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Car Ergonomics – Inclusive Design for Seniors

Development of a system-level concept of a car's luggage space

A Master's Thesis in the Master's Program Product Development

VIKTOR BARNÖ
SIMON HALLBERG

DEPARTMENT OF INDUSTRIAL AND MATERIAL SCIENCE

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Department of Industrial and Material Science
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Industry partnered supervisor: Pantea Marandi, attribute leader physical user
experience at CEVT
Supervisor: Jenny Tolf, Division Design & Human Factors at Chalmers
Examiner: Anna-Lisa Osvalder, Division Design & Human Factors at Chalmers

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Department of Industrial and Material Science
Division Design & Human Factors
Chalmers University of Technology
SE 412 96 Gothenburg
Sweden
Telephone +46 (0)31 772 1000

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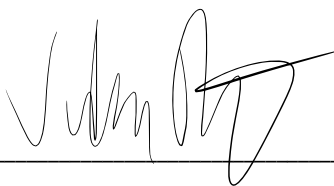
PREFACE

This report describes a master's thesis project carried out at Chalmers as part of the examination of the Product Development master's program.

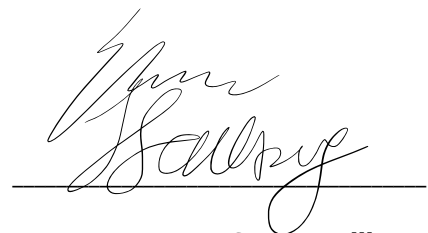
Firstly, we want to thank our supervisor at CEVT, Pantea Marandi (Attribute Leader Physical Experience at CEVT), for all the help and aiding us during periods of uncertainty and always allocating time, among other answering our constant Skype-messages. Thank you for supplying us with all necessary information and your area expertise. We would also like to thank Emelie Heimersson (Director at Customer Experience), and the department of Customer Experience. It has truly been a joy to meet and work with you, even though it was during a shorter time than expected.

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Viktor Barnö
Gothenburg, May 2020



Simon Hallberg
Gothenburg, May 2020

ABSTRACT

This master thesis covers the development of an innovative concept that was designed to facilitate the loading and unloading of a car's luggage space to include the senior with natural disabilities caused by age. The project was performed at the Division Design & Human Factors, at Chalmers University of Technology and was initiated by the Ergonomics department at CEVT with the aim to increase the knowledge and competence of how to include users with special needs or disabilities. This was enabled by general exploratory research through a literature study and a market analysis. The research displayed the special needs and disabilities among marginalized groups. The project pivoted towards the target group where an improvement has the highest potential of generating an influential impact. Due to the global growth of the aging population and the market potential it entails, the focus was directed towards seniors and the natural disabilities caused by age. An investigation regarding which natural disabilities aging brings about and how they affect the seniors' daily car usage was carried out. Common physical disabilities are change in body size and body posture, also a decrease in muscular volume and strength. The research also demonstrated that general impairments of the motor, sensor and cognitive functions are common among seniors. All these disabilities had to be taken into consideration in the development of a car that should be ergonomically appropriate for the senior user.

To further understand the special needs of the senior user, an empirical study, including observations and interviews was performed to outline the user requirements regarding the usage of the luggage space. The user study consisted of four Swedish seniors in the age span of 75-80 years old, with various tangible disabilities among the participants.

To facilitate the loading and unloading of the luggage space for seniors, a concept development was initiated. The objective was to address as many different experienced problem areas as possible to reach a higher inclusivity. Hence, the generated concept should be on a system-level, consisting of several different sub-solutions, focusing more on the general functionality than the detailed design. The development started with a requirement setting and functional description, that was established by the exploratory research and empirical study. This led up to a concept generation phase, which was followed by a concept screening process that resulted in a final innovative concept. The presented concept consisted of several sub-solutions that fulfills the stated user needs and is possible to implement in current cars to reach a higher level of inclusiveness.

Finally, it was concluded that if a product development project designed towards a marginalized group, in this case, seniors, both the targeted group and the norm users would benefit from the outcome while still retaining the same attractiveness and quality of the product.

Keywords: Inclusive Design, Universal Design, Innovation, Ergonomics, Product Development

ABBREVIATIONS

AIAP	-	Alternative Interface Access Protocol
BMI	-	Body Mass Index
CEVT	-	China Euro Vehicle Technology
DFA	-	Design For All
HTA	-	Hierarchal Task Analysis
HFC	-	Hands-free Closing
HFO	-	Hands-free Opening
IEA	-	International Ergonomics & Human Factors Association
ME	-	Myalgic Encephalomyelitis
NPD	-	Neuropsychiatric Disability
OECD	-	Organization for Economic Co-operation and Development
QFD	-	Quality Function Deployment
REBA	-	Rapid Entire Body Assessment
RPE-D	-	Rating of Perceived Exertion - Discomfort
SCB	-	Statistiska Centralbyrån
UN	-	United Nations

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1 INTRODUCTION

1.1 Background

Cars are very complex products, take years to develop, and in some aspects, tend to adapt slowly to change. At the same time, other technologies and user behaviors seem to change with ever-increasing speed. A company that is trying to push the development in the car industry is CEVT (China Euro Vehicle Technology). They are an innovation company operative in the Geely organization, and has the vision to be a world-leading innovation center, creating mobility solutions for a different tomorrow. To strive towards this vision, CEVT must understand and predict future user needs and behaviors.

One area where there is an increased need for knowledge is; how can cars be more inclusive and adaptive towards special needs and disabilities? The concept of *including* implies universal design that is the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaption or specialized design (Coleman, 2004). These special user needs can be everything from physical and mental, to pure personal preferences. These individually specific needs should be adapted for and included accordingly by product developers. With the worldwide growth of the aging population, there is a significant interest to explore the needs of the senior citizens and their car usage (United Nations, 2019), (BIL SWEDEN, 2019).

1.2 Scope

The objective of this master thesis was to perform a general research study, conduct a user study, and develop a concept based on how the car can be designed to be more inclusive for seniors. The final concept would contain a visualization that will be able to showcase the function adequately. The final concept would be an overall innovation concept, with state-of-the-art characteristics, that would inspire new features for further development. CEVT requested that the final concept should address as many problem areas as possible to reach a high level of inclusivity. The innovation concept focused on the activity of loading and unloading the luggage space of a car of the brand Lynk & Co, model 01.

The purpose of CEVT's initiation of the project was to include marginalized groups as users and widen their customer segment and enhance the product experience by eliminating possible discomfort for the user. As well as the positive social impact of inclusive design, CEVT also saw the market potential of the newly targeted user segment as a business opportunity. Therefore, were the senior user chosen as the target group, with the objective to find where the seniors' need was the greatest and then align the project in the problem area direction where it could generate the largest impact. In this report, the senior users are defined as people aged 65 or above (Folkhälsomyndigheten, 2019). The project was performed at the Ergonomics department at CEVT, who is responsible for the requirements setting within the organization regarding the user's physical interaction and experience with the vehicle, hence the project scope was aligned towards senior's physical disabilities and their consequences.

This project addressed the senior population and the problems they faced in their interaction with the luggage space of the car. The user study within this project included people age 70-80 years old. In this age span, the physical disabilities caused by age were both visible and tangent. This target group was chosen because of the senior population's global growth. Also, in mature markets, the senior generation tends to possess most of the population's purchasing power. Furthermore, natural aging results in disabilities that are common in several other user segments, which results in a wide amount of people that could benefit from the project result.

1.3 Delimitation and Disclaimer

The project observed an SUV vehicle, included the senior individual with natural disabilities caused by age as the user profile, and focused on the elements included in the activity of loading and unloading the luggage space of a car. Also, Sweden was used as the reference market for the user study. Furthermore, no finished product was produced or commercialized. The finished concept is not a whole brand-new concept car, should be viewed as an innovative concept of how a future luggage space for the Lynk & Co model 01 could be designed.

Some of the theoretical content may be perceived as idle and unused in the product development. However, some of the presented theory serve the purpose of informing and explaining, to provide insight into the senior user, and not being a theoretical basis for later examination and analysis.

1.4 Research Questions

To comprehend the overall purpose of the project, the research question was stated in its general form as:

- **How can cars be more inclusive for seniors with natural disabilities caused by age?**

The definition of the research question evolved in parallel to the progress of the research project to be declared more precisely as:

- **How can the procedure of loading and unloading the Lynk & Co 01 be facilitated for seniors with natural disabilities caused by age?**

with the sub-questions:

- What problems do seniors experience when interacting with cars?
- What special needs are important to focus on when including seniors?
- How can these needs be addressed in the design of the luggage space?
- What new features and solutions can be developed to enable an effortless loading and unloading of the car?

2 METHOD

The project work was performed according to the agile way-of-working methodology (Collier, 2011), having several interactions and loops. The design process was of participating in nature with a high level of involvement of the user. The targeted user group was included in feedback-loops during the development process to shorten the lead times for observations and interviews. Also, the project kept a high level of innovation using existing technology in a new context.

Development process/cycle (Vigmo, 2020):

- Understanding the brand & market.
- Defining the user for the project.
- Understanding the user's problem.
- Defining personas.
- User cases.
- Identification of major requirement/function problem area.
- Determination of problem to solve.
- Benchmarking.
- Concept generation.
- Visualization.

The initial step of the project was to gather information and statistics about the market to delimit the scope, since the preliminary framing of the research question composed by CEVT was too wide to be investigated during the time available during the project. The information-gathering was done through a literature study, using secondary sources of information. Furthermore, to ensure that the project aligned itself with CEVT's visions, statements, and strategies, consultation with internal business professionals was carried out.

The competitive analysis and benchmarking were carried out through observations, where the project team members visited car retailers, and secondary sources research, where existing solutions and innovations to include seniors with disabilities were investigated and examined.

Throughout the project, decisions on how the development should proceed occurred continuously. To justify the decisions made, and to achieve a valid project result, this decision-making procedure was performed using acknowledged and approved engineering methods. Methods that came into use during the screening process of the concept generation phase were "House of quality", and "Kesselring matrix" (Almefelt, 2018). In the requirement setting for concept functions, methods acknowledged within ergonomics, e.g. Borg's RPE-scale (Heart Online, 2014) and REBA-assessment (Freytag & Hollensen, 2001), were used to quantify the requirements.

In the empirical study, semi-structured interviews (Almefelt, 2018) and observations (HaptiMap, 2009) with target users were conducted to gather information from their product experiences. The structure was chosen due to the widespread physical and mental capability among the interviewed/observed users, allowing the interviewers/observers to adapt the interview/observation to the specific attributes of the interviewed/observed person in question, and in turn, generate more information. A more detailed layout of the method of the empirical study is described in the user study (“5. *EMPIRICAL STUDY*”) section of the report, “5.1 *Method of Empirical Study*”.

3 THEORY

3.1 Inclusive Design

A common mistake to make when designing a product where user interaction is required is that the designer tends to use themselves, or a perception of a norm “average” user as the model for the product. User-centered design has largely addressed the healthy adult (Kroemer, 2005). Construction of society and the development of products are often based on the assumption that people can see, hear, and move around, as well as understand and react adequately to signals. This kind of product development is coined as “*the illusion of mankind*”, a commonly used expression among inclusive design experts. This product development mindset has a narrow-minded perspective and implies that all people have the same; cultural background, sexual preferences, socio-environmental background, independent way of relating to the context, ability to use technology, and physical and cognitive skills (Osvalder, 2019).

This will inevitably result in a large segment of the market that is outside the definition of an “average” user to be excluded from the product. As the average user only accounts for a small span of a normally distributed curve the non-average user account for a large part of the general population. To reach out to more users and to create a better product for the masses, designers must widen their scope and design for more than an average user. One way of doing this is “Inclusive design”. Inclusive design is often associated with the design terms “Universal design” and “Design for all”, which are other terms but implies the same design mentality, just used in different contexts and countries.

Inclusive design is an approach that aims to take a holistic view of users and is used to describe a design philosophy targeting the use of products, services, and systems by as many people as possible, without the need for adaption. Inclusive design is design for human diversity, social inclusion, and equality (EIDD, 2004). Inclusive design refers to barrier-free accessibility, targeting people with disabilities, but has lately become a strategy for the mainstream. It emphasizes inclusive solutions, ensuring that environments, services, and interfaces work for people of all ages and abilities in different situations and under various circumstances (EIDD, 2020). Utility, usability, and user experience have influenced user-centered design, intending to obtain a solution that is functional, operational, and satisfying for all users (Ames, 2001). Utility, usability, and user experience is described further in the next chapter about the topic *Ergonomics*.

Inclusive design recognizes that people differ from each other and everyone has their preferences and needs (Figure 1), and it sees disability as an extension of the ways we may differ as people. Further, it recognizes that designs that would benefit a disabled person could also benefit a nondisabled person, or at least not result in a disadvantage. This would mean that designing for disability could create a larger potential customer base, not while creating an alternative design, but perhaps a better design (Jordan, 1999). When working in the field of inclusive design, the most studied and examined user group is the senior, with their decreased physical and mental conditions, children, people using a wheelchair, and people with decreased vision and hearing. Also, the user group of expectant mothers is occasionally discussed, but there is however a fairly little amount of research performed on how to design for people with NPD (Kroemer, 2005).



Figure 1 - Infographic universal design (Choi Design Group, 2018).

There are seven defining criteria for inclusive design (Story, 1997):

1. *Equitable use*

The design is useful and marketable to people with diverse abilities. This is an AIAP device's key feature because it can take any form appropriate for the user. One person might have a sophisticated system integrated into his or her wheelchair that uses eye-tracking for control, while another might prefer a cell phone with a headset for voice control and audio display. So, all users can access the ideal interface for their needs.

2. *Flexibility in use*

The design accommodates a wide range of individual preferences and abilities. Although users can personalize an AIAP device, designers must still consider flexibility. When interactions will occur in a mobile environment especially, the user's interaction needs could vary, and the device must allow for this flexibility. For example, the user might normally prefer audio display except when he or she has privacy concerns in a crowd. In this case, a discrete graphical display of information on a head-mounted display would be preferable.

3. *Simple & intuitive*

The design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level. This principle is the goal of all interactive systems but achieving it can be difficult. A simple and intuitive interface is especially important in a mobile setting, where the user might be focusing on other tasks. Designers must also consider cognitive impairments when developing a device for the disabled population. The designer must be aware of the limitations of memory, recognition, and understanding that can accompany various cognitive disabilities.

4. *Perceptible information*

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities. For a system to be effective, a user must be able to comprehend its state. Again, in a mobile environment, ensuring that the user is receiving the necessary feedback from the device can be difficult. The user might miss the icon showing an error if he or she is driving a car or concentrating on crossing the street. A common problem with current mobile devices is their reliance on only one output mode for important information, thus making them unusable by people with disabilities. For example, cell phones often rely heavily on visual displays for output and use, making them inaccessible to blind users.

5. *Tolerance for error*

The design minimizes hazards and the adverse consequences of accidental or unintended actions. Designers must always allow for easy recovery or error avoidance in an interactive system. In a mobile environment, error tolerance is even more important because the incidence of error will increase due to environmental factors and the changing focus of attention. With the AIAP device, the user might be interacting with critical systems, such as an ATM, where a poor error tolerance could cause serious consequences. The ideal solution keeps the user from making errors by providing a simple and intuitive system, but the system must at least allow for easy recovery from inevitable user mistakes.

6. *Low physical effort*

The design can be used efficiently and comfortably with minimum fatigue. A device's necessary physical requirements certainly factor in when a target user could suffer from impaired dexterity. For example, a senior user might have trouble pressing buttons that require excessive force. Physical effort is always an issue when devices might require the user to wear equipment or use an interface that can be fatiguing or require excessive strength and dexterity. When designing a product such as an AIAP device, the developer must evaluate the required physical effort for carrying and interacting with the system throughout the day in various situations (carrying groceries, climbing stairs, or walking the dog, for example).

