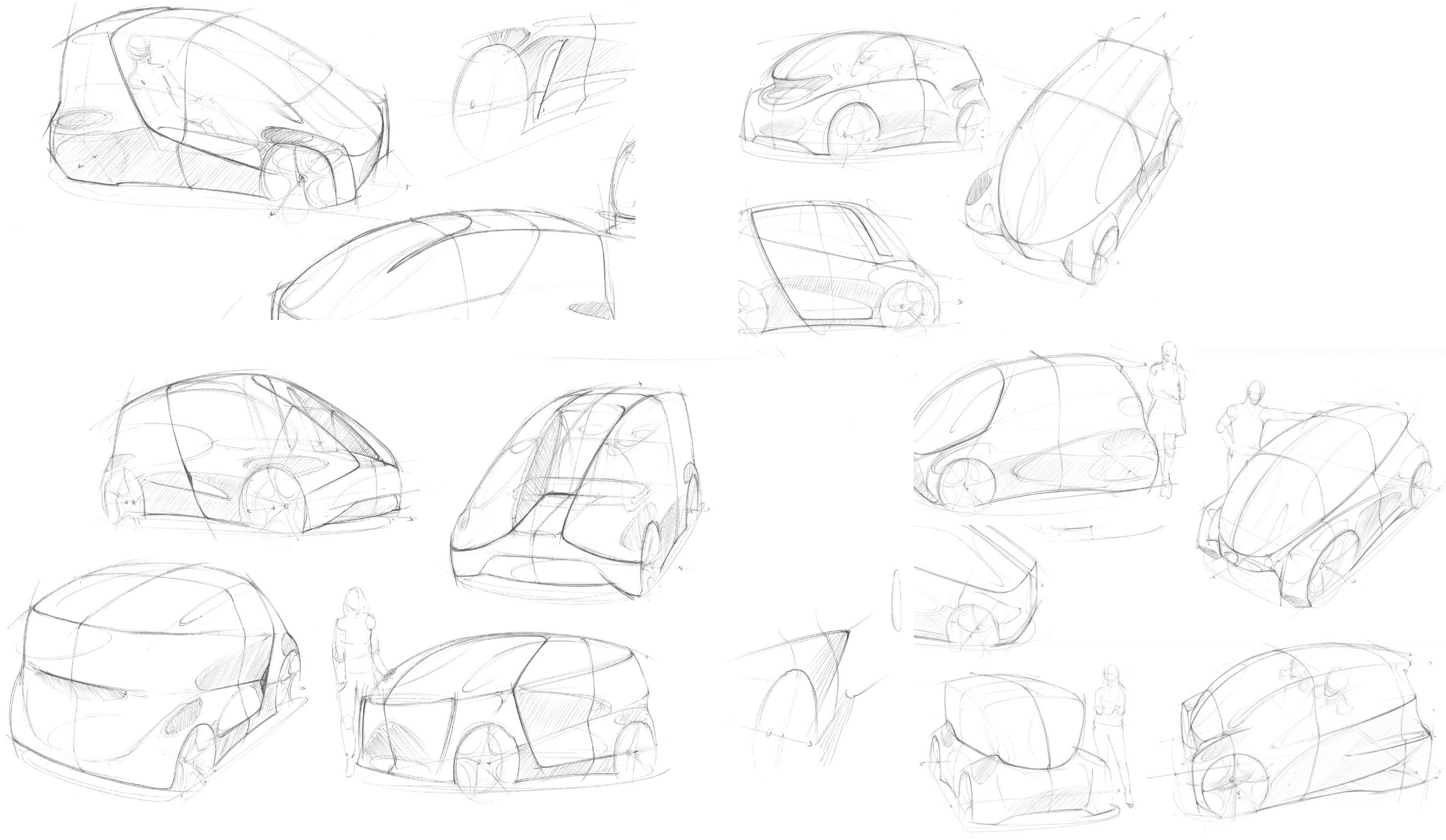
Appendix I

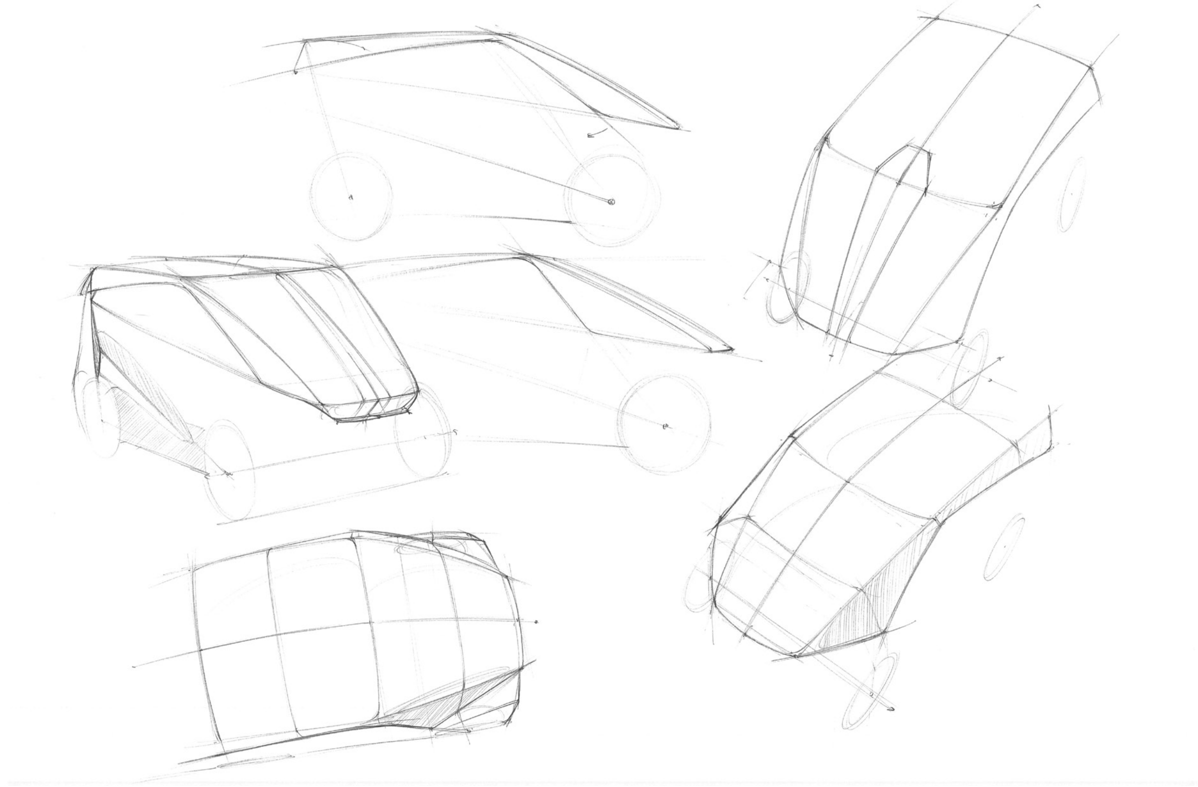
Drawn out storage functions for the car

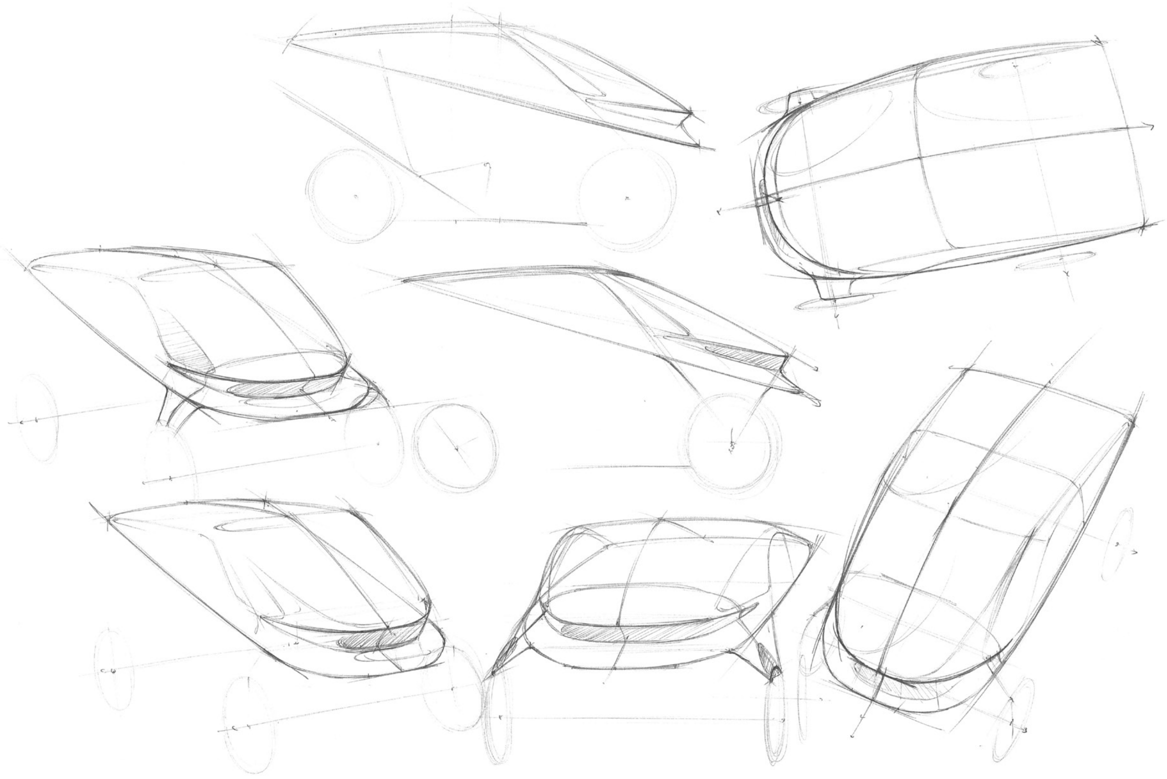


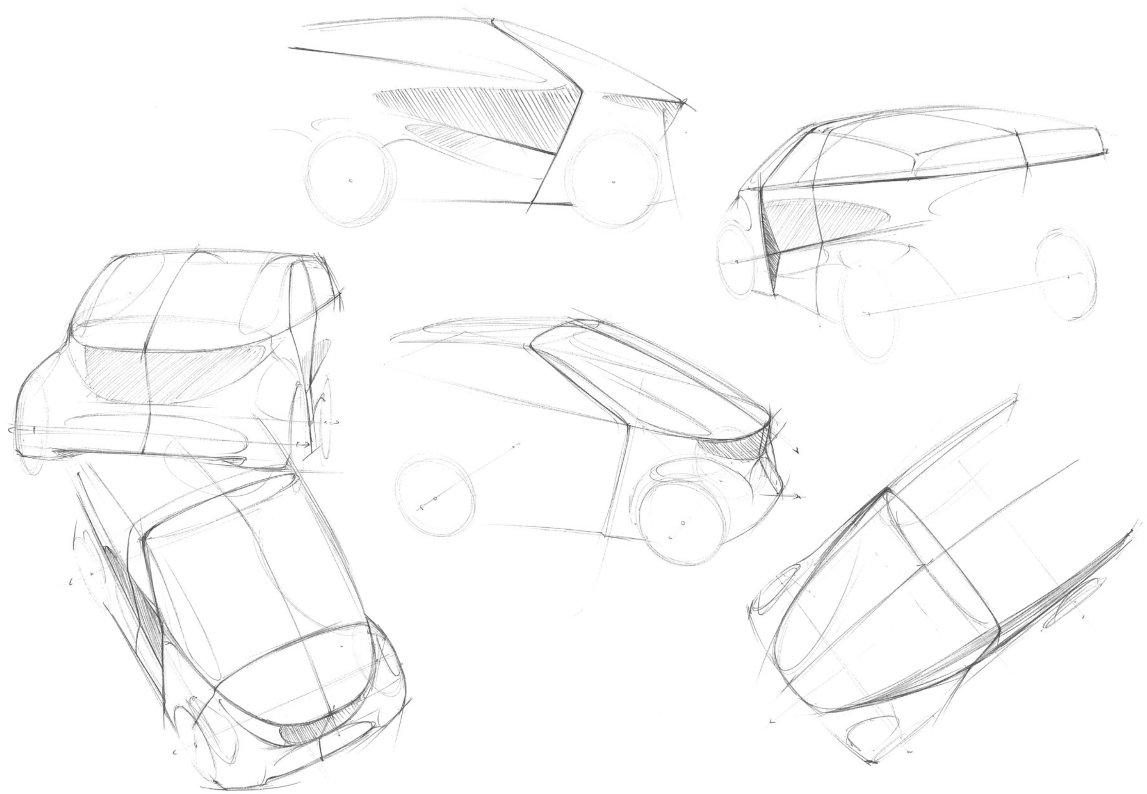
Appendix J

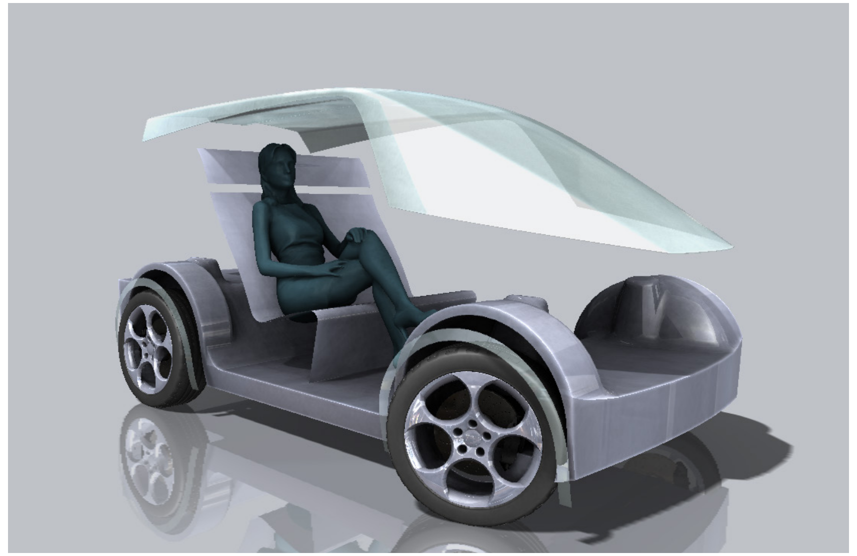
Exterior sketches ideas and development