7. *Size and space for approach and use*

The design provides appropriate size and space regardless of users' body size, posture, or mobility. One problem with trying to make systems such as ATMs accessible to everyone is the size and space issue. Often these public devices are too high for a user in a wheelchair or too low for a tall person, or perhaps the space around the system is difficult for a user with a walker to navigate. Letting users access these public systems from their own portable devices offers an easy solution to the problems induced by system placement and allotted physical space.

3.2 Ergonomics

In the scientific discipline of ergonomics or “human factors”, the understanding of interactions between humans and other elements of a system is fundamental (Wilson, 2014). It applies knowledge about human physical, cognitive, social, and behavioral abilities and limitations to the design of products, tasks, and environments to optimize human well-being and overall system performance.

To explain the terminology of ergonomics, several definitions are used within the knowledge area and practiced in the industry (Osvalder, 2019):

- The science of human in work and the interaction between the human and the working tools.
- The study of people's efficiency in their working environment.
- An applied science concerned with designing and arranging things so that people and things interact most efficiently and safely.
- The study of how equipment and furniture can be arranged for people to perform work or other activities more efficiently and comfortably.

According to the IEA (International Ergonomics & Human Factors Association), ergonomics is officially defined as:

“The word ergonomics – “the science of work” is derived from the Greek ergon (work) and nomos (laws). Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design to optimize human well-being and overall system performance.” - (IEA, 2020).

Alphonse Chapanis, an American pioneer in the field of industrial design, indicates that the teaching of ergonomics has evolved from a scientific existence to a large and wide area of application in engineering, and in turn product development. The human factors engineering emphasizes on the application of knowledge about human behavior, abilities, limitations and other characteristics to the design of tools, machines, equipment, devices, systems, tasks, jobs, and environments to achieve productive, safe, comfortable, and effective human use (Chapanis, 1985).



Figure 2 - Definition: Tasks that require a person to lift, lower, push, pull, hold, or carry any object or material (AREVA, 2007).

Ergonomics was at first a term only used within the improvement of a work area, to reduce strain for the employee or ensure safe handling of equipment. It was applied to a lot of different work areas, for instance line assembly work where the assembler had a monotonous movement pattern where repetitive strain injury was common. In these situations, the ergonomic perspective would ensure that a correct working position was established, minimize movements that have a high strain, such as heavy lifts above the head, and ensure that the user rotated on the different work assignments (Stack, 2016). See Figure 2 for a definition regarding working positions.

However, ergonomics is now used to a broader extent, and it is no longer only used in a situation related to work but to any product or situation in everyday life. Because of higher living standards and higher expectations on the products as well as the services we purchase and surround ourselves with, the knowledge within ergonomics has been applied to everyday products. One example is the car where people spend a lot of time and plays a significant and determining role in the quality of life of their users (Stack, 2016).

Ergonomics are sectioned into three different domains (Osvalder, 2019):

- *Physical ergonomics* – is concerned with human anatomical, and some of the anthropometric, physiological, and biomechanical characteristics as they relate to physical activity.
- *Cognitive ergonomics* – is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system.
- *Organizational ergonomics* – is concerned with the optimization of socio-technical systems, including their organizational structures, policies, and processes.

This project strived for a user-adapted ergonomics design, fitting the task, tools, and environment to the human by taking physical, mental, and social human characteristics into consideration in the design. Since the focus of the design was to facilitate senior's loading and unloading activity in cars, only *physical* and *cognitive* ergonomics were considered.

Additional ergonomic topics that will be considered in this project are *utility*, *usability*, and *user experience*, earlier mentioned in the chapter *Inclusive Design*. Utility means how practical and useful an object/activity is. Usability consists of five components related to user interaction: learnability, efficiency, memorability, errors, and satisfaction (Nielsen, 2012). The term user experience describes the overall user experience of a product, system, or environment, including emotional fulfillment, satisfaction, and comfort (Crew, 2006).

Utility and user experience differentiate from each other; utility is not concerning the user, whereas user experience is heavily user-oriented. Both utility and user experience incorporate functionality, but user experience emphasizes on issues closely related to the user (Rubinoff, 2004). Some of the user issues include emotional fulfillment and satisfaction. However, the earlier mentioned term comfort is an issue of user experience and is something that people perceive as a reaction to an activity or performed task. Comfort can be described in terms of physical, mental, and functional comfort and is not a static state, it varies over time (Helander, 2003).

3.2.1 Ergonomics in Cars

Ergonomics within cars includes a wide spectrum of different areas and attributes, as the earlier definition of the term *ergonomics* indicates; *“The study of how equipment and furniture can be arranged for people to perform work or other activities more efficiently and comfortably.”* (Osvalder, 2019), it can be noted that this contains several different subjects: *furniture*, *equipment*, *comfortability* and *efficiency*.

Explanatory example: *Furniture* and *equipment* consider for the seat and seating position. While *comfort* and *efficiency* consider how easy this comfort is acquired with the help of adjustability, such as back support, seat positioning, and how these adjustments are achieved. The two requirements of comfort and effectiveness also apply to equipment, which includes other interactions with the car, for example opening the luggage trunk, folding the seats, infotainment system, steering wheel, etc., see Figure 3 for illustration on interaction with Lynk & Co 01. These systems must also be designed for comfort in use to minimize the strain of the person in the car and be as effective as possible to achieve their purpose.



Figure 3 - Ergonomic simulation of three mannequins (Woman, German, 5-50-95 percentile) using the luggage space of a Lynk & Co 01.

Although these requirements are the same in many areas within ergonomics, it is further hampered by the fact that the car provides additional difficulties. In a car, influencing factors such as vibrations, bumps, sideways movements, acceleration, deceleration make it harder to acquire an optimal ergonomic situation (Streetfleet, 2018).

3.3 Disabilities of the Senior User

Among the usually marginalized user groups, this product development project focuses on the older generation of users and their capabilities that deteriorate gradually with their aging. This section exemplifies which disabilities it usually entails to get older, where these disabilities are derived from, and how they influence seniors in their daily life car usage. Along with aging, the physical characteristics of older adults change. What differs the older population from the younger regarding the musculoskeletal characteristics and physical abilities is body size, rate of motion, joint flexibility, and skeletal and muscular strength. Muscle weakness can occur due to several possible causes; lack of exercise, injury, chronic fatigue syndrome (commonly referred to as ME), etc. (Keller & Engelhardt, 2014). However, the most common is the inevitable human aging. The aging process is associated with changes in muscle mass and strength, with a decline in muscle strength after the 30th life year. Physically inactive people may lose as much as 3 to 5 % of their muscle mass each decade after age 30 (Keller & Engelhardt, 2014).

With age, muscles tend to lose strength, bulk and become weaker. As this decrease in muscular strength has to be accepted as a natural consequence of age, it can still be frustrating to be unable to perform the activities that could be managed previously. Muscle strength decline can be prevented by exercise. However, it has to be performed carefully since injury recovery times are much longer with higher age, balance is impaired and thinner bones are easily broken (Harding & Cox, 2016). The age-related loss of muscle mass is defined as the scientific term “*Sarcopenia*”, and the age-related loss of muscle strength is defined as the scientific term “*Dynapenia*”, see Figure 4 (Seene & Kaasik, 2012).

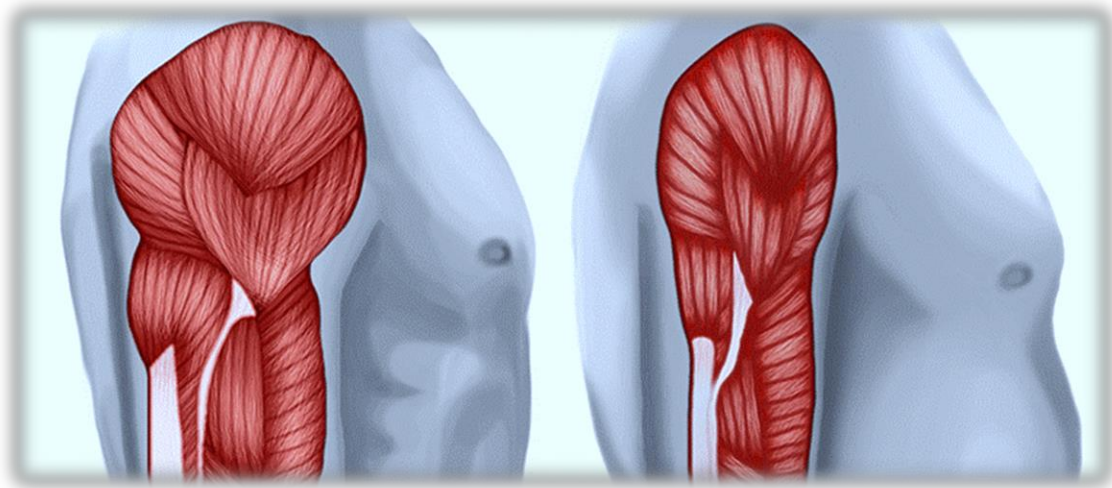


Figure 4 - Young man vs. old man with Sarcopenia (Fanatic Cook, 2018).

Sarcopenia is considered to be a minor modifiable risk factor for health outcomes, playing a significant part in the etiology of disability as one of the main contributors to musculoskeletal impairments among seniors (Seene & Kaasik, 2012; Papa, Dong, & Hassan, 2017). Sarcopenia typically happens faster around age 75 but may also increase in speed as early as age 65 or as late as age 85.

Addressing the crucial factor of change in body size and body posture; the standing and sitting height of the older body decreases, due to the degeneration of the intervertebral discs. Approximately 20–40 % of the older generation have fully developed kyphosis; an excessive convex spine curvature. Together with the change in the muscular-skeletal system due to age, this results in an altered posture, both in sitting and in standing, see Figure 5 (Osvalder et al., 2019).

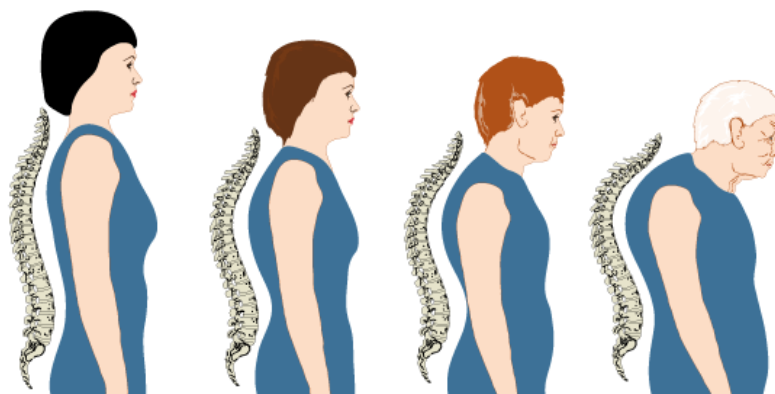


Figure 5 - Postural change with age (Cohen, 2019).

Furthermore, redistribution of fat occurs with higher age, resulting in more fat, less muscle mass, and increased BMI, leading to a change in body shape and strength. Some studies have shown increased upper and central body fat deposition with age for both women and men, others have proved that upper body obesity for those over 65 is more common among men than women. However, there are changes in the distribution of fat, related to age, that are not adequately captured by an increased BMI. Older people are more fragile than younger and thereby have an increased risk of injury or fracture due to weaker muscles, lower bone mineral content, and stiffer ligaments and joints (Osvalder et al., 2019).

Lastly, according to Canadian research, five types of chronic diseases largely contribute to the disability amongst people aged over 65 (Tidy, 2016):

- Foot problems.
- Arthritis.
- Cognitive impairment.
- Heart problems.
- Vision.

Other common and important problems are:

- Hearing impairment.
- Chronic respiratory and cardiovascular disease.
- Falls and hip fracture.

Amongst the weak and fragile seniors, a decline in mental and physical function can result from small continuous insults. This is commonly called the “domino effect”; small initial insults leading to a cascade of adverse events

3.3.1 Risk Factors

Weakness among seniors may be due to a combination of predisposing factors, such as choice of lifestyle and early childhood development, followed by contributing factors such as physical inactivity, malnutrition in later adulthood, and chronic disease (Tidy, 2016).

One research in Brazil established that the main risk factors for functional disabilities among seniors were chronic diseases, arthritis, diabetes, visual impairment, obesity, poor self-perceived health, cognitive impairment, depression, slow gait, sedentary lifestyle, and tiredness while performing daily activities. These factors may be influenced by access to healthcare and healthcare costs in different communities and countries (Tidy, 2016).

3.3.2 The Normal Aging Process

Age is correlated to a 1-2% decline in functional ability each year. Inactive practice behavior boosts the loss of performance. Physiological changes associated with age includes (Tidy, 2016):

- Change in body composition – reduction in muscle bulk and lean body mass (sarcopenia). Eventually an increase in body fat.
- Reduction in bone mass and strength with increased risk of fracture – osteoarthritic changes in body joints.
- Reduction in ventilatory capacity.
- Nervous system changes, reduction in cortical function, and reduced motor and sensory peripheral nerve function – resulting in changes in autonomic function.

- Reduced elasticity of eye's lenses, high tone hearing impairment.
- Stroke can lead to weakness, coordination problems, locomotor difficulties and problems with communication.
- Diabetes – complications which can contribute to disabilities resulting in poor mobility.
- Falls are associated with injury, pain, and function loss. Falls are likely to result in fractures.

A lot of research has been dedicated to the identification of risks for disability amongst seniors, commonly by applying the *disablement model*. The main pathway of the model consists of four components: pathology, functional impairments, functional limitations, and disability. In old age, pathology creates impairments, e.g. decreased muscle strength, poor balance, and low oxygen consumption. Impairments predispose seniors to functional limitations, e.g. slow walking speed and inability to grasp with hands, which leads to disability, e.g. difficulties in self-care and mobility (BURDIS, 2004).

3.3.3 Consequences of Disability

The percentage of seniors is increasing worldwide. By 2050, the number of people aged 80 or above will most likely triple in the OECD-countries, in comparison to today (2020), and a third of the earth's population will be older than 65 years (OECD, 2001). This advancement will lead to an increasing number of older people who want to, or must, keep themselves mobile. Using the car as a mobility tool is a significant factor in the quality of life and independence in social and working life (Karthaus & Falkenstein, 2016). However, using the car is a complex task involving motor, visual, and cognitive skills that the seniors often have problems with. The earlier mentioned disabilities caused by aging contributes to perceived discomfort and other problems in the car interaction for seniors. This section summarizes different age-related functional changes with relevance to car using, concerning the crucial sensory, motor, and cognitive functions.

From the holistic perspective, mobility is described through five fundamental determining categories; cognitive, psychosocial, physical, environmental, and financial. The restriction of mobility amongst seniors can lead to a decrease in social activities and evolve into impairment of cognitive status and mental health, such as depressiveness (Karthaus & Falkenstein, 2016).

There is also an interesting safety concern that should be addressed to get an additional perspective on how these functional changes affect the context of car use. In car accidents, the participation of seniors is altogether lower (12%) than their share in the population, which is about 20%, in Germany. However, when considering kilometers driven, the accident rate of older drivers is relatively high and similar to the rate of very young drivers. For instance, drivers aged 75 years or older, who drive fewer than 3000 km each year, perform the highest accident risk. In Germany, 75% of the drivers aged 75 and above are primarily responsible for the accident they are involved in. An analysis of the causes of car accidents involving seniors shows that there are typical situations that are certainly difficult for seniors, which leads to the causing of accidents. These are mainly giving right of way, turning, and reversing. The age-typical driving errors are due to age-related deterioration of cognitive and sensory functions (Karthaus & Falkenstein, 2016).

The complex task of driving a car requires different sensory, motor, and cognitive functions and their interaction. Age-related changes in these functions may have an impact on the everyday tasks of senior's car usage, especially under external time pressure. The task of driving is such an activity, hence driving competence may be flawed due to these age-related functional changes. For instance, vision and cognitive ability stand for 83-95% of the capacity to use a car safely (Karthaus & Falkenstein, 2016).

1. *Sensory functions.*

Age-related impairments of vision are most determining for driving since the greater part of the traffic-relevant information is received via the eyes. Aging implies structural changes in the eye that results in reductions in visual acuity and contrast sensitivity and increased glare sensitivity. Acuity can be compensated for with glasses, but some visual problems cannot, which results in increased risk during driving at night for the seniors. Besides, with the normal changes, certain eye diseases that impair the vision and the driving security is more common with increasing age. For example, eye cataracts, which applies more than 50% of the population aged over 65. Hearing is also heavily impaired due to normal aging but is of significantly less importance for traffic security (Karthaus & Falkenstein, 2016).

2. *Motor functions.*

Age-related motor changes influence the driving ability and general usage of the car. With higher age, the muscle strength strongly decreases, and the movement speed is reduced. When driving, this can result in a decrease in reaction speed during emergency maneuvers with the steering wheel or an increase of braking distance. When reversing, it is essential to be able to look back during the activity. Trunk and neck flexibility is severely reduced with age, leading to insufficient detection of targets in the back view, which certainly increases the accident risk, since the driver may overlook important targets approaching from behind (Karthaus & Falkenstein, 2016).

Motion coordination and dexterity deteriorate with higher age and are already worsen for people in late middle age. Hence, complex and fine-grained movements, that are necessary in some driving situations, for example unexpected situations and emergencies, are impaired among the seniors. Also, studies have shown that seniors who has been in falling accidents, due to impaired motor functions, are associated with the rate of senior's involvement in car accidents (Karthaus & Falkenstein, 2016).

3. *Cognitive functions.*

Certain cognitive functions that are relevant for car usage show a distinct deterioration with increasing age. However, impaired cognitive functions do not only apply to the senior generation, some functions, such as visual search, are already considerably decreased among healthy persons in their middle-age. Additionally, for the seniors, it is the cognitive functions that reflect fluid intelligence that deteriorates. Such functions are essential for problem-solving and coping with unexpected car situations. In particular, the executive functions, are highly relevant in the daily car usage. The executive functions control and support the attention ability, e.g. visual search and attention switch, inhabitation of irrelevant information and inadequate responses, management of multiple tasks, and monitoring of own performance. Several studies suggest that seniors have problems inhibiting inappropriate information and actions. In their car usage, it is shown that the seniors process irrelevant stimuli as intensively as relevant. Processing of irrelevant information to that high extent binds too many resources and can lead to cognitive overload. When the seniors use a car in a complex and unaccustomed situation or environment with multiple distractors, this "filtering problem" of older people can lead to discomfort, displeasure, misinterpretation, and misuse of product intention, and even safety risk (Karthaus & Falkenstein, 2016).

Notation: Even though these three presented functions have a major influence on the seniors' car experience, it has to be emphasized that behind these sensory, motor and cognitive functional changes underlies a massive and interindividual variability, which is influenced by many various external and internal factors, independent of age.

Example of car features in the existing industry that facilitates seniors' problems and enhances their mobility experience can be seen in the list "15 Best Cars for Older Drivers" published by U.S News, 2019. Some of the discussed areas in the list are the ingress/egress, the safety technology, the usability of the infotainment system, and the visibility of some of the cars in the industry. The list offers several cars designed for the older user and some common characteristics among the cars recommended are many safety aids, like lane departure warning, blind-spot monitoring, and pedestrian detection to help the seniors navigate on the road, see Figure 6. Also, the cars presented provide good visibility, easy-to-use features, and large doors that facilitate the ingress/egress of the vehicle (U.S News, 2019). More about suitable cars for seniors is presented in the later *Market Analysis* chapter.

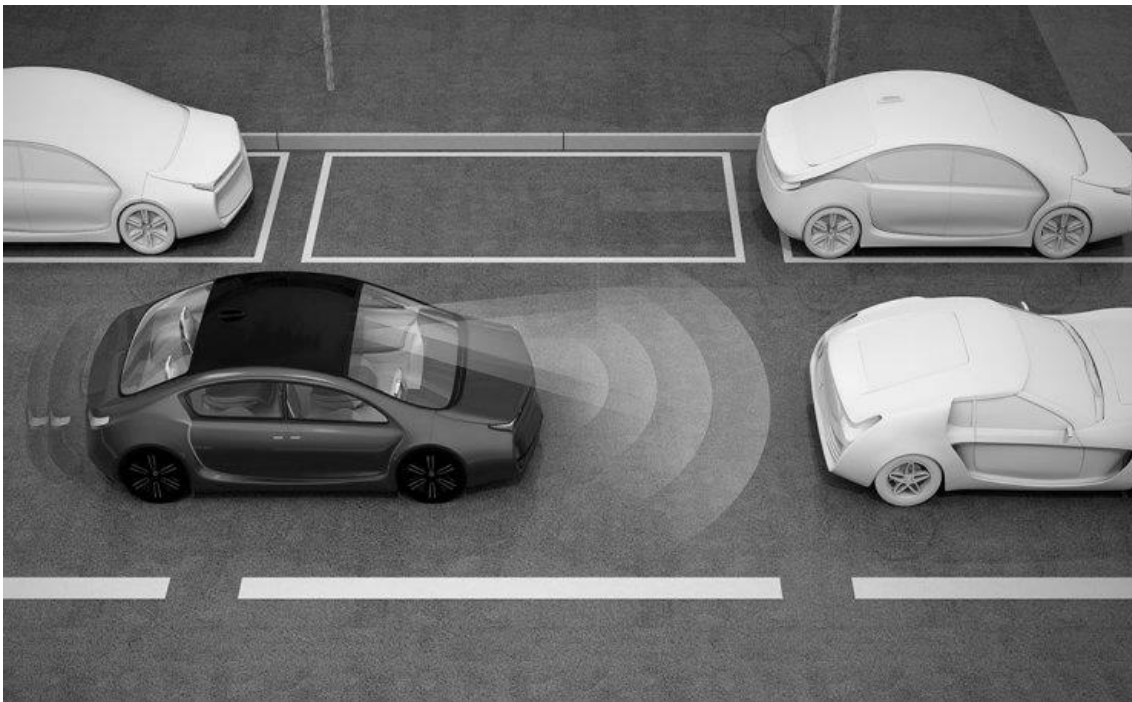


Figure 6 - Example of a feature that aids the driver's perception of its surroundings (Pinterest, 2017).

4 MARKET ANALYSIS

4.1 The Ageing Population

Consumer trends are driven by several developments in the consumer's environment. To analyze the market, the market intelligence philosophy is to structure the outlook of the future's market into a framework built up by *drivers of megatrends* (Niklasson, 2020). These drivers are used to outline market changes in the mid- and long-term perspective. One of the drivers is *population change*. As a result of fertility rates falling below the natural replacement level in the developed world, the population aging is one of the most important forces of global population change. The size of different demographic consumer segments will fuel the diversification of mobility types on offer since the aging population will have different needs compared to the single households and families (Niklasson, 2020). Hence, the following section illustrates how the senior population is a factor that has a determining role in the future market trends of mobility.

The aging population is growing globally. Today, the estimated life expectancy in the western world is 83 years (Osvalder et al., 2019), and in 2030, one in four persons will be over 65. Currently, 20 % of Sweden's population is above 65 years old, and in the upcoming years, the country's population will continue to age, and the proportion of seniors is estimated to keep growing, see Figure 7 for illustration. Even though the health of the senior individuals has improved over the past few decades, disabilities of different kinds will still be common in this group. As mentioned in earlier sections, with age, people change physically, mentally, and psychologically. For most people these changes involve multiple, minor impairments in eyesight, hearing, dexterity, mobility, and memory (Gheno et al., 2012). At present, such changes have a significant impact on older people's independence due to unnecessary mismatch between the designed world and their changed capabilities. In Sweden, 515 000 people over the age of 16 have a motion reduction, half of them are above 75 years old (Funka, 2020). Motion reduction: not able to take a shorter walk of about 5 minutes at a reasonably fast pace (Statistiska Centralbyrån, 2019).

In the UK, which has similar demography as Sweden, 50 % of the adult (16+) population is aged 50 or over. Over the 20th century, life expectancy rose by the excess of 2.5 years per decade on average. During the same period the only real growth in the population was the 50+ age segment. In effect, every new consumer on the street will become an older consumer, and this has been the case for the past 100 years. Across Europe, and in other countries where the process is well advanced, large numbers of people are now in retirement and embarking on new careers and pursuits to fill their longer lives. This trend will impact strongly on consumer markets and have extensive design implications, while a similar increase in those aged 80+ has significant implications for welfare (Coleman, 2004).

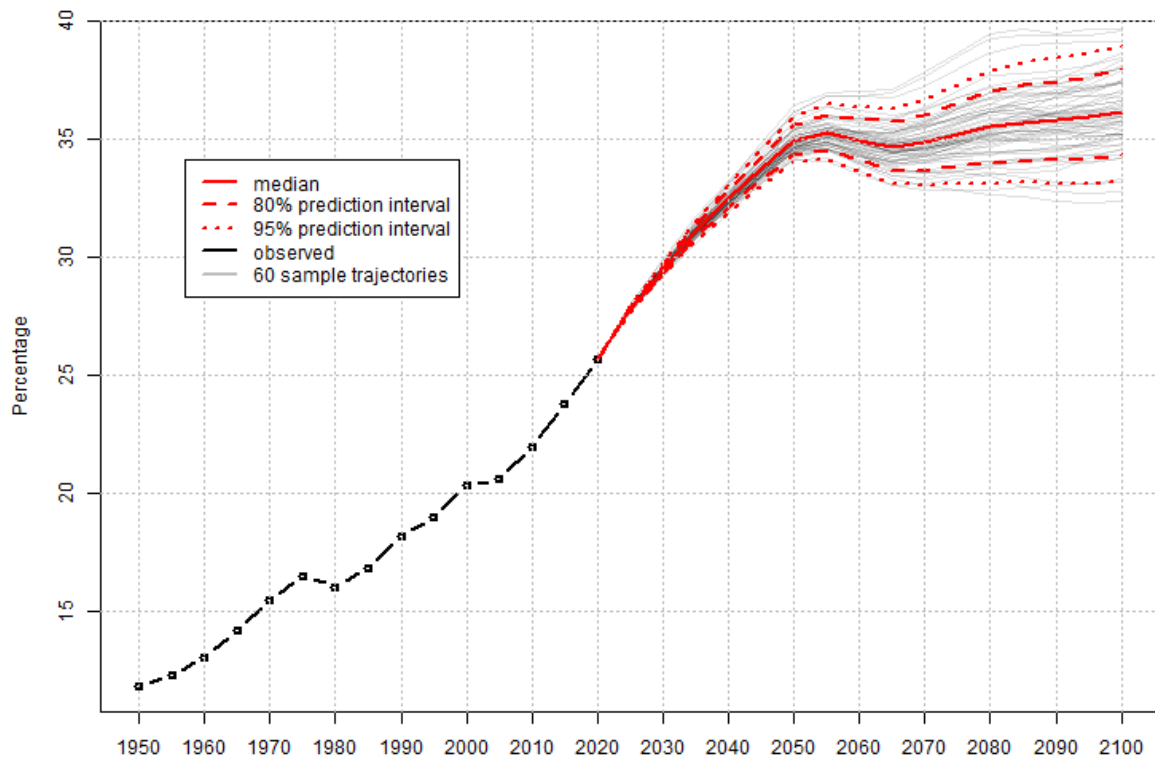


Figure 7 - Europe: Percentage of population aged 60 or over (United Nations, 2019).

4.2 Inclusive Design Market

UN, who recognizes the increasing longevity as a societal challenge to the welfare systems, claims that the seniors can no longer be neglected in the design process as a minor segment with low influence on user experience. Instead, the needs of the senior should be addressed and included in a greater occurrence in society (United Nations, 2019).

In recent years, there has been a shift in attitude, away from treating older people as special cases requiring special design solutions, and towards integrating them in the mainstream of everyday life through a more inclusive approach to the design of buildings, public spaces and, more recently, products and services. This is important for social equity but is also a significant opportunity for business growth through new products and services (Coleman, 2004). Two major market trends have driven this shift in attitudes:

- Population aging
- The growing movement to integrate disabled people into mainstream society.

These trends have been accompanied by growing legislation and convergence of consumer dissatisfaction, governmental concern, and business interest around inclusivity as a social goal and commercial opportunity (Coleman, 2004).

Industrial designers are challenging the dominant view of treating older people as a special and separate group and the problematization of population aging. Older people are better served through social integration and self-generated activities. To facilitate the shift from dependency to independence and social integration, the design community within ergonomics uses the *designing for our future selves-philosophy*: Move the focus from “them” to “us” and emphasize the duty of care for the future. Create a future world in which things could be done and enjoyed in ways not previously envisaged for older people. Address not simply the physical needs of older people, but their hopes and aspirations (Coleman & Clarkson, 2013).

During the last few years, designers and human factors have advanced the awareness of disability within our society. This might be based in moral obligations that come from the social prerequisites where “... *the democratic values of non-discrimination, equal opportunity and personal empowerment*” (Mullick & Steinfield, 1997), , but also the growth of legislation and government control to decrease discrimination and allow everyone the same kind of opportunity in the society, regardless if this is the ability to access buildings or the opportunity to get an employment. The change in attitude towards disability has led to a higher expectation on the products and services available on the market by people outside the previous design scope (Jordan, 1999). The expectations on social integration for disabled people and participation in everyday life have escalated dramatically.

These radical changes in the expectations among the disabled community and the growth of the older age group are challenging the common belief about how products and services should be designed if they should meet the needs of the majority. The fallout of this is that mainstream consumer markets will have to concern themselves with the increase of less able-bodied people, but yet want to enjoy, and be active in, an independent lifestyle (Coleman, 2004).

Further, manufactures have started to notice the growing market share held by the seniors which is steadily growing and seems to keep this trend during the near future. As mentioned previously, the seniors have a considerable purchase power and thereby a great commercial benefit is possible if companies starting to design for this segment. To achieve this, designing for disability is central since it's a higher percentage of seniors who have some kind of disability, compared to a younger target group (Statistiska Centralbyrån, 2019).

Another design aspect of inclusive design for seniors, that is present on the market, is the *designing for the extreme user*. Designing for the extreme user is appealing to producers because of the collateral benefits of targeting a user segment, that with its extreme characteristics, simultaneously satisfies the needs of an additional, less extreme, user segment. If you satisfy the ergonomic needs of the mobility impaired senior user, you satisfy the ergonomic needs of the normative user. For instance, if a 75-year-old woman with a hip replacement enters a car comfortably, a fully-abled 25-year-old woman surely would be able to enter comfortably as well. The attractiveness of having the senior user as a target group in the design process by many product producers can be described and summarized by the quote: “*Design for the young and you exclude the old; design for the old and you include the young*” (Coleman, 2004).

4.3 Market Potential – The Customer Needs of Seniors

Other than the product design benefits of targeting the senior user, there is also a potential business opportunity for large revenue. In the mature car market of Sweden, there is an established aftermarket for cars, resulting in that the new-car buyers are the individuals with higher purchasing power. Furthermore, in the developed national market of Sweden, the purchasing power of the population increases with age. New groups of users are appearing on the market, e.g. seniors with locomotive disabilities, making it necessary for the car industry to become interested in these groups of buyers. It is evident from demographic investigations that very soon, drivers over 65 years of age will constitute 1/3 of all drivers of personal cars (Zablocki & Sydor, 2009).