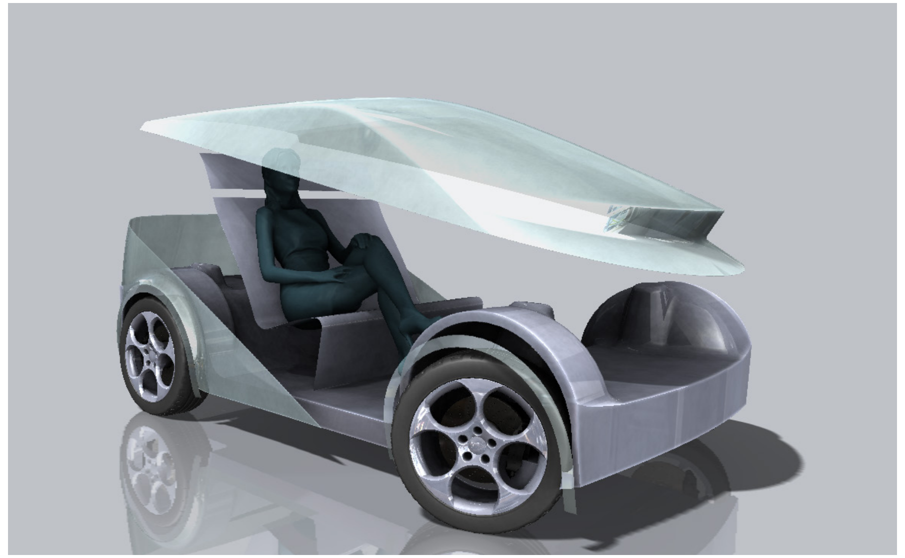


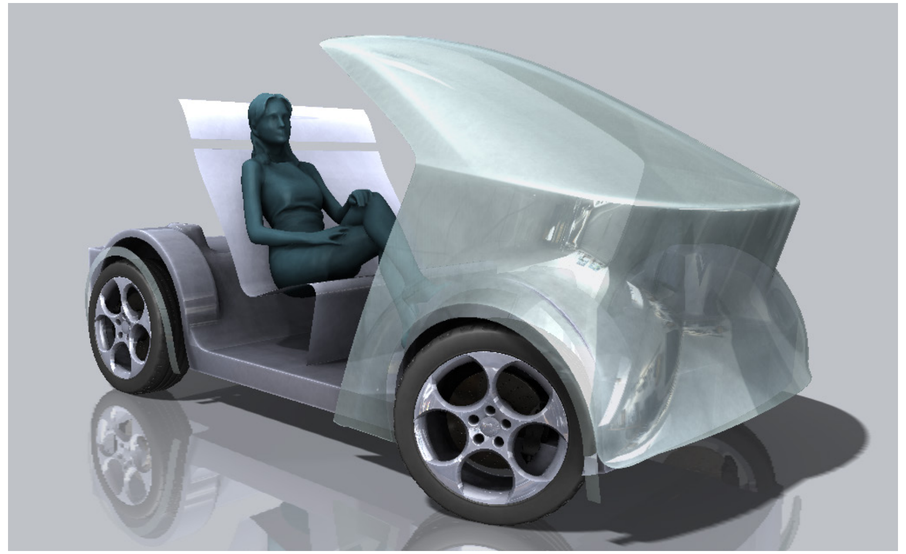




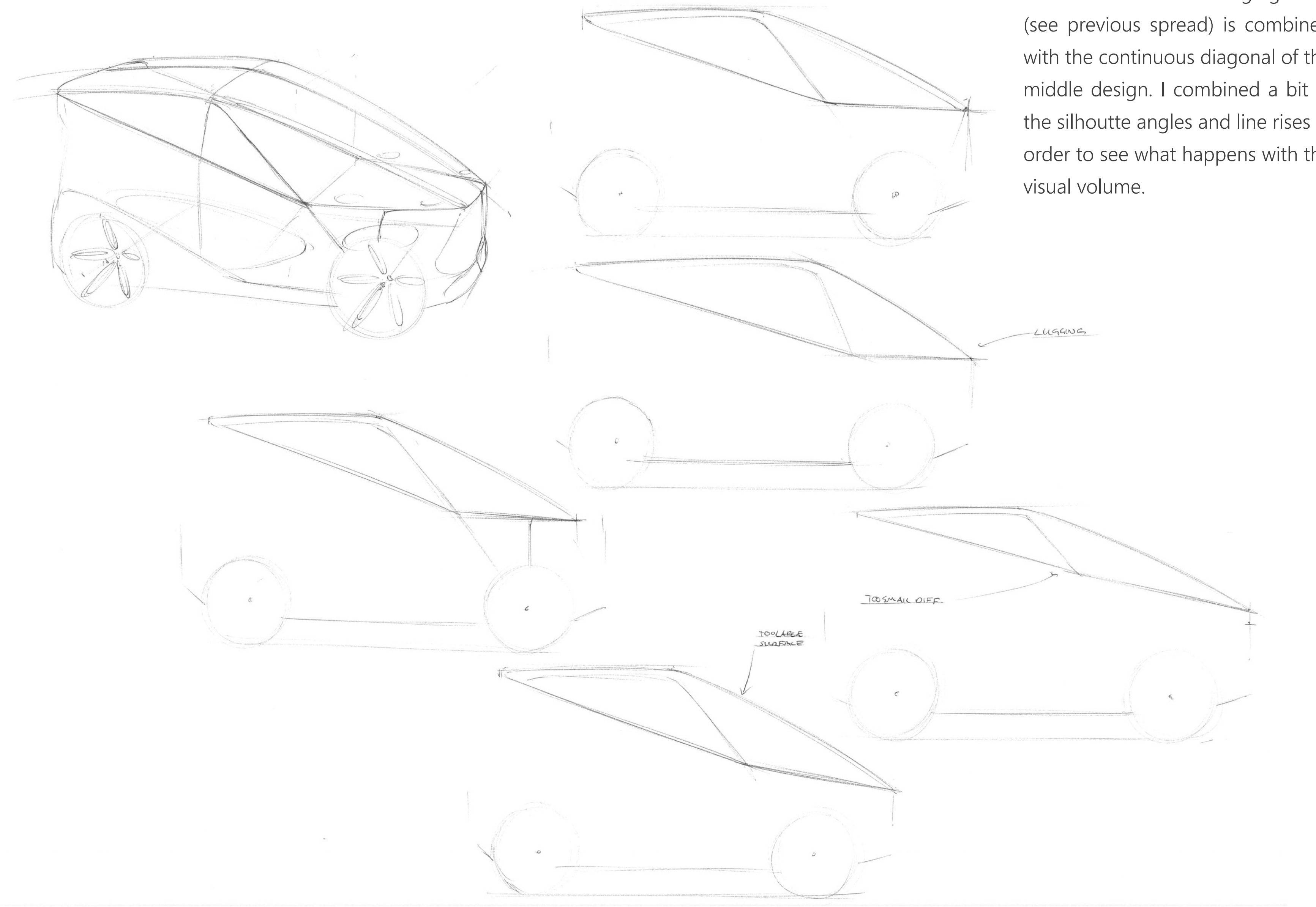


Translating some initial DLO ideas into CAD

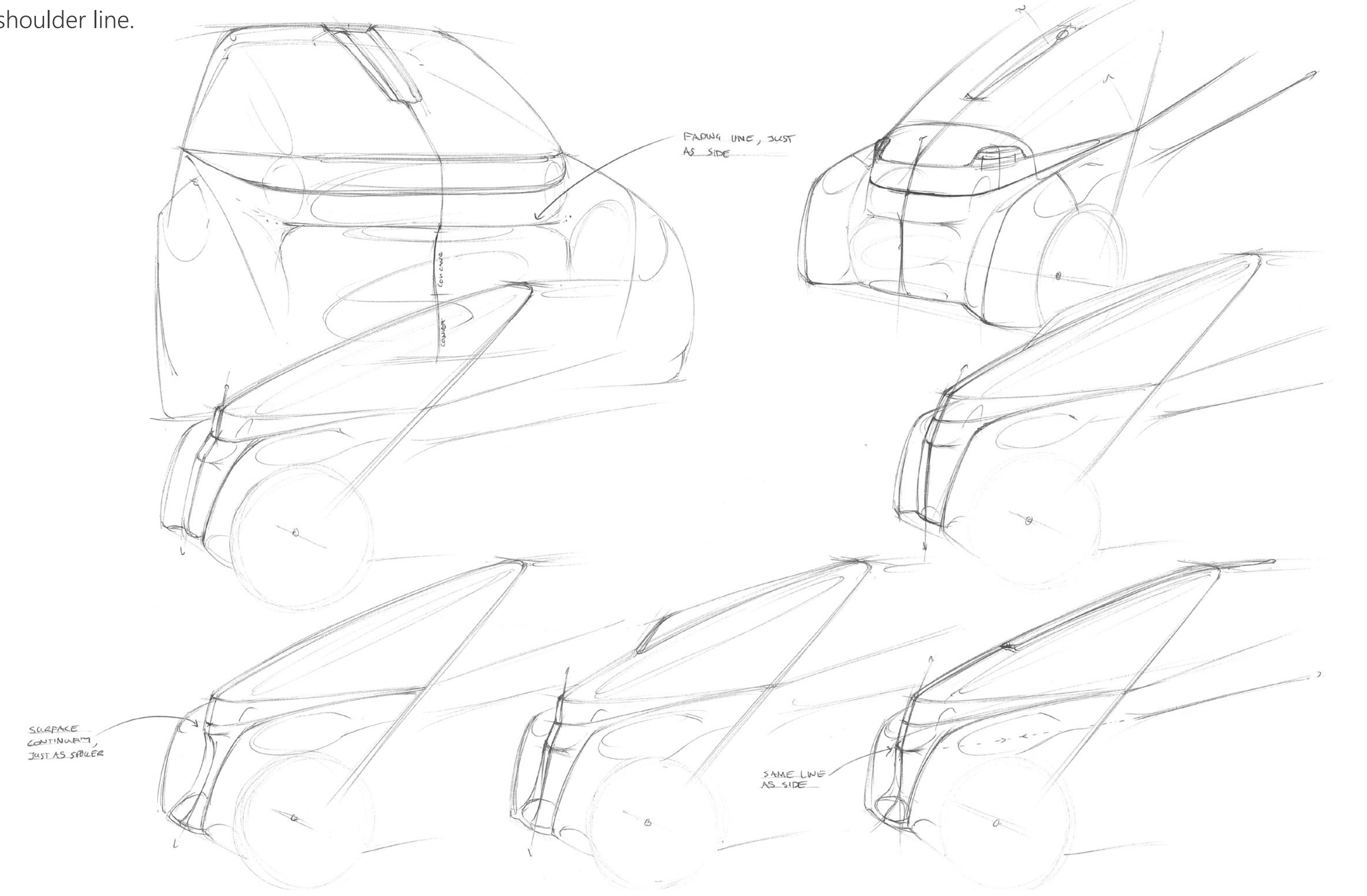




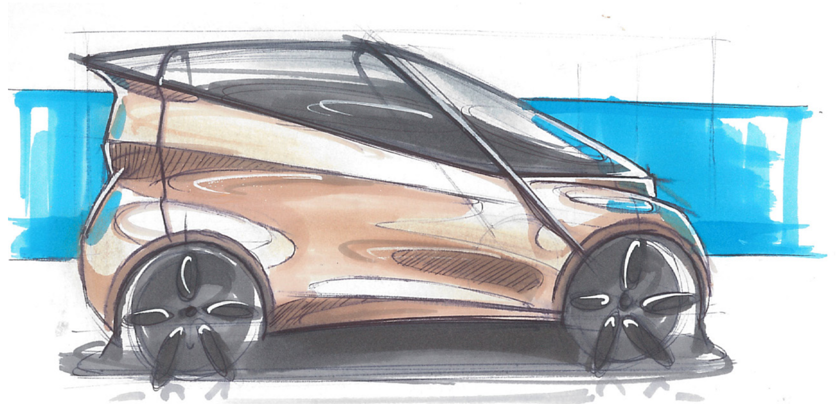
The idea of the left lozenge glazing (see previous spread) is