Senior citizens are, as previously shown, a very diverse group. However, they belong to a generation that values self-sufficiency and the ability to live as usual regardless of infirmities. Seniors want products and services that are functional as well as aesthetic. Currently, the values associated with the ideal life for senior citizens are activity, freedom, and dignity. Also, many seniors travel a lot, take part in sports activities, and are involved with local associations. For them, the quiet and calm life is a deceptive prejudice. According to a Danish report, Danish senior citizens, whose economic situation is equally compared to Swedish senior citizens, are wealthy and belong to the first “welfare generation” (Danish Enterprise and Construction Authority, 2009). There is a huge commercial potential in this group of seniors who have time to travel, shop, socialize, and look after their physical needs. In other words: there is a lot of money to be made from meeting the needs of this user group.

In Sweden, 2019, there are 4.9 million active cars in the pool and approximately 350 000 new cars are sold each year. Table 1 shows further information. The average age of the new car buyer in Sweden is 52, compared to the average age of China’s new car buyers that is 35 (Niklasson, 2020).

Table 1 - Distribution of new car purchasers in Sweden 2018 (BIL SWEDEN, 2019).

<i>Age span (y/o)</i>	<i>Percentage of private new cars market (%)</i>
18 – 35	14.4
36 – 60	49.1
60 +	36.5

It is also worth mentioning that this group, seniors, represent buyers of more expensive cars. Hence, car manufacturers become increasingly interested in the specificity of the senior purchaser (Zablocki & Sydor, 2009).

An interesting observation is which ergonomic features the customer value and prioritize in the purchase of a new car. Among the 356 020 new cars purchased in Sweden 2019, 64 % (229 330) of them were purchased as company cars. When the customer chooses a new car that its employer reimburses, the significantly most purchased new car is the Volvo S60, see Figure 8. Described as:

“A challenger on the road: The new S60 sets a new standard in its class. Impressive driving characteristics, user-friendly technology, and well-balanced chassis redefine what sportiness is all about.” – (Volvo Cars, 2020).



Figure 8 - Volvo S60, 2019 (Volvo Cars, 2020).

The rest of the new car purchases in Sweden 2019, 36 % (126 690), were personal cars. When the customer chooses a car that they pay for themselves, the most purchased car is the Volkswagen Tiguan, see Figure 9. Described as:

“Tiguan means safety, entertainment, and passability.” – (Volkswagen, 2020).



Figure 9 - Volkswagen Tiguan, 2019 (Volkswagen, 2020).

The secondary choice in popularity among personal purchases is the KIA Niro, see Figure 10. Described as:

“Balance between technology and pleasure, with smart ideas to maximize comfort. A generous interior, high ceiling, and superb spaciousness. Many smart storage solutions; wholesale and fit the whole family.” – (KIA, 2020).



Figure 10 - KIA Niro, 2019 (KIA, 2020).

With the different characteristics between the most common car among company-reimbursed customers and personal-purchase customers, it is evident that the interest of the ergonomically favorable features is higher when the customer is personally financially responsible. The company-reimbursed customers have a higher interest in new cars that are perceived as aesthetically appealing and luxurious. This demonstrates that car manufactures should have an interest in the benefits of targeting the special ergonomic needs of older people, since the personal car market, including all ages, prioritizes the features of ergonomic comfort, safety, and storage. Features that earlier were directed towards the separate group of seniors have now matured to be in the interest of other segments when it comes to the purchasing of a new car.

Also, it turns out that even if car producers do not explicitly target seniors, it is fruitful and beneficial for businesses to indirectly include them in the design process by enabling them to adapt to the produced car. The Volvo XC40, see Figure 11, is a practical example of a car that expressively is targeting the younger generation, but also has the ergonomic features that attract the older generation. The Volvo XC40 is described as an authentic city SUV with smart and connected solutions that are built for the modern urban lifestyle to attract the young adults that commonly live in the inner city (Volvo Cars, 2020).



Figure 11 - Promotion image from Volvo Cars' XC40 marketing campaign (Volvo Cars, 2020).

However, in 2019, 25 % of the new XC40's customers were 60 years old or above, and it was the second most bought car among new car customers aged 70 or higher (BIL SWEDEN, 2020).

4.4 Internal Analysis (CEVT)

To explain how the mobility market affects this project, this section describes where the initiator China Euro Vehicle Technology AB, abbreviated CEVT, is present in the market, how they operate in it, and how, it is relevant to this project. CEVT is a technical research and development company founded in 2013 by the Chinese parent company Geely Automobile. CEVT was initiated to be a company that prioritizes innovation and is developing new technology for the owner's car brands *Geely*, *Volvo Cars*, *Lynk & Co*, and *Lotus*. Now, CEVT's major focus is on developing towards Lynk & Co. Lynk & Co's global strategy and product planning are described and characterized below through "*The Code*", an employee handbook released in April 2019. "*The Code*" presents the strategy of Lynk & Co for car attributes, and is described as "*a systematic collection of laws or statutes*".

Lynk & Co strives to be the world's first next-generation car brand, differentiating itself from existing traditional car brands with a focus towards mobility as a service, rather than cars as a product. They want to boost the mobility experience in a sustainable way and strives to offer their customers radical convenience and premium as standard. Lynk and Co describe their target audience as the "*Open Urbanites*", see Figure 12

"Customers as the open urbanites is the new generation, born global and the ones who set the rules. For them, personal freedom and embracing new technology gives full access to their life in the city – living it the way they want to." – (Statement from *The Code*, Lynk & Co).



Figure 12 - Persona example of Lynk & Co customers (Lynk & Co, 2019).

Lynk & Co's customer personas personify their users as *cosmopolitans* – modern global citizens embracing the big city life pulse, *connected* – digitally savvy, demand seamless and omnipresent connectivity, *collaborative* – taking part in the creation of things and have a sharing mentality and *conscious* – updated and demanding and want honest brands.

4.4.1 Lynk & Co Branding

The purpose of presenting Lynk & Co's product attribute profile in this report is to show what is important for the Lynk & Co customer, give input to the engineering requirement setting and to compare the project deliverable to Lynk & Co's competitors.



Figure 13 - Lynk & Co 01, 2017 (Lynk & Co, 2019).

The model concerning this project is Lynk & Co 01, see Figure 13. It is classed as a small SUV and is at the moment sold in China but will be launched in Europe in due course. This car, together with the rest of the Lynk & Co's range has been created through a mindset grounded in Lynk & Co's prioritization of key characteristics. They use a hierarchical approach, portrayed as a pyramid, see Figure 14.



Figure 14 - Lynk & Co prioritization pyramid (Lynk & Co, 2019).

Top of the pyramid: "What distinguishes Lynk & Co from the competition."

- An innovative experience, not a follower.
- Technology advanced in new existing areas.
- Awesome in looks and solutions.

Centre of the pyramid: *“What Lynk & Co’s cars must deliver.”*

- Electrified engines and sustainable materials.
- A great transport experience, to drive and ride.

The base of the pyramid: *“Qualifiers to succeed as a global car brand.”*

- High-quality product and experience.
- Smart solutions and easy usage.
- Leading in safety standards in the competitive set.

To describe where Lynk & Co want to position themselves on the car brand market, their competitive set and benchmark in car attributes are hereby presented. Table 2 is Lynk & Co’s aspiration benchmark, including industry leaders that Lynk & Co want to compare and compete with, sectioned by car attribute:

Table 2 - Lynk & Co’s benchmark competitors in different car attributes.

<i>Car attribute</i>	<i>Industry brand</i>
Safety	Volvo Cars, Volkswagen
Digital	Tesla, Google, Apple, Amazon
Quality	Audi, Volkswagen
Comfort & Convenience	Volkswagen
Dynamics	Volkswagen
Sustainability	Volvo Cars
Perceived Quality	Audi
Noise, Vibration & Harshness	Audi

Furthermore, *“The Code”* emphasizes on Lynk & Co’s objectives with these different car attributes and what their strategy is to achieve the targeted goals within each attribute area. The attribute area that is relevant for this project is *“Comfort & Convenience”*, more specifically its sub-attributes *“Daily Life Usage”* and *“Ergonomic Accommodation”*. The following is stated about these attribute areas in *“The Code”*:

Car attribute: *Daily life usage.*

“Lynk & Co should be competitive within daily life usage. Strategy, Lynk & Co will:

- *Support Lynk & Co customer needs. There are places to store items in the vehicle, big and small. Performing daily routines is a seamless experience. The user tasks are smooth and hassle-free.*
- *Offer a connected and shared vehicle with a competitive user experience. There shall be functionality and features to support the needs of all users in the vehicle. We will strive for a hassle-free, joyous and smooth usage, offering the users a feeling of support in their active and hectic life.*
- *Offer smart solutions for the storage of personal items for all occupants.*
- *Design our cars emphasizing the convenience of loading and unloading luggage and other cargo. Forces and handling are of great importance.”*

Car attribute: *Ergonomic accommodation.*

“Lynk & Co should be competitive within ergonomic accommodation. Strategy, Lynk & Co will:

- *Offer all customers from different parts of the world good physical user experience.*
- *Offer good space and comfortable seating postures for all our occupants. The perceived roominess is of great importance to enhance the feeling of space.*
- *Design all physical controls in the vehicle to enhance the digital user experience. The controls shall be easy to find and logical to use for all occupants.”*

4.5 Competitive Analysis & Benchmarking

To ensure that a company has their desired position in the market, it is important to compare against competitors. Companies usually define a targeted position where they see a market opportunity or a chance to contend regards to possible market share. When doing this, defined competitors, and a created competitive set, can be used to align the entire product development project towards the same goal and ambition. A competitive set is a collection of competitors who achieve the desired level of quality, design, pricing, or any other attributes of which one wants to compare against (Freytag & Hollensen, 2001).



Figure 15 - Extraction of benchmarking, showcasing from top left the Audi Q3, 2020 (Audi, 2020) , Volvo XC40, 2020 (Volvo Cars, 2020), VW Tiguan, 2020 (Volkswagen, 2020) , Jaguar E-Pace, 2020 (Jaguar, 2020), BMW X3, 2020 (BMW, 2020).

Based on the competitors set stated by CEVT, benchmarking is conducted including two larger activities. A competitive benchmarking is conducted to identify different solutions and designs within the competitive set. To include more data, the competitor set is extended with cars of the same price point, classification, and cars who has a unique solution or feature. A small extraction of the benchmark can be seen in Figure 15. The benchmarking also considered premium and luxury cars to include solutions and ideas from the absolute top tier car manufacturers, see Figure 16.



Figure 16 - An example of a luxury SUV with a unique trunk solution (Rolls-Royce Cullinan, 2020).

To gain a better understanding of the market, products, and problems that exist, a field study is carried out. Through visits and short interviews with different local car retailers, a good understanding and inspiration from companies' solutions and designs were obtained. Data, such as measurements, pictures, notes, was collected and implemented into the benchmark, and an excerpt of the gathered lift-in-height can be seen in Table 3.

Table 3 - Extraction from benchmark regarding lift-in-height.

Car Brand	Model	Price Range (SEK)		Lift-in Height (mm)
Volvo	XC60	430 000	570 000	616
Merceders	G-Class, 3rd Facelift	800 000	1 500 000	646
Volkswagen	Tiguan	230 000	470 000	678
Range Rover	Evoque	400 000	700 000	691
Audi	Q2	260 000	410 000	740
Jaguar	F-Pace	350 000	750 000	747
Audi	Q3	360 000	550 000	748
Jaguar	E-Pace	300 000	500 000	748
Lynk & CO	01	-	-	750
Volvo	XC40	290 000	420 000	755
Audi	Q5	460 000	650 000	759
Merceders	G-Class, 2nd Gen.	1 800 000	5 000 000	766
BMW	X5	710 000	1 700 000	780
Volvo	XC90	650 000	850 000	782
Audi	Q7	650 000	1 200 000	788
Audi	Q8	710 000	1 320 000	820

5 EMPIRICAL STUDY

This project was performed by using “*user-sensitive-design*”, which is an approach that designs for marginalized groups of people. Rather than suggesting that designers rely on standards and guidelines, it is suggested that designers need to develop real empathy with their user group people (Newell et al., 2010). In this project, this design mindset was realized by visiting seniors in their homes and by following them during their everyday life to increase the degree of empathy.

5.1 Method of Empirical Study

The empirical study was performed with three user study activities; observations, interviews, and diaries. The three different phases’ embodiment is presented and described below.

5.1.1 Observations

A thorough observation (HaptiMap, 2009) was carried out for several reasons, firstly to categorize and locate the problems the seniors face when interacting and using a car. This only included the physical activities within car usage, such as ingress/egress, seating position, infotainment system interaction, etc. The observation also included inspection of different areas where the participant experienced difficulty or had an alternative solution than the norm. The data was collected in several different ways, mainly in written notes as the observation progressed. If further clarification or documentation was needed, some actions were also recorded or photographed, see Figure 17 for an observation example.



Figure 17 - Observation object X1 loading the Lynk & Co 01.

The observation was performed through visiting the persons who were to be observed while using their cars, of which they were familiar, in hope that this would generate the most realistic everyday life scenarios. (Some scenarios were defined prior to the observation, see Appendix M for further explanation). To further achieve the “everyday-usage” atmosphere, the initial part of the observation was performed without mentioning the specific angle of the study. During this part of the observation, the observers were mostly silent and instructed the participants in what actions that were to be performed, for example: “*Step into the car and drive to location Z.*” During which the observers took notes of the usage and interaction with the car, such as seating position, handling of controls, driver aids, etc. Notes were also taken where the observed perceived problems or difficulties. To make use of the participants' knowledge and perception, the observation progressed to a dialog-based observation where the observers asked questions during similar actions as previously. The acknowledged user study guidelines presented by HaptiMap was used as a foundation and as an inspiration for the method used in the user study (HaptiMap, 2009).

5.1.2 Interviews

To verify and gain more knowledge, further investigation by a semi-structured interview (HaptiMap, 2009) was performed after the observations. At this point the participants were informed about the exact angle of the study to promote a better discussion and thought-process between the observer and the participant. The interview was conducted while interacting with the car and afterward in a different location. The objective was that actions and contrasting settings can induce reflection of various areas within interacting with a car, hence retrieving more data. The interviews and observation took in general three hours per person.

5.1.3 Diaries

The participants were asked to keep a diary (HaptiMap, 2009) of their use of the car and to note any difficulties or problems they might think of when using it in their everyday life. Diary studies are an appropriate method to capture the user's daily activities without any external influences and might also enable the participants to express issues in writing that they may have omitted if asked directly in speech. The diary was constructed around three focus questions: 1. what was the problem, 2. when/how did it happen and 3. how did you solve it?

5.1.4 Looping & Pivoting

Further looped observations (Lehikonen, 2017) were conducted. During the concept generation and the development of the product, there was continuous interaction and communication with potential customer segments (seniors who participated in previous observation) to create value and carry on the development process under uncertain conditions. Asking the seniors for feedback and looping their input to validate hypotheses was a beneficial way to test if the ideas were interesting and helped in the process of choosing which idea to keep developing.

By including the user group in feedback loops during the development process, the project gets an agile approach, which shortens the lead times for observations and interviews. An additional round of careful observations would demand more time and force the project's prioritization towards being a user study, more than being a product development project.

5.2 Presentation of Observation Objects

The initial observation included four people. To match the empirical study with the market focus and problem scope, the observation focused on Swedish car users at the age of 75-80. The project team members also strived to find users that would match, or be similar to, the pre-defined personas, see Appendix I.

The users included in the observation had common normal disabilities, varied amongst them, that was caused by aging which affected their daily car experiences. The persons observed in the empirical study were chosen through “snowball” sampling, which means that an existing observation object recruits future objects among their acquaintances (Baltar & Brunet, 2012). This sampling technique was considered appropriate for the study’s purpose since the desired user population was difficult for the project team members to access. It was not the magnitude of disability of the observed person that was the deciding factor if she/he should be included in the study, but it was rather the spread of disabilities in various functional areas amongst the observed that was prioritized. Hence, a wider range of the disability spectrum was explored to give the empirical study a broad operating range and increased academic credibility.

The observed persons were chosen since they exemplify the extreme user of cars, as described in the scope of the project, because of their characteristic disabilities that affect their car usage. The observed persons were anonymous to prevent exposure of personal traits and to avoid opinions and eventual sensitive information being tracked back and associated with the observed person in question. Table 4 presents the observation object’s characteristics, where the heading “*Mobility*” is the ability to move rate according to SCB’s indicators of definition (Statistiska Centralbyrån, 2019), and the heading “*Car Model*” is the car used during the observation of the specific object.

Table 4 - Presentation of observation objects.

ID	Sex	Age	Height (cm)	Weight (kg)	BMI	Mobility	Car Model	Disability
X1	Male	78	166	68	24.7	No impaired mobility	Toyota Aygo 1.0, 2013	<ul style="list-style-type: none"> No major disability. Previously had Sciatica.
Y1	Female	76	163	75	28.2	Impaired mobility	Mazda Demio 1.5, 2000	<ul style="list-style-type: none"> 2 knee-prosthesis, uses cane. Whiplash damage causing stiffness/pain in upper body.
Y2	Female	78	162	81	30.9	To a high degree impaired mobility	Skoda Octavia 1.6, 2000	<ul style="list-style-type: none"> Arthritis in right knee, uses cane. Shingles, severe impaired mobility in right arm and bad grip strength. Stiff in back and left leg. Problems with the macula of retina.
Y3	Female	76	156	59	24.2	Impaired mobility	Lynk & Co 01, 2008	<ul style="list-style-type: none"> Previous stroke. Right side of body and right leg temporarily paralyzed - Side effect: Permanent weakness of muscles in the affected area

5.3 Result & Analysis of Observation

The empirical study identified problems in the following applications:

- Driving.
- Ingress/Egress.
- Seat/Seating Position.
- Luggage Space.
- Car Door.
- Infotainment System.
- Seatbelt.
- Steering Wheel.

The results that are presented below are compiled from observations, interviews, and diaries. The various points are composed in a way to easier interpret the compilation of results. For a more detailed and thorough analysis and presentation of observation results, see the observation protocols in Appendix I–L.

Problem area: *Luggage Space.*

- Found it difficult and physically demanding to load the trunk because of the height. Often, the back row was used for the loading of luggage, instead of the trunk (Figure 18). This because it is perceived as easier and more comfortable. However, having loose objects in the cabin initiates a safety risk.



Figure 18 - Observation object Y3 intuitively using the passenger door for loading.

- The user has a discontinuous motion when loading the trunk, impaired mobility of the user prevents it from easily loading the trunk. The multiple stage loading tends to result in the baggage is being placed on the threshold of the trunk to relieve some of the strain.
- Lightweight baggage, or when the user is under time pressure, is often put in the back row. While the trunk is used when larger or more baggage is transported
- Closing of the tailgate is perceived as difficult. The control button to activate the automatic closing of the tailgate is either out of reach or demands physical effort to fully reach it (Figure 19).



Figure 19 - Observation object Y3 reaching to close the tailgate.

Problem area: *Driving*.

- Avoids spine rotation during driving, especially during the reversing activity, because it is perceived as discomforting due to stiffness and pain in the back and neck. This results in full reliance on the capability of the car mirrors. Assistance in detecting obstacles when reversing was asked for, “*I would have like to get some warning if I get too close to something when I’m reversing*” – (Observation object Y1).
- The driving position tends to be more comfortable than ergonomic and optimal for driving. This leads to:
 - Strenuous leaning movements of the body backward and forward in the seat due to that the A and B-pillar are obscuring the field of vision when driving.
 - Hands tend to glide downwards on the steering wheel for more comfortable driving. Due to some strain in shoulders, arms keep relocating to a lower position on the steering wheel.

Problem area: *Ingress/Egress.*

- Due to a broad threshold, a long ingress step is needed which results in perceived discomfort and risk of staining trousers. A long step also led to a higher reliance on different support points to keep balance and ensure a controlled ingress.
- In some cases when seated after an ingress movement, due to a high threshold, the user must use their hands to pull up their leg into the cabin. This is perceived as an uncomfortable action and requires arm strength. Furthermore, the action commonly results in stains on the user's pants (Figure 20).



Figure 20 - Observation object Y2 using arm to support leg during ingress.

- During egress, especially if the car has a lower seat, the user is forced to pull themselves out of the car using features of the car as support points. This requires strength and balance and is often applied in an inconvenient body position.
- During ingress/egress, the door frame is forcing the user to position the neck in an awkward position. If the user has an impaired neck motion, the user compensates by finding an alternative ingress method that was more strenuous for the back.
- Having too little space to easily move in and out of the car, the user constantly needs to manually change the position of the seat, back and forth, to allow free movement of the legs during ingress/egress.
- When settling down in the seat, different support points are used to assure a slow and controlled descent. The support point is usually not designed to act as such but normal features of the car, for example the steering wheel, door frame, headrest of the seat.
- The steering wheel is preventing the free movement of the legs. This results in the users bending their knees in an awkward position and a need to tilt the spine sideways to move the legs.

- Since some users found the egress action straining, some actions were made to ease the action. A small “jump” forwards on the seating position to shift their weight to ensure balance and an easier egress position. The jump can be followed by a rotation out towards the door to further ease the egress by ensuring that there are no obstacles present when the egress action takes place.

Problem area: *Seat/Seating Position*.

- Perceived discomfort when adjusting the settings of the seat. The adjustment controls were poorly positioned and, in some cases, poorly designed. This puts the user in an inconvenient position while operating the controls, making it physically demanding for the muscles and joints.
- While seated in the passenger seats, it is important to be able to have a good visual of the road and the environment without having to sit in an uncomfortable position. Often, the neck support of the front row is hiding parts of the view.
- Not fully up to date with modern guidelines of car usage, for instance poor awareness of the correct seating position and the correct use of the supportive features in the car. This applies to both the increase of safety and the achievement of optimal driving.

Problem area: *Car door*.

- The opening of car doors can be somewhat difficult because of the weight of the doors and the opening mechanism. Due to weak arms, these can be hard to control and adjust as intended. It can also be difficult to reach a fully open door when seated in the car.
- The car door opening can be difficult to enter, both because of the door disallowing a free path for the user, and the design of the door opening.
- To open the door a pressure must be applied from the shoulder/elbow which in some cases is perceived as awkward.

Problem area: *Infotainment System*.

- Difficulties in reading and understanding the infotainment system, colors, and contrasts.
- Appreciates unity, standardization, and similarities between car brands to achieve as few misinterpretations as possible. This applies to all cognitive interaction with cars.

Problem area: *Seatbelt*.

- Difficulties reaching the seat belt, both with right and left arm, front and back row.
- Perceived discomfort when wearing the seat belt. Some users alter the design of the seatbelt to better suit themselves, even though they knew that their alteration would impair the safety aspect of the seat belt.

Problem area: *Steering Wheel*.

- Adjustment of the steering wheel is inconvenient since the steering wheel may be heavy and difficult to manage with reduced muscle strength.

5.4 Screening of Problem Area

It can be concluded by the presented problem areas in the section 5.3 that there is an abundance of car attributes that are concerned in the senior's problematic car experience. However, for product development to be fully possible within the project's configured framework, a scope screening to focus on only one problem area was necessary for the project to result in a tangent result.

Before finalizing the empirical study, and before the initiation of the subsequent project phase, which is the concept generation, a screening process was conducted in collaboration with the branch operative ergonomics team at CEVT. The identified problem areas were presented and discussed to work out where the project focus and resources should be placed to generate the most possible value, relative to the project's prerequisites and circumstances. For instance, the problem area "ingress/egress" was too extensive of an issue to be considered in the development project timeframe. The problematic ingress/egress matter is an issue that ergonomic experts within the industry have been trying to solve for decades without achieving optimal results. However, CEVT recognized one problem area that they have witnessed before, which they thought would be interesting to examine with a new perspective to find alternative solutions. Furthermore, it was estimated by the project team members that an action of improvement within the chosen problem area seemed to have the potential to make a relatively large beneficial impact. Together with the input from CEVT, the screening of the project scope concluded the project to be developing a product concerning *Loading and Unloading of the Luggage Space*.

5.5 User Needs List

The empirical study was concluded with the establishment of a list of needs regarding the activity of loading and unloading the luggage space for seniors. The "user needs list" became the foundation and the cornerstone in the concept generation phase.

The user needs derive from several "user stories" that were established in the user study and the story's purpose is to tell the problem context and where the need emerged from. The user needs were defined according to the INVEST-criteria (the characteristics of the user need should be *Independent, Negotiable, Valuable, Estimable, Small and Testable*), a tool commonly used by designers in agile software development to achieve a user insight of high quality (Wake, 2003). The user needs are presented in the list below (Table 5), and are categorized into "*Physical Needs*" and "*Behavioral Needs*".

Table 5 - User needs list.

USER NEEDS LIST		
<i>User Story</i>	<i>User Need</i>	No.
Physical Needs		
During loading and unloading of the luggage space: <i>"I find it strenuous when I have to lean into the car trunk to place or take out my luggage."</i>	Access to the luggage in the trunk without putting the user's body into an awkward position.	1.1
During loading and unloading of the luggage space: <i>"It's annoying that I sometimes get dirt on my clothes while loading and unloading my luggage in the trunk."</i>	Access to the luggage in the luggage space without getting the user dirty.	1.2

<p>During loading and unloading of the luggage space: <i>"To get my luggage in/out the trunk I must do it in two separate motions, one to get the luggage up onto the threshold, and one to lift the luggage from the threshold in/out of the car."</i></p>	A continuous body motion while loading and unloading the luggage space.	1.3
<p>During opening/closing of the tailgate: <i>"I always get my hands dirty when I open/close my tailgate."</i></p>	To be able to open/close the tailgate without getting dirty.	1.4
<p>During loading and unloading of the luggage space: <i>"The lift-in height of the luggage space is too high for me, it's physically demanding."</i></p>	A lift-in height (Appendix B) that facilitates the loading and unloading of the luggage space and prevents putting the user in any strain.	1.5
<p>During opening/closing of the tailgate: <i>"It's straining to use the tailgate since I have to reach/push above my head."</i></p>	To be fully able to operate the tailgate without any greater need for physical effort or perceived discomfort.	1.6
<p>During operation of the tailgate: <i>"I think the opening/closing of the tailgate is uncomfortable and inconvenient."</i></p>		
<p>During operation of the tailgate: <i>"I cannot reach the control for closing the tailgate."</i></p>		
<p>During the loading of luggage: <i>"When I load or unload it is difficult sometimes to see where I put down my wares."</i></p>	To be guided by visual means.	1.7
<p>During the opening of the tailgate: <i>"How does this work, is this a button or... Did I do it incorrectly?"</i></p>	To be assisted by visual and haptic feedback.	1.8
Behavioral Needs		
<p>Behavior: <i>"I want to be comfortable, I neglect other factors, for instance safety."</i></p>	The activity must be comfortable and user-friendly.	2.1
<p>Loading behavior, heavy luggage: <i>"I usually pack heavy luggage in the passenger seats, because it is easier than using the luggage space."</i></p>	An easy way of loading heavy luggage in the car.	2.2
<p>Loading behavior, light luggage: <i>"I usually pack light luggage in the passenger seats, because it is quick and convenient, and I do not need to bother with the procedure of using the trunk."</i></p>	An effortless usage of the luggage space without experiencing an extensive process.	2.3
<p>Loading behavior, large luggage: <i>"I only use the trunk for large luggage."</i></p>	An easy and nonstrenuous loading and unloading of large luggage in the luggage space.	2.4
<p>Loading behavior, small luggage: <i>"It so easy to just put small luggage in the passenger seat, and it feels unnecessary to use the large volume of the trunk."</i></p>	The required effort of loading and unloading the luggage space, should not be perceived as overwhelming for the considered luggage.	2.5
<p>Loading behavior, under time pressure: <i>"When I'm stressed or in a rush, I usually just toss the luggage onto the passenger seat."</i></p>	A fast access into the luggage space.	2.6

In conclusion, the user study confirmed that the seniors perceive the loading and unloading of the luggage space so strenuous that they rather use the passenger seats as storage space for luggage. This issue needed to be addressed and treated. With this, the empirical study gave the product development project a clear and achievable goal to strive for. The object of this project became to make the usage of the luggage space so attractive, comfortable and easy to use, that the senior car user indeed chooses to use the luggage space for its intended purpose.

6 FUNCTIONAL DESCRIPTION

The way forwards to develop a new product was far from straight and required an explorative mindset, along with appropriate structure, methods, and tools. The product development process needs effective, efficient, and scientifically evidenced, design methods and tools. The systematic design procedure of going from the theory, market, and empirical study to a finished product can be sectioned into three phases: *functional description* (Figure 21), *concept generation* (Figure 22), and *concept evaluation* (Figure 28) (Almefelt, 2018).

6.1 Specification of Requirements

With the design theory perspective, the initial step (Figure 21) was to analyze the problem and state system requirements, with the deliverable output: a specification of requirements.

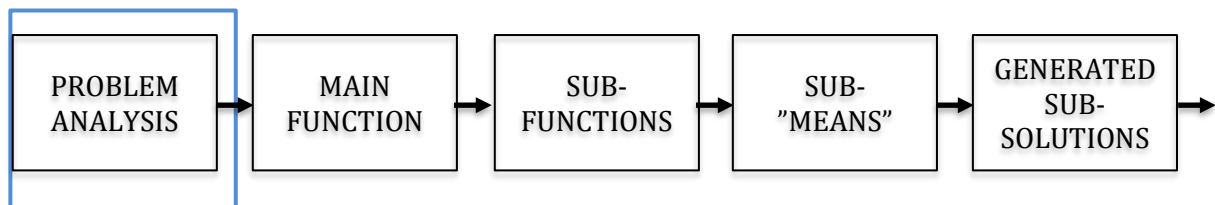


Figure 21 - Product synthesis in design theory (Almefelt, 2018). Requirement phase.

Since the user is highly prioritized in this project, the seniors' preferences are of high importance. To achieve this prioritization, the user needs list (Table 5) was used as a foundation in the generation of the specification of requirements that would set specific demands on the developed concept's characteristics. Every requirement derived from a stated user need to enable the requirement to be traced back to its origin to motivate its existence and importance.

The purpose of the specification of requirements was to give the developed concept a design framework of tangent values in several areas of characteristics. These characteristics have to be quantified in a tangent value for the concept testing and validation to be performed fairly and transparently.

In addition to the internally developed specification of requirements, the development team received another specification for the Lynk & Co 01 from CEVT. The external specification was used for inspiration, e.g. how the CEVT organization formulates their requirements. It was also used as a framework in the development of the actual requirements specification. Some of the requirements from CEVT were inherited and transferred into the internal specification, thereby considering CEVT's input in the product development process.

The layout of the requirements specification is described by the following excerpt (Table 6):

Table 6 - Extraction of the specification of requirements.

Requirements Specification								
ID	Criterion	Derived From	Unit	Target Value	Justification	Evaluation	R/D	Degree Of Fulfilment
1	Elderly User Loading/Unloading Car							
1.1	User Physical Requirement							
1.1.1	Access to luggage in luggage space	U.N. - 1.1	REBA - score	≤ 3	User	REBA	R	
1.1.2.1	Comfort loading/unloading luggage space, <10kg	U.N. - 1.1	RPE-D - scale	≤ 1	User	RPE-D	R	

Explanation of table headlines in Table 6:

“ID” – Each criteria criterion is given a number.

“Criterion” – Description of the criterion.