combined with the continuous diagonal of the middle design. I combined a bit in the silhoutte angles and line rises in order to see what happens with the visual volume.

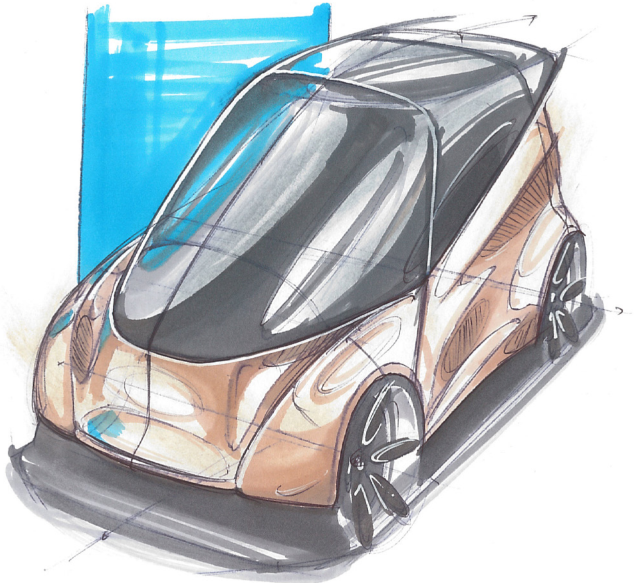


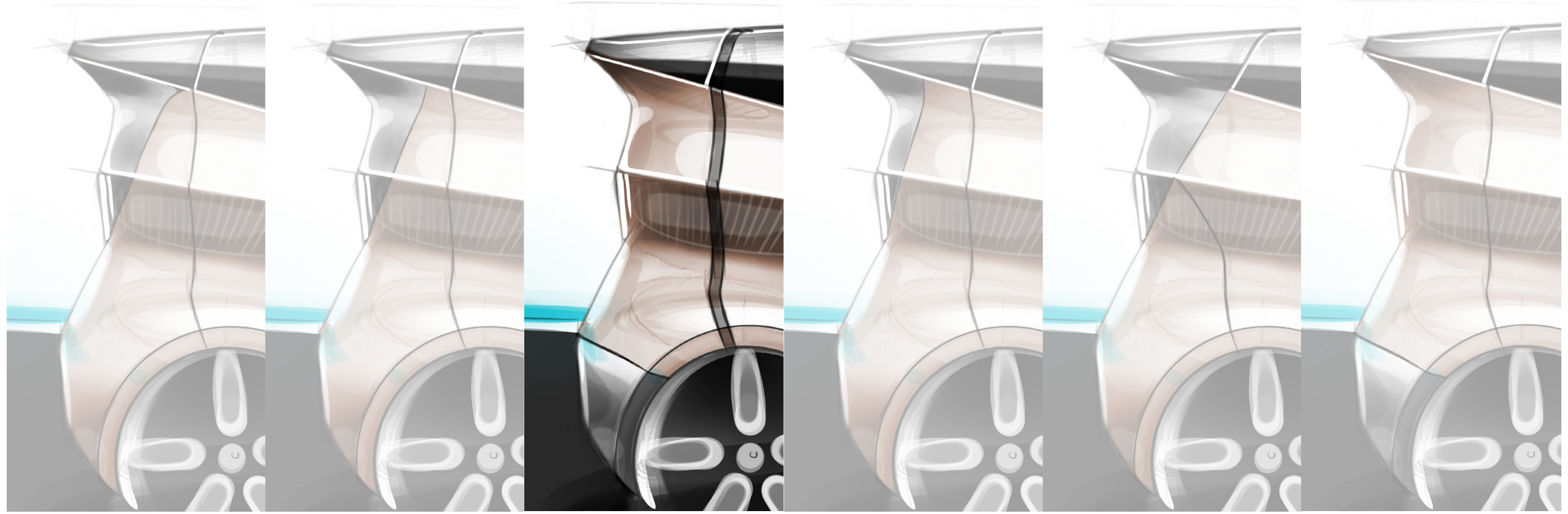
Some variation on the front were made in order to see what