“Derived From” – Which source the specific criterion derives from, e.g. “U.N. – 1.1” for user need 1.1. A criterion could also derive from external sources, e.g. the safety department at CEVT.

“Unit” – Sets a tangible measurement unit for the specific requirement, for example will the fulfillment of criterion 1.1.1 be measured in a “REBA-score” from a performed REBA-assessment. REBA is an physical ergonomic assessment tool that uses a systematic process to evaluate whole body posture and risks associated with job tasks. REBA is used to evaluate required or selected body posture, forceful exertions, type of movement or action, repetition, and coupling (Ergonomics Plus Inc., 2019).

In criterion 1.1.2.1, the value is quantified by the unit “RPE-D-scale” (Table 7). The scale is a widely used and reliable indicator to monitor and guide exercise intensity. The RPE-D-scale allows individuals to subjectively rate their level of exertion during their activity. Developed by Gunnar Borg, the scale is often referred to as “the Borg scale” (Heart Online, 2014). In the requirement specification, a revised category-ratio scale of 0-10 is applied.

Table 7 - The Borg scale of perceived discomfort (Steele, Fisher, & McKinnon, 2017).

The Borg Scale	
How much discomfort do you feel?	
0	No discomfort
1	Minor discomfort
2	
3	Mild discomfort
4	
5	Moderate discomfort
6	
7	Severe discomfort
8	
9	Very severe discomfort
10	Maximal Discomfort

The rating scale is used in the specification of requirements as a proactive analysis of an intended design to avoid pain or discomfort, also as a tool during the product development process to achieve a safe and comfortable product. Other units that occur in the requirement specification are “Yes/No”, “Number of motions”, “mm”, “sec” and “N” (Newton).

“*Target Value*” – The required value that the concerned feature must achieve.

“*Justification*” – Which stakeholder that sets the specific requirement, e.g. the user, CEVT, or the development team.

“*Evaluation*” – How the developed concept’s fulfillment of the requirement will be assessed. Other evaluation methods that occur in the requirement specification are “*HTA*”, “*Prototype*”, “*CAD*”, “*Simulation*” and “*Observation*”.

“*R/D*” – Sets the level of importance to fulfill the specific requirement. *R* – Requirement. Must always be completely fulfilled as specified and is used to eliminate design solution alternatives inferior in the sense that they do not fulfill the requirement. *D* – Desire, on a scale of D1–D5, where D5 is of high importance. Shall be fulfilled as well as possible and used as a base for eliminating inferior solution alternatives among the ones fulfilling the requirements.

“*Degree of Fulfilment*” – To what degree the developed concept fulfills the specific requirement, stated in (%).

The detailed requirement specification can be observed in its proper format in Appendix A. The term “*Lift-in-height*” is used occasionally, see Appendix B for definition and specific explanation.

6.2 Function-Means-Tree

The requirements specification set design and functional criteria, which in turn generated requirements and desires. These requirements and desires can be characterized and classified into *functional* requirements and *constraints*. The deliverable output of this phase (Figure 22) is a functional description, in the shape of a *function-means-tree* (Almefelt, 2018).

Functional requirement: Requires a design solution to be fulfilled and used as input to the design synthesis process.

Constraint: Limits the design solution space and used to rule out designed solutions alternatives outside the allowed solution space.

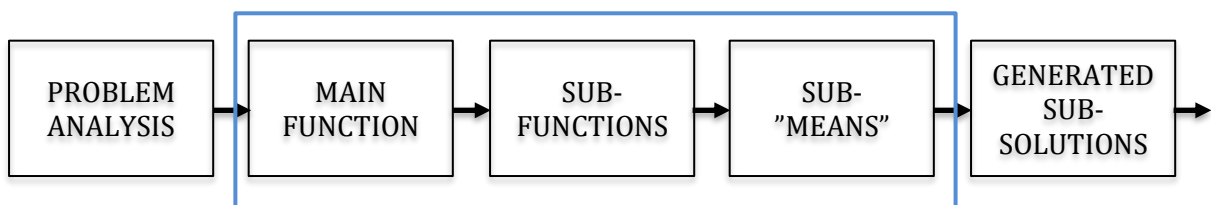


Figure 22 - Product synthesis in design theory (Almefelt, 2018). Function-Means phase.

“*Function*”: In design methodology, a *function* expresses what a system does, or should do, without stating the solution. A function is formulated: *Verb + Noun*, e.g. “*Decrease lift-in-height*”. A *transforming function* in a system is the ability of the system to create those effects that *transform* an operand (material, energy, signal, information) from one input state to another output state.

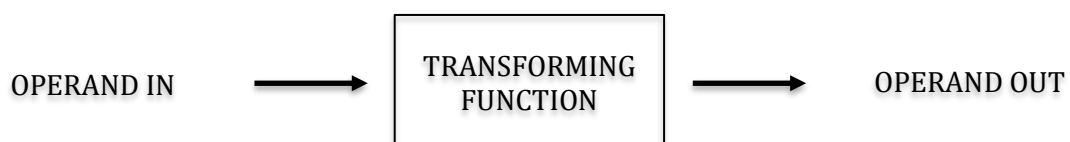


Figure 23 - A black box diagram of a functional transformation (Almefelt, 2018).

Functions in a product, or any of its parts, are the abilities of the individual parts, or of interacting parts, to create effects that result in the behavior of the product or the environment’s perception of it. There are also non-transforming functions, termed *purpose functions*, e.g. “Store luggage” (supporting function), or “Allow free motion” (ergonomic function).

There are several different strategies in the industry to model a system’s included functions. In this project, a function modeling independent of design solutions was used in the shape of a hierarchic function-means-tree.

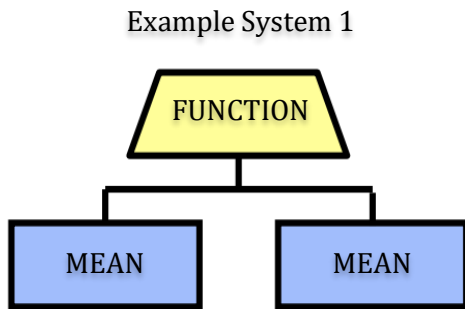


Figure 25 - Two alternative means to implement one function (Almefelt, 2018).

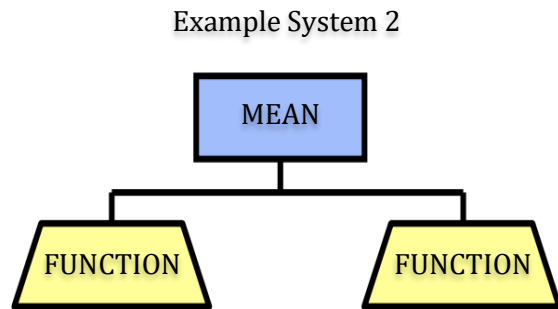


Figure 24 - Two necessary functions due to one chosen mean (Almefelt, 2018).

The primary functions of a machine system are supported by a hierarchy of sub-ordinate functions, which are determined by the chosen means. The function-means-tree was used as a tool to achieve a breakdown structure of the extensive system of the loading and unloading activity. The main activity “Facilitate Vehicle Packaging for Seniors” (Figure 26) was modularized into the included sub-tasks (“Allow Access to Luggage Space”, “Load Luggage”, “Unload Luggage”, “Close Luggage Space”, “Store Luggage”) to facilitate the subsequent phase of idea generation, by enabling the designers to find sub-solutions to each sub-task.

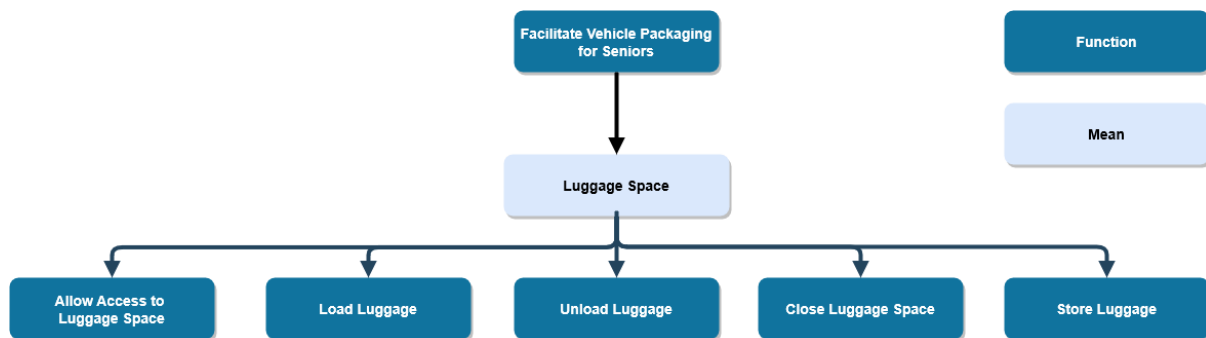


Figure 26 - Function-means-tree top-level.

To display the function-means-tree’s characteristics, an explanatory excerpt of the function-means-tree is presented in Figure 27. Figure 27 is a sectioned hierarchal breakdown of the subtask “Allow Access to Luggage Space”, the other four subtasks are presented in their full format in Appendix C – F.

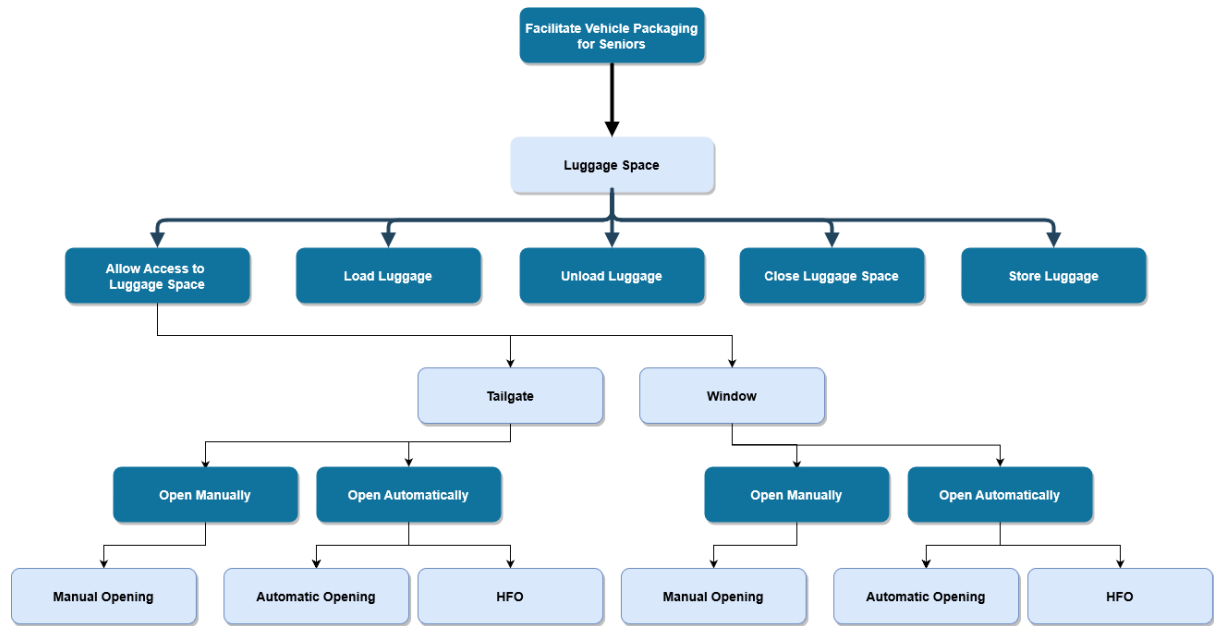


Figure 27 - The hierarchal function-means structure of the subtask "Allow Access to Luggage Space".

7 CONCEPT GENERATION

The purpose of the subsequent *Concept Generation* phase (Figure 28) is to process the functional input from the *Functional Description* and the deliverable output is competitive concepts for screening and further development. The phase consists of two sections, *Idea Generation* and *Concept Creation* (Almefelt, 2018).

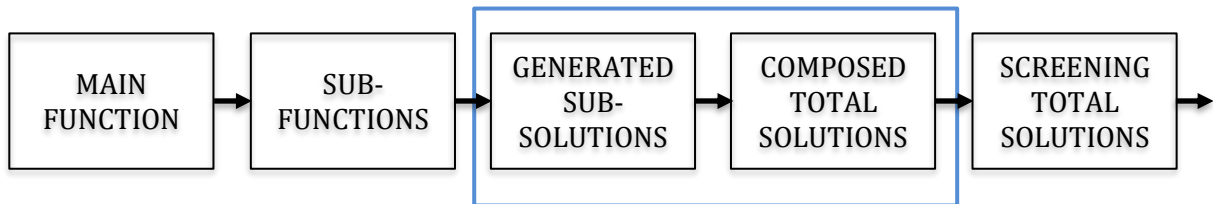


Figure 28 - Product synthesis in design theory (Almefelt, 2018). Concept Generation phase.

7.1 Idea Generation

The idea generation activity was performed with a “creative” mindset, processing the sub-functions to generate sub-solutions (Almefelt, 2018). The idea generation phase was carried out over the time of one workweek and consisted of recurring internal brainstorming workshops with the project team members. The “solution-workshops” processed internal knowledge within the project team, input from external area experts, inspiration from existing solutions of market competitors, as well as the feedback generated by the looping with stakeholders and the senior lead users. Even though the idea generation was relatively creative and informal, some systematic and rational methods were applied, e.g. utilization of other idea sources such as literature, patents, analogies with biological systems (“biomimicry”) and analogies with technical systems in other domains.

The project team members strived to derive as many sub-solutions as possible to each sub-function to account for all possibly successful solutions and not limit the following concept creation phase. An assemblage of generated sub-solutions to some of the sub-functions presented in the function-means-tree is featured in Figure 29.

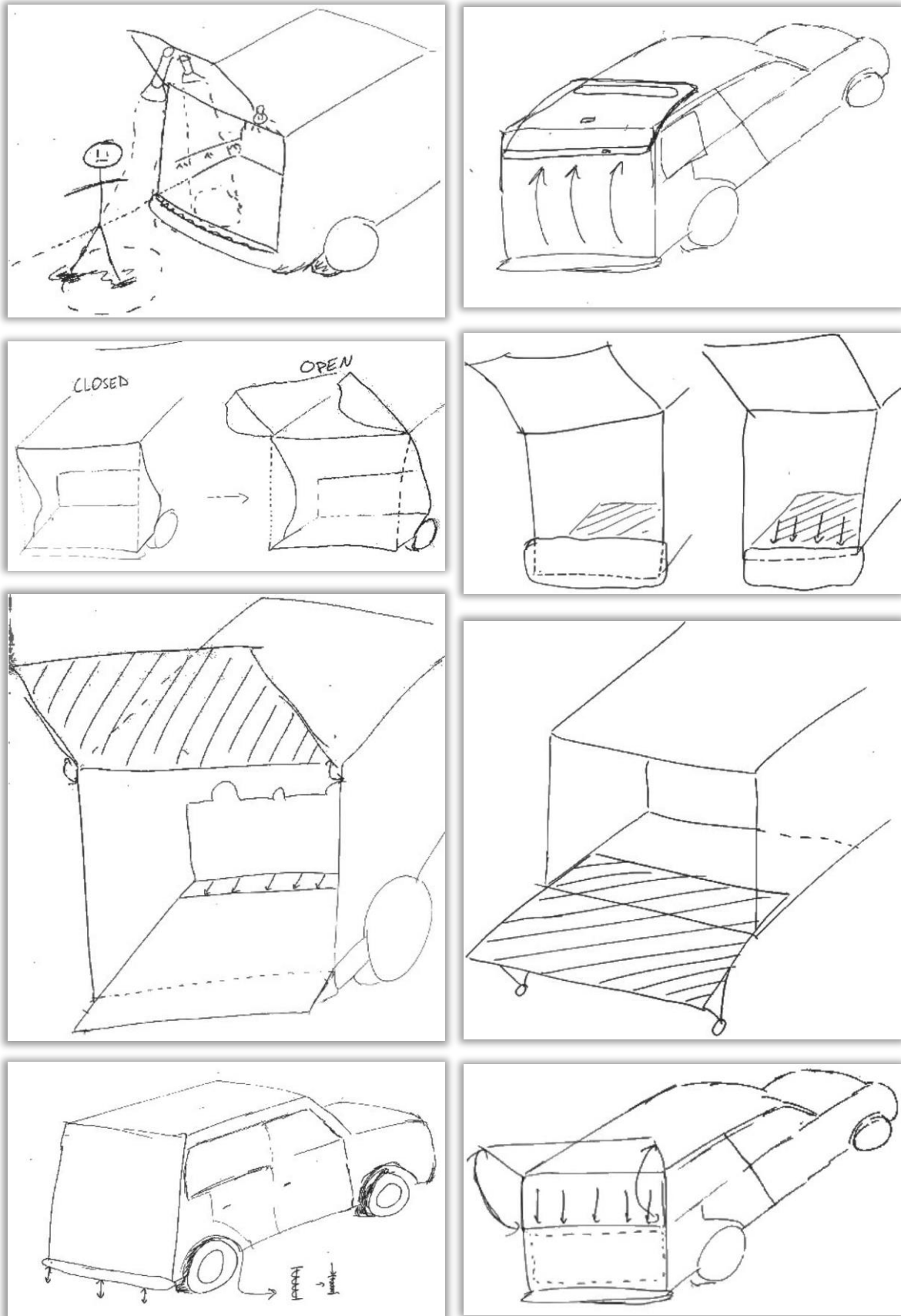


Figure 29 - An excerpt from the sketches generated by the workshops in the idea generation activity.

7.2 Concept Creation

To create concepts, a pre-screening was carried out where the superior solution for each sub-function was chosen. The superior for each sub-function was the one that was most feasible, had the most potential for customer satisfaction and had the potential of generating largest positive impact. The pre-screening was due to the large amount of generated sub-solutions, and the clear superiority of certain sub-solutions. To consider all the possible solutions in the concept generation would not be beneficial relative to the demanded implementation time.

The project team combined these different superior sub-solutions, fulfilling various sub-functions, into several compositions of total concept solutions (Almefelt, 2018). Instead of generating all possible concept combinations, and obtain the maximum number of concepts, the project team chose to further streamline the development process by only creating concepts that were estimated to be feasible, innovative, and had the potential of adding maximum value. The concept creation activity resulted in seven unique concepts, that were named after their most characteristic feature:

- Concept A – *"Automatic"* – A concept that focuses on automatic features and smart solutions. High complexity.
- Concept B – *"Bare minimum"* – A concept that implies minor yet significant improvements of the current Lynk & Co 01 model. High feasibility rate.
- Concept C – *"The manual"* – A concept that goes the opposite direction of the digitalization, emphasizing traditional and somewhat outdated yet simple solutions. The characteristics of the concept can be regarded as an opposite to *"Automatic"*.
- Concept D – *"Mechanical"* – A concept that contains a characterizing mechanical solution of the tailgate construction. A system structure that consists of many moving parts and prime engineering.
- Concept E – *"Big tailgate"* – A concept that is characterized according to its major solution of an extensive tailgate including the majority of the rear of the car.
- Concept F – *"Kitchen cabinet"* – A concept that is characterized by its solution feature of a tailgate that is operated similar to a kitchen cabinet.
- Concept G – *"Low as possible"* – A concept that focuses on optimizing the lift-in-height and all its included solution parts are designed towards the designated objective, even if it is an efficient use of sub-solution potential or not.

8 CONCEPT SCREENING

The seven generated concepts from the concept generation phase were processed in a concept evaluation (Figure 30) to deliver a final chosen concept.

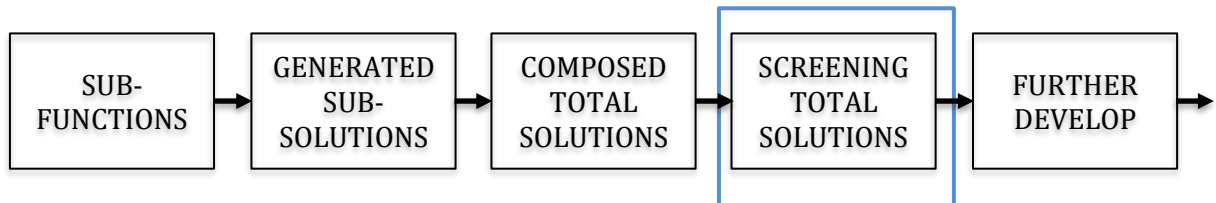


Figure 30 - Product synthesis in design theory (Almefelt, 2018). Concept Evaluation phase

The screening phase (Figure 31) was performed using two engineering-recognized decision-matrix methods: *Kesselring matrix* and *House of Quality*. The benefits of using these decision-matrices are that the decision process is documented, and different perspectives are effectively integrated. The decisions will be based on requirements and needs stated in the requirements specification (Appendix A) and the user needs list (Table 5). Further benefits are that the matrices give a good overview of a great amount of information, also complex and unknown decision situations are supported.

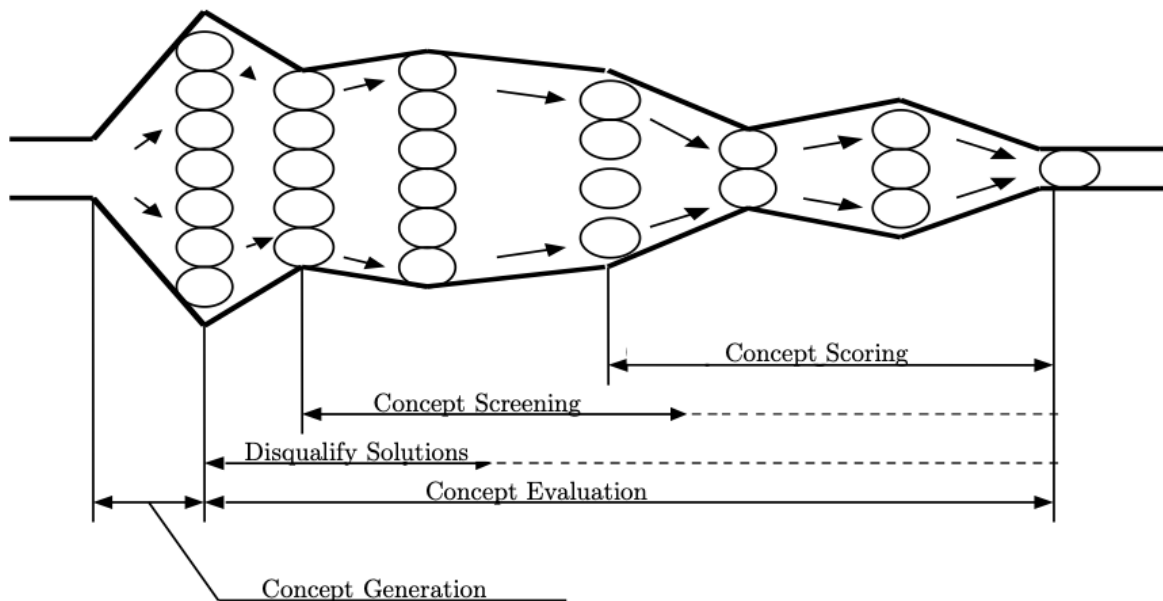


Figure 31 - The product development funnel (Almefelt, 2018).

Disclaimer: The value of a design solution depends on many different properties, and different properties have different relative importance. Different stakeholders value properties differently, and some properties can be measured quantitatively while others must be judged qualitatively. Furthermore, there is always information missing about the design solution alternatives when decisions must be made.

8.1 Concept Screening – Kesselring Matrix

The major screening activity was carried out with the usage of a Kesselring matrix, an evaluation matrix of scoring nature (Almefelt, 2018). The process of the Kesselring matrix started with determining weight factors. Since the objective of the project was to be user-centered, the needs of the user need list were imported as rating tools. The next step was to determine the grading scales for criteria fulfillment, named “*Wt.*” for *weight* in Table 8. The weight scale of every criterion was estimated by the input from the empirical study, based on their importance stated by the user, their observed impact on the user’s experienced car satisfaction, and their relevance to the user’s perceived comfort.

Table 8 - An extract of the Kesselring matrix.

No.	Evaluation Criteria	Wt.	Remarks	IDEAL		Existing Solution		Automatic		Bare Minimum	
				Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted
1.1	Access to the luggage in the trunk without putting the user's body into an awkward position.	5	Give minus score if back is in bad position	5	25	2	10	5	25	3	15
1.2	Access to the luggage in the luggage space without getting the user dirty.	4	All our users mention it as a problem. Extreme users have spoken	5	20	2	8	5	20	3	12
2.6	Fast access into the luggage space.	4	If the tailgate manages to open quickly this is irrelevant	5	20	1	4	4	16	1	4
SCORE		55			275		123		239		177

The evaluation of the generated concepts was carried out, (also an “*Ideal*” concept and the “*The Existing Solution*” of CEVT was taken into consideration), and the concept scores were calculated based upon their criteria fulfillment to be concluded with a final comparable merit score. The computed Kesselring matrix can be observed in its entirety in Appendix G.

Based upon the assigned final score, inferior concepts were rejected, and remaining alternative concepts were chosen to be further developed (concepts A, D, and F). The matrix was also used to locate which specific features among the concepts that were significantly valuable and beneficial in the fulfillment of the user need. These features could singly be secluded from their present concept, and integrated into any of the favored concepts.

8.2 Concept Screening – House of Quality

Continued concept screening was carried out with House of Quality (Tapke et al., 2001), a QFD-tool, Quality Function Deployment, where data regarding customer requirements gathered from market research and market analysis is translated into engineering targets. It is with regard to these engineering targets the product will be evaluated, and strive to achieved. The goal of the House of Quality is to identify which technical features that are critical for the product, and to identify the strengths and weaknesses of the design (Tapke et al., 2001).

The House of Quality is built upon six components (Tapke et al., 2001);

- Customer requirements: To capture the voice of the customer, the customer needs are clarified and specified in a manageable format.
- Functional requirements: To satisfy the stated customer requirements, a product may have several functions as a way of achieving these requirements. These functions shall be identified and stated.

- Planning matrix: To compare different solutions/products in the aspect of the different customer requirements, rated from 1-5 where 5 is high fulfillment.
- Interrelationship matrix: To establish relations between user requirements and functional requirements. They are defined as, strong, moderate, or weak relations.
- Technical correlation matrix: To highlight functional requirements that might affect each other, in agreement or conflict. A “+” sign represents a positive impact between two functional requirements, a “-” represents a design conflicting and an “o” represents a non-correlation.
- Technical importance rating: To prioritize which technical areas the developers should focus on working with to maximize value for the user.
- Competitive Assessment: To compare different solutions or products regarding the gathered data and discover/determine design targets for their product.

From the House of Quality can several results can be extracted, these are presented in section 8.2.1, 8.2.2 and 8.2.3, see the full House of Quality in Appendix H – House of Quality.

8.2.1 House of Quality - Technical relations

Technical relations help the designer to better understand their product by defining positive, negative, or non-relations between functions. It is important to resolve the negative relations where possible, to not dissatisfy the customer in any aspect of the final product. The functions had the following relations:

Lift in Height was positively connected with functions regarding accessibility, which is to be expected since modern car design has some problem with loading/unloading and the reachability within their luggage space due to the high backline of the design and a rather large tailgate. It was also connected positively with regards to a safety risk since a less strenuous use will result in fewer injuries/hurts on the user. Lift in height was however negatively connected to quick access to luggage space since these solutions tend to compromise the height for convenience. Furthermore, was the connection with sporty design regarded as negative as well since this function strives towards a higher line backward of the car resulting in a higher bumper.

Contact with Dirt had positive connections with functions that might alter the car's height and ensure better accessibility since the user would not need to lean/support themselves over or against any part of the car. Further positive connections are with the functions of which would include the user being in contact with the car, such as Quick-access to Luggage Space or Smart Door-handle for Tailgate. Perceived quality was also connected positively.

Personalize/Customize Luggage Space had positive connections to functions that would ensure better accessibility within the luggage space since users who have the opportunity to set up the car for their specific needs can optimize their accessibility if desired.

Visual Assistive Guidance had positive connections to many different functions since it covers a wide range of solutions. Trough guidance by light, both Smart Door-handle for Tailgate and Accessibility in Luggage Space will benefit since it will guide the user in performing their task. Highly Automatic Opening, Safety Risk, and Intuitive Usage benefits through the feedback a user can receive from visual assistance. Furthermore, by lightning and visuals, a desirable environment can be created to enrich the user experience resulting in both Perceived Quality and Inviting / Welcoming / Pleasant Tailgate Movement is beneficial.

Highly Automatic Opening is beneficial to all functions concerning the opening/closing of the tailgate since it enhances the user experience in this aspect. It also allows additional safety features which also resonates with decreasing Safety Risk. However, adding additional complicated systems might increase the chance of failure which in turn contradicts the function of Safety Risk which is the reasoning behind it being rated as a negative relation.

Smart Door-handle for Tailgate has positive connections with functions that contain physical interaction with the tailgate, such as Awkward / Inconvenient Opening of the Tailgate and Quick-access to Luggage Space since both would benefit from an improved design regarding opening/closing controls. Likewise, might a new design of controls result in a sportier design and give the product a higher perceived quality.

Quick Access to Luggage Space generated positive relations with functions regarding accessibility and the user posture when interacting with the tailgate or loading/unloading. However, since the tailgate probably will be more restricted in a design aspect and the complexity will increase, these relations are considered negative.

Roominess During Loading/Unloading has positive connections together with functions regarding accessibility and the user positioning during interaction with the luggage space. Since the design might be more restricted due to more design requirements, it was considered a negative relation.

Accessibility During Loading/Unloading has positive connections with Accessibility in Luggage Space, an improvement in one area would most likely also benefit the other since they influence the same goal. It also has a positive connection with a safety risk, since better accessibility will result in a decreased probability that the users put themselves into an unfavorable position. Further positives related to Accessibility During Loading/Unloading has been mentioned previously. A negative aspect that occurs is regarding Sporty Design where the requirements might contradict each other.

Sporty Design has the most amount of negative connections since the ergonomic design aspects are not always aligned with the attractive and story design that is desired. A negative aspect that occurs is regarding Accessibility in Luggage Space where the requirements might contradict each other. The other negatives have been mentioned previously in this chapter. However, a positive connection is Perceived Quality which might benefit from a sporty design

Accessibility in Luggage Space has a positive connection with Safety Risk because a decreased risk that the user will put themselves in an awkward position while depositing/extracting their luggage

Intuitive Usage has a positive connection with Perceived Quality since an overall thought-tough product will give a qualitative impression. Further, it is positively connected to Safety Risk due to a decreased chance of misuse

Conclusively, it can be noted that “Sporty Design” has a lot of negative relations and that this must be further investigated before implementing any alterations to the product. Quick access and Lift-in Height also had negative relations that need to be considered.

8.2.2 House of Quality - Technical Importance Rating

Trough calculation based on the weight of the Customer Requirements and the relations between functional requirements, a Technical Importance Rating has been calculated. This rating shows the importance of each functional requirement relative to each other. The result can be seen in Table 9.

Table 9 - Technical Importance Rating.