happens when the silhoutte and shape transition changes. I decided on a wide 'band' from which the top half is glazing and the bottom line continues in the side shoulder line.

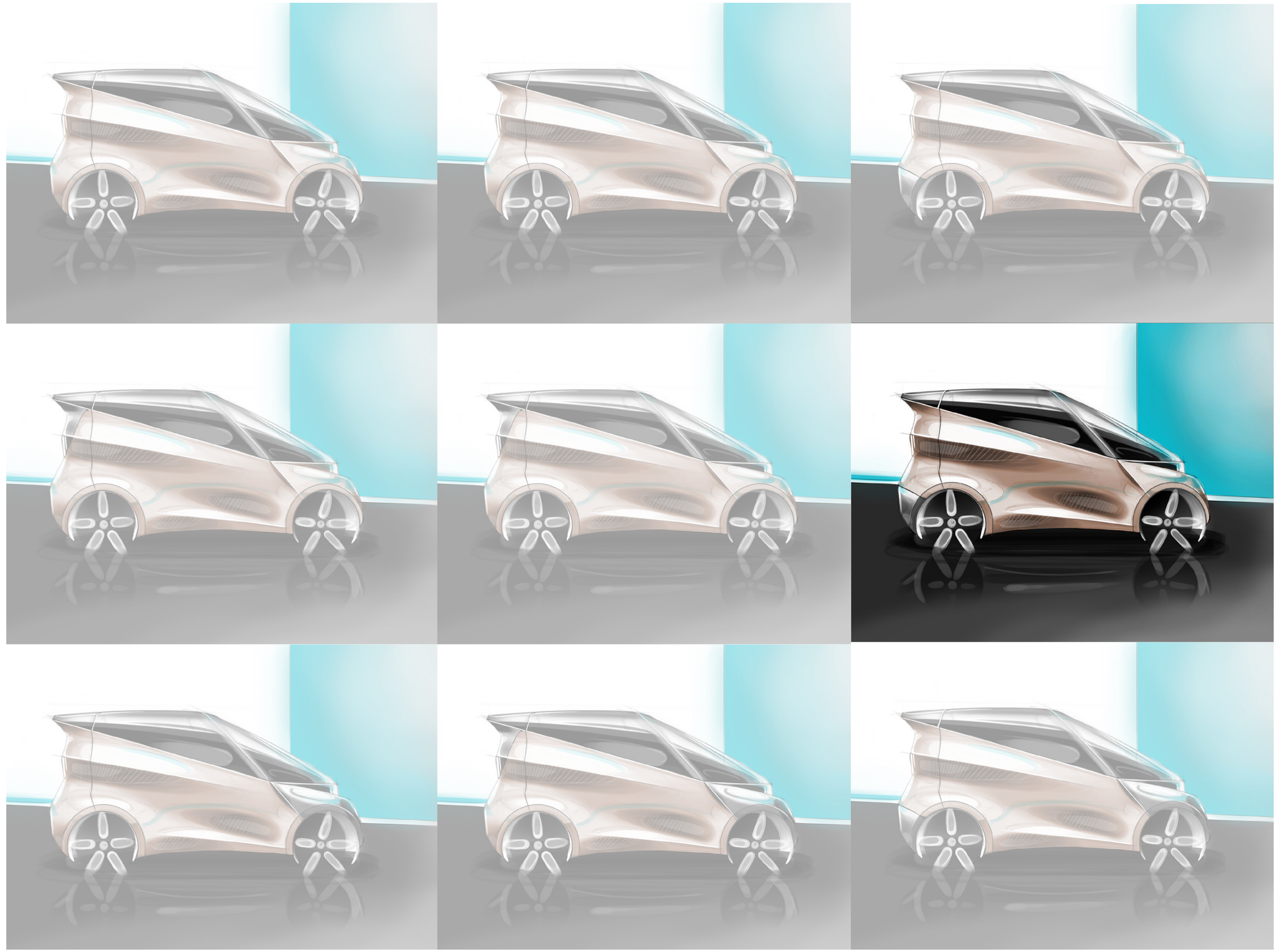


Ideas for how and where to split parts and work with color contrast or different materials.





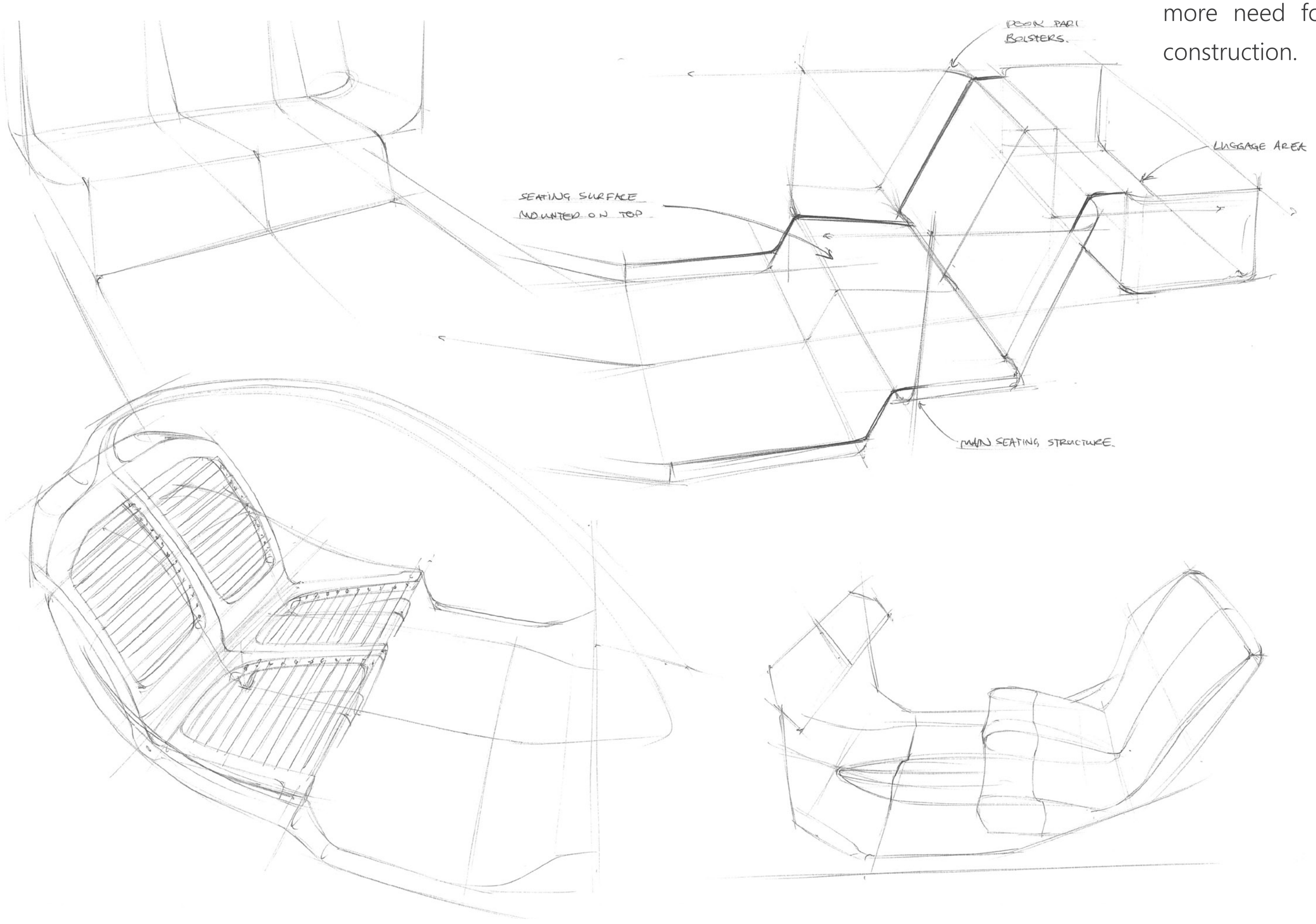


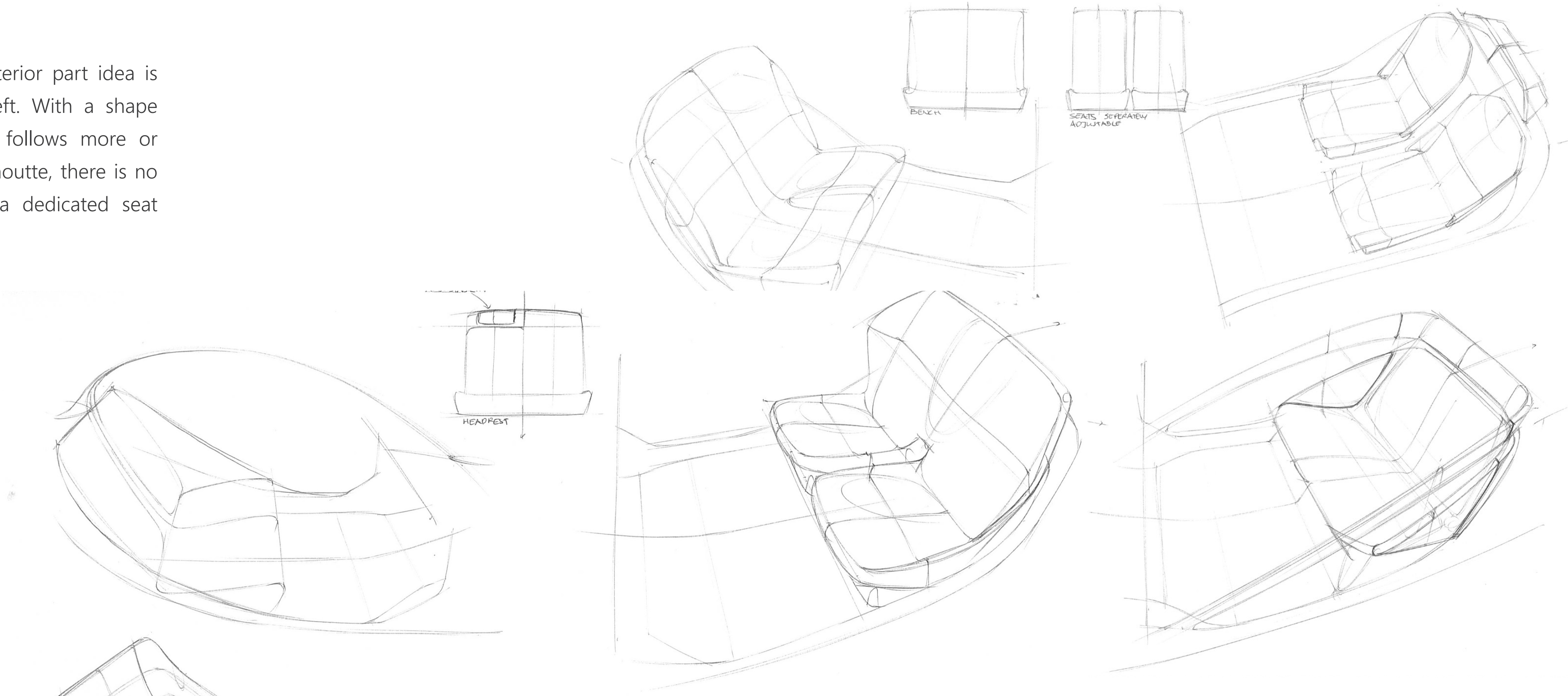


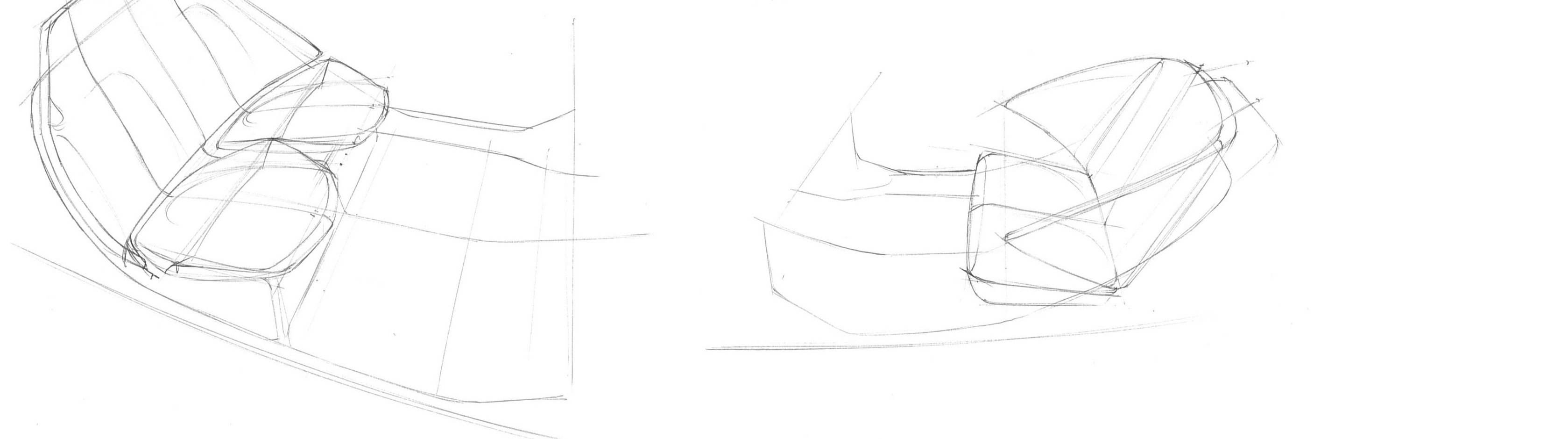
Appendix K

Interior sketches ideas and development

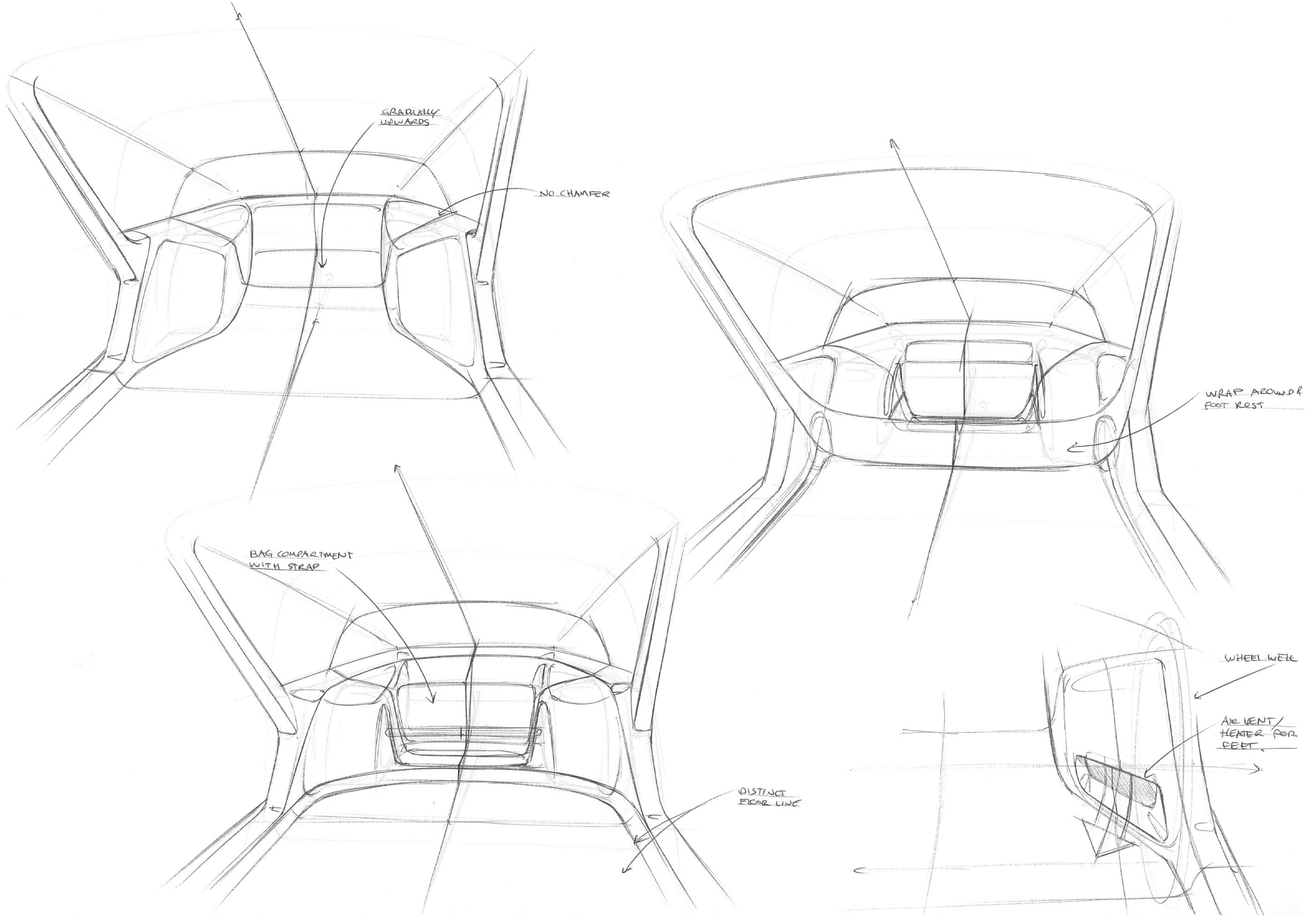
The structural interior part idea is shown on the left. With a shape of the tub that follows more or less the seats silhoutte, there is no more need for a dedicated seat construction.



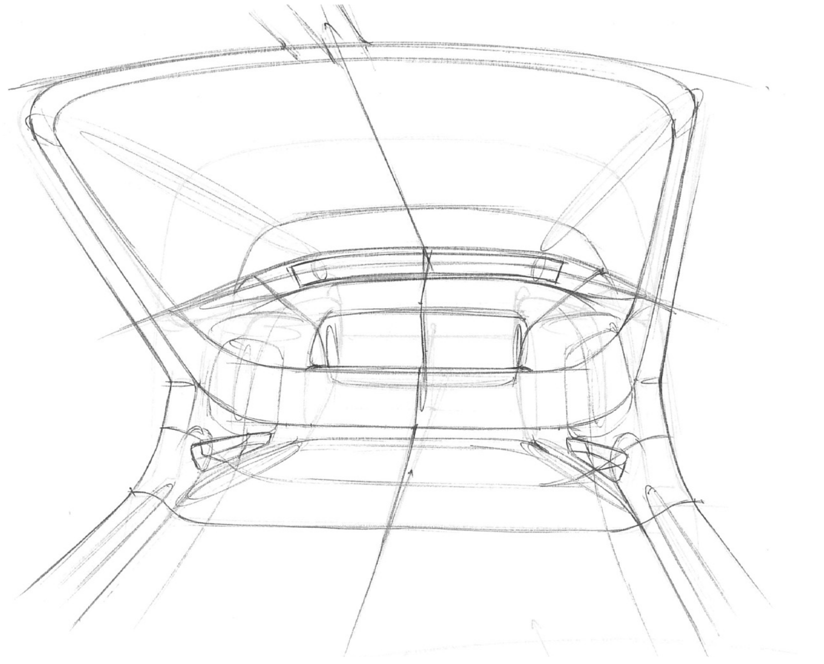


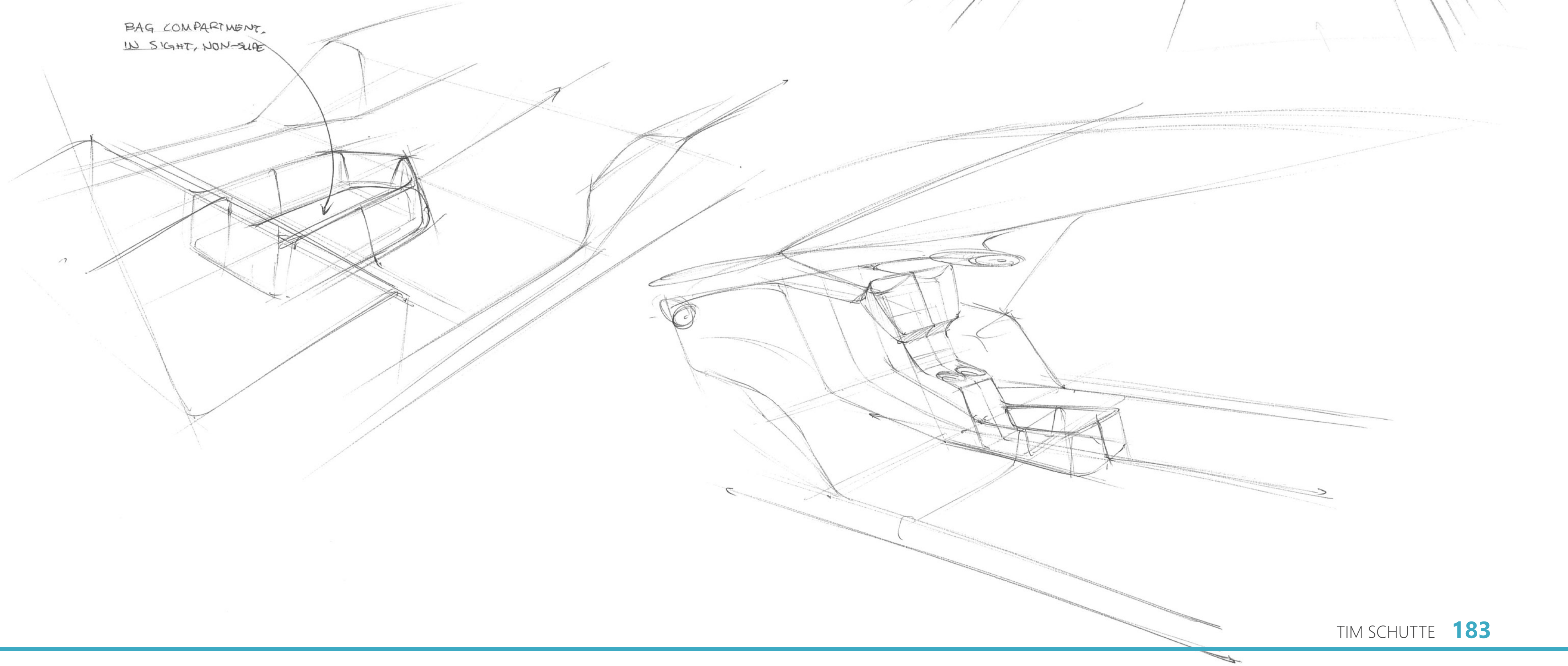


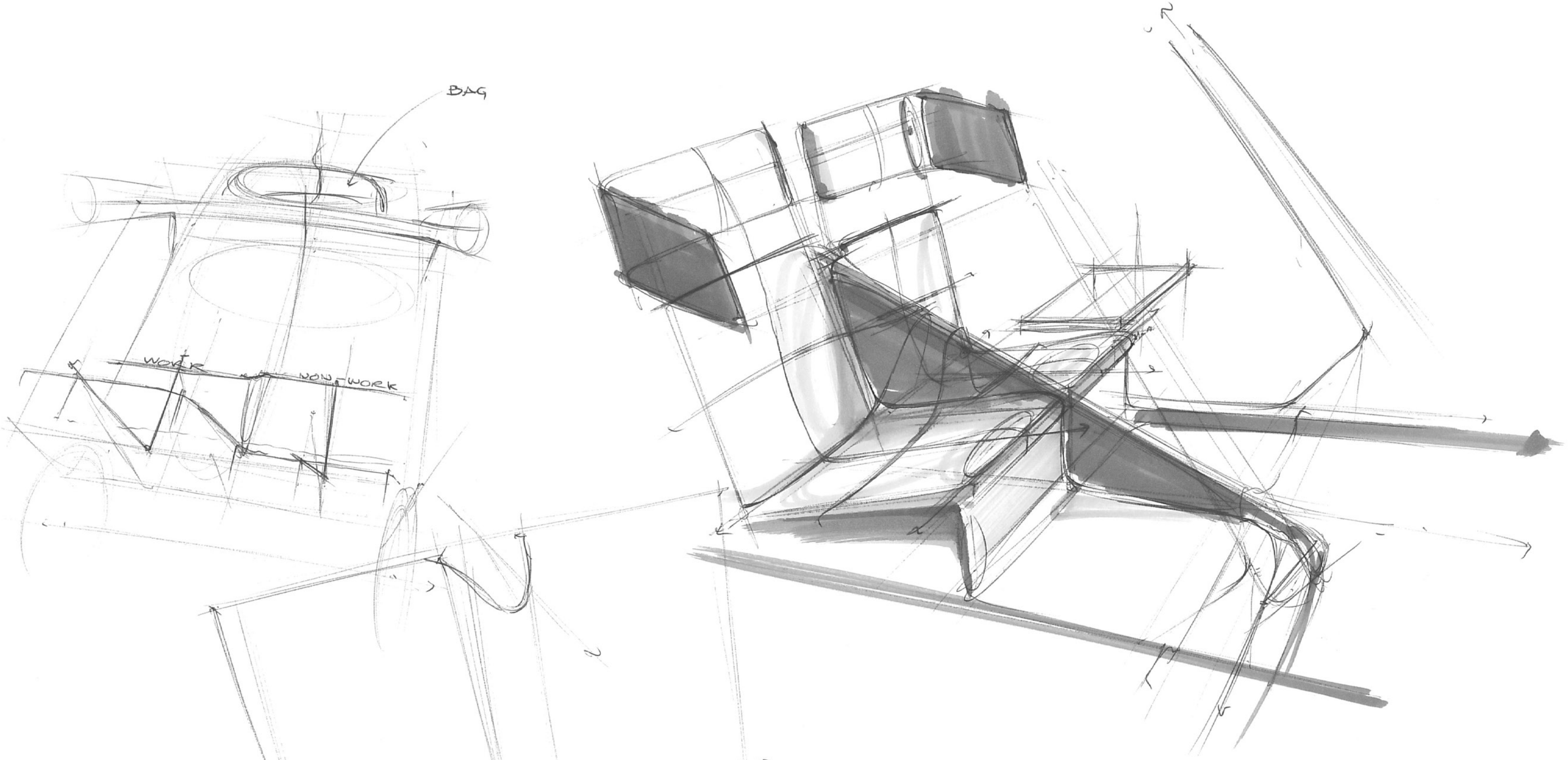
Seats can of course be designed in severeal different ways. It has to comply with my envisioned theme of perceived safety and trust. The recurring element is the shape that is wrapping around the user, creating the perception of a safe area.

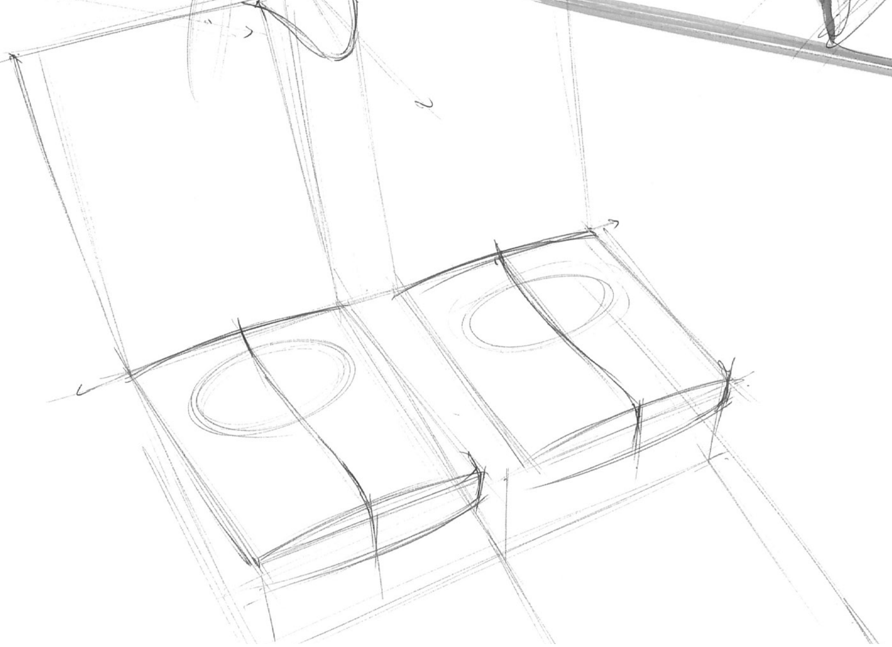


The front part of the interior is the place where the personal belongings, such as bags, of the passengers can be stored. In the interior I wanted also to accentuate the distinct diagonal and revolving shape of the the a-pillar into the roof, just as at the exterior. That is why I developed the design on the right further and implement it in the final design.



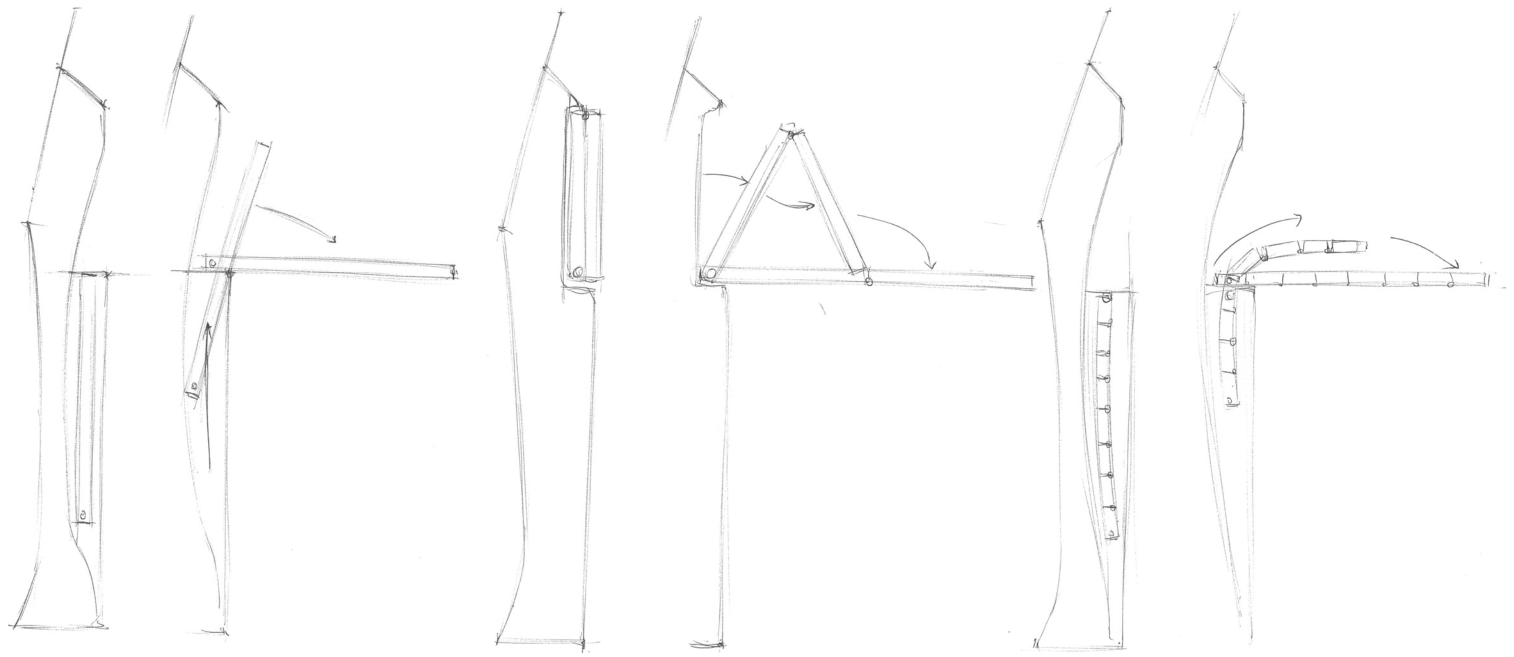


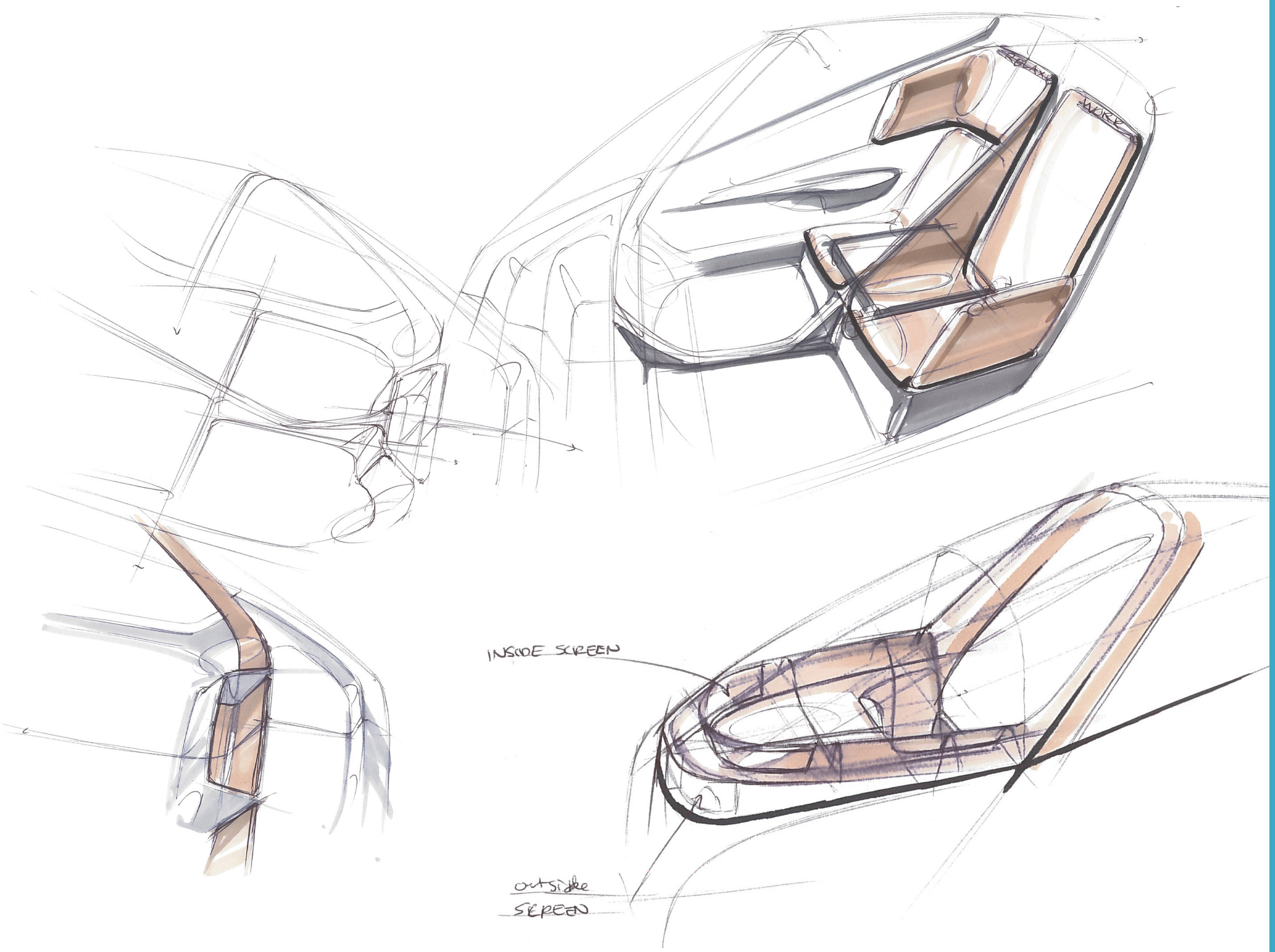




I decided on a physical devision between the two seats, in order to accentuate the different possible functions of the two sides and realised that there is a opportunity to play around with asymmetry in the interior, even more emphasizing the duality in functions.

Possible folding mechanisms for a retractable table




INSIDE SCREEN
outside SCREEN