Product Targets	Lift in Height 600mm	No Contact With Dirt	Able to Customize Luggage Space	Visual Assistive Guidance	Automatic Opening	Smart Door-handle for Tailgate	Low entrance time and effort into Luggage Space	No Movement Restrictions	Enable Good Reach Within the Luggage Space	No Perceived Awkwardness / Inconvenience	Enable the Sporty Design	Easy to Reach Luggage within Luggage Space	Appropriate Response of your Intention	No Perceived Discomfort	FMEA score ≤ B & No User Injuries	Perceived Quality
Max Relationship	9	9	9	9	9	9	9	9	9	9	3	9	9	9	3	9
Technical Importance Rating	457,14	242,86	264,29	210,71	528,57	364,29	685,71	385,71	489,29	371,43	246,43	432,14	203,57	253,57	214,29	192,86
Relative Weight	8%	4%	5%	4%	10%	7%	12%	7%	9%	7%	4%	8%	4%	5%	4%	3%
Weight Chart																

From the Technical Importance Rating it is gathered that a Low Entrance time and effort into Luggage Space is ranked highest regarding important focus targets to reach high customer satisfaction. Because Quick Access to Luggage Space is highly correlated to many customer requirements, a well-executed improvement in this area will have a positive impact on several customer needs. However, it must also be noted that the distribution of importance is rather small, which implies that the workload should be spent on all functional requirements to achieve a great product.

8.2.3 House of Quality – Comparison and Assessment

From the product targets, a comparison between the favored concepts and the Lynk & Co 01 was established. The degree of fulfillment of the product targets was graded by the project team members. The result can be seen in Appendix H – House of Quality or in Figure 32. This showcase which concept that surpasses the performance of the others in the different technical targets.



Figure 32 - Technical Competitive Assessment.

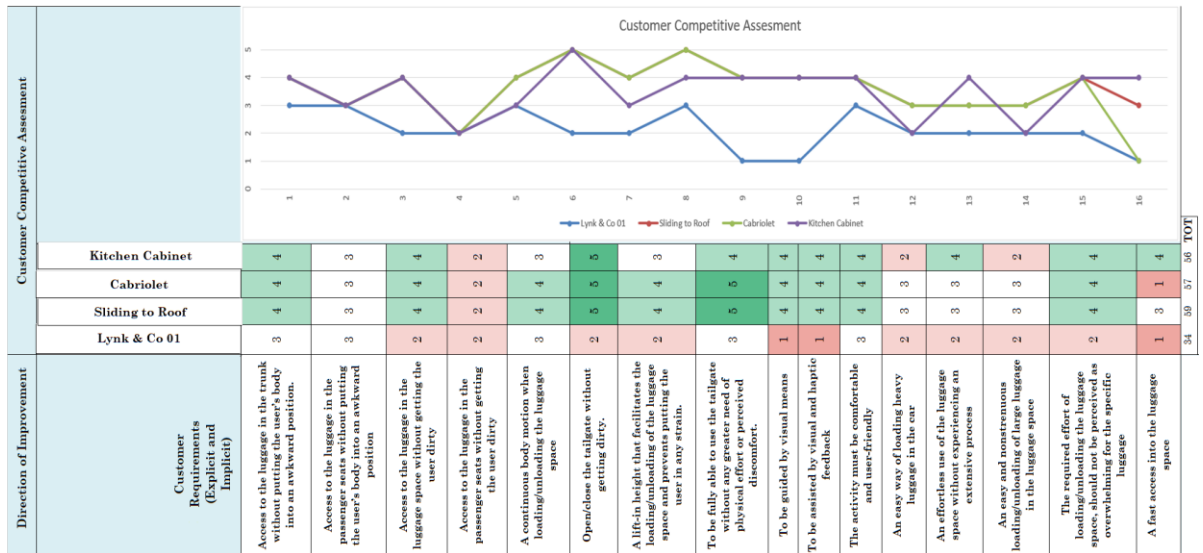


Figure 33 - Customer Competitive Assessment.

Analysis based on the user needs was also performed, giving further information on how the concepts compare against each other and the Lynk & Co 01, see Figure 33. Given the information from both assessments, an analysis of the reasons behind the grading was carried out to understand why they differ and what pros and cons they possessed. Further investigation regarding possible cross-implementation of features was carried out to ensure the feasibility of the overall concept. From this, the final concept was created with features that together generated the most extensive inclusivity possible. The final concept was named *“The Innovation Concept”*.

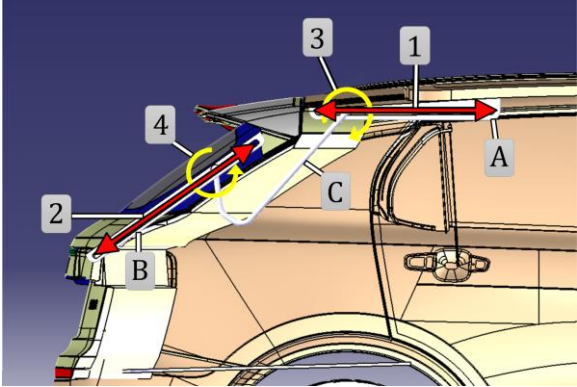
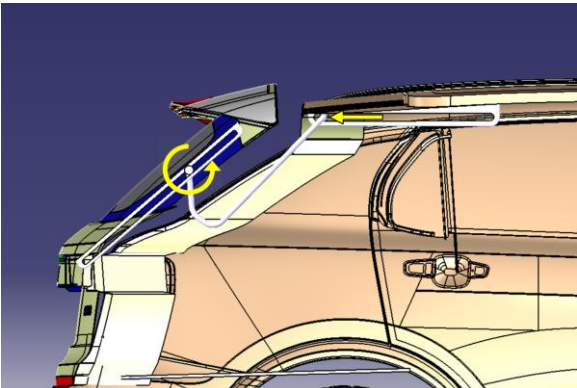
9 THE INNOVATION CONCEPT

The main goal of this product development project was to achieve such an attractive, comfortable, and easy to use solution, that the senior car users choose to use the luggage space for its intended purpose. To address this, it was important to grasp why seniors today chose other alternatives to facilitate their storage, these reasons can be found in the user needs list (Table 5). This chapter will present the innovative concept that has been created to address these needs. These solution features can be implemented separately, or be combined into an improvement package, to reach a higher degree of inclusiveness.

9.1 The Tailgate

To ensure the use of the luggage space as the primary choice for storage, an inviting and non-strenuous solution of the tailgate must be implemented. The design that has been created uses a pioneering and unique power-operated motion created by two translational joints and two rotational joints. Together they manage the tailgate operation smoothly and pleasantly through a custom connection arm which allows the tailgate's movements. In Table 10, the tailgate movement and a description of the joint's actions, are presented in text and illustration.

Table 10 - Description of tailgate movement.

Description	Illustration
<p>The starting point of the tailgate is the same as today's solution. In Figure 34 the three main components are noted, A-C, and the four joints 1-4:</p> <p>A - Car rail B - Tailgate rail C - Connection arm 1 - Translate along X-direction 2 - Translate along with tailgate window 3 - Rotation around Y, connected to A 4 - Rotation around Y, connected to B</p>	 <p>Figure 34 - Tailgate opening solution: Position 1.</p>
<p>Figure 35 shows how the tailgate opening initiates with a translation of A and a rotation of 4. This will unlock the tailgate from the body and set-up for the following motion.</p>	 <p>Figure 35 - Tailgate opening solution: Position 2.</p>

Upward motion is initiated where a rotation of 3 and 4 works together to ensure that the tailgate travels in a straight vertical path, as shown in Figure 36. A horizontal translated along 1 is introduced into the motion giving a sliding motion of the tailgate towards the main body of the car.

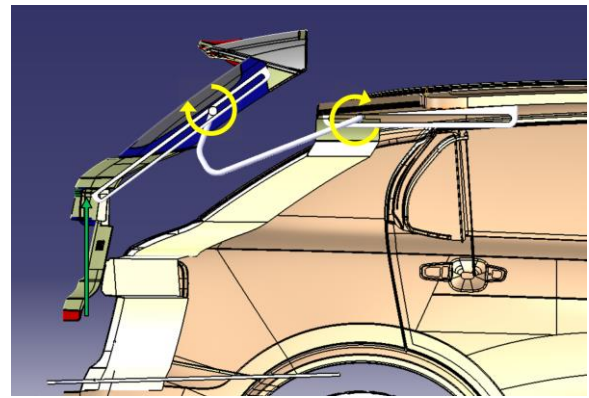


Figure 36 - Tailgate opening solution: Position 3.

The translation along the car's length, 1, is continued and a translation along 2 is begun. Rotation of both 3 and 4 ensures that the tailgate positions flat over the roof. These together ensure that the tailgate is removed out of any interference of handling of the luggage space and creates a slick feature when the tailgate is open (Figure 37). The total process of opening and closing is completed in the same time as the current tailgate of the Lynk & Co 01.

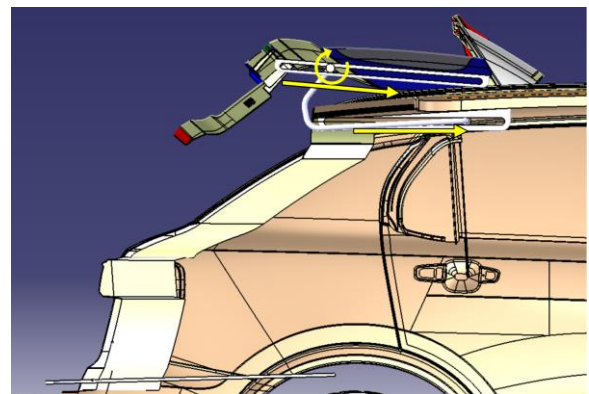


Figure 37 - Tailgate opening solution: Position 4.

With this updated tailgate motion, several benefits are attained. Firstly, the seniors that were observed and interviewed complained about the movement path of the normal tailgate; outward and up towards the user. They felt that this both were difficult to handle manually due to its unnatural movement and they perceived discomfort during the activity. Given the opportunity to interact with the Lynk & Co 01 and a power-operated tailgate, they encountered the same discomfort during the opening of a power-operated tailgate.



Figure 38 - Perspective view of the new solution of the tailgate.

To avoid the perception of discomfort due to the tailgate's path, the motion of the new solution strives to be as close to the car as possible (Figure 38 & Figure 39). Since, users create an idea of a boundary box around the car when they approach it, and how much space it perceives to take, for example height, length, and width, it is important to not extend the motion beyond the perceived boundary box of the car, resulting in a welcoming opening tailgate operation.

The discomforting feel due to the tailgate's path was also caused by the sense of exposure while standing beneath the tailgate and especially due to the risk of injury after they pressed the closing button and the downward movement of the tailgate was initiated. The new solution is perceived as less intimidating since its position is not hovering above the user.

Further, the seniors experienced that the activity of getting into the luggage space, load/unload, and close the tailgate was extensive and overwhelming. To counter this, the new solution creates a nice and pleasant feel of the tailgate movement. By making the path of the tailgate in close proximity to the rest of the car body, and removing visual leverage points, which gives a heavy impression, the new design creates the perception of a sleeker, smoother tailgate operation procedure.



Figure 39 - Perspective view 2 of the new tailgate solution.

The solution feature addresses the following user needs from the "User Needs List":

- **U.N. 1.6** – "Access to the luggage in the trunk without putting the user's body into an awkward position."
- **U.N. 2.1** – "A continuous body motion while loading and unloading the luggage space."
- **U.N. 2.5** – "A lift-in height that facilitates the loading and unloading of the luggage space and prevents putting the user in any strain."
- **U.N. 2.5** – "The required effort of loading and unloading the luggage space, should not be perceived as overwhelming for the considered luggage."

Pros:

- State-of-the-art design with premium product feels with a welcoming design.
- The tailgate motion is kept inside of the precepted boundary box, eliminating any discomfort from objects moving towards the user.
- An exciter. A unique feature that will exceed customer expectations and deliver a "wow"-experience.
- Minimize the risk of injuries during the closing of the tailgate.
- A non-overwhelming sensation to use the tailgate.

Cons:

- To implement the solution, it might result in expensive product development, proof of concept, feasibility assessment, and implementation process.
- More complex than today's solution will most likely result in a more expensive product.
- In case of failure, for instance electric, it might be difficult to open and close the tailgate.

9.2 Tailgate Operation, Handling, Control & Maneuver

To facilitate an easy usage of the tailgate and ensure that seniors, of their own accord, choose the trunk as their storage compartment, it is important to assist users for them to access the full functionality of the solutions. Therefore, has several functions been designed to support user's interaction with the tailgate.

9.2.1 Ease the use of the Product – Smart Key, Manage Tailgate, Smart Tailgate Opening

A new placement of the opening button has been designed. This new design gives a premium impression and ensures a comfortable and intuitive use while guarantees an interaction without the user getting dirty (Figure 40). This solution is based on a design where the opening button is hidden behind the exterior design of the tailgate, in Lynk & Co 01, the position is behind the Lynk & Co logo. This hidden compartment is showcased as the user approaches the vehicle and the car detects the presence of the owner's key fob. The compartment will also open if the car is stationary and unlocked. The compartment is otherwise hidden and sealed off from the outer environment (Figure 41).



Figure 40 - New opening button solution.



Figure 41 - (Left) illustrates the design when the opening button is hidden. (Right) illustrates an open hatch.

In a revolving motion the open button is displayed to the user, on a clean and visually appealing surface. The surface is slightly angled towards the user to deliver a more welcoming impression. The button position is placed upwards to prevent the misuse of the tailgate. During the user study, several seniors tried to pull the tailgate upwards, as if it was a manual tailgate, which led to the tailgate malfunctioned. As the new design features the opening button upwards, it is intuitive that the action of pressing the button will initiate the opening of the tailgate (Figure 42).

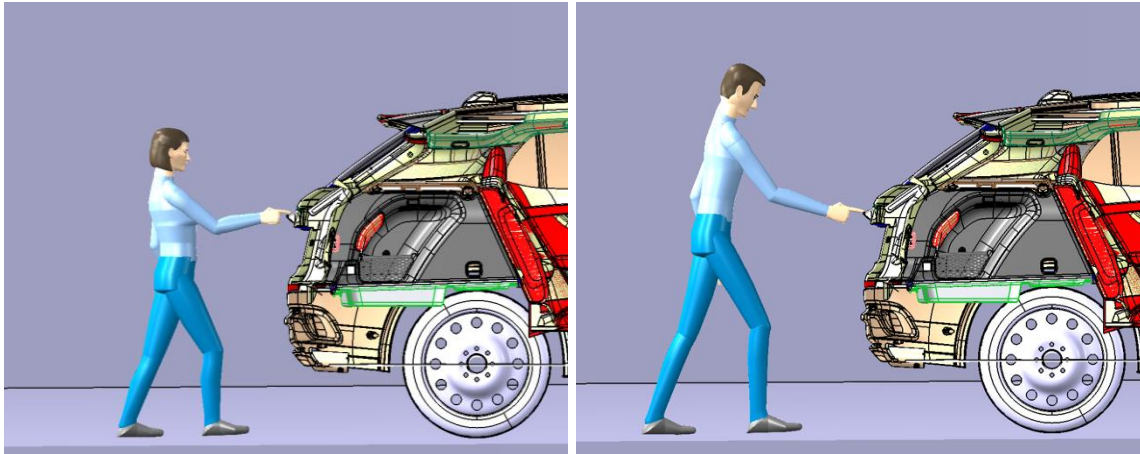


Figure 42 – (Left) A 5-percentile woman, European, interacting with the opening button.
(Right) A 95-percentile man, European, interacting with the opening button.

To further assist seniors in the usage of the tailgate, the ability to fully control the tailgate has been implemented and extended as far as possible. The infotainment system for the front row, together with the key fob (Figure 43), now has full control over the tailgate giving the users the ability to control the tailgate from their desired position. The need for this control was derived from observation where users were unsatisfied with today's solution which only offered to lock and unlocking control from the key and a button to open the tailgate from the driver's seat.

Implementing the new features to the key can be done without any change in the design of the key itself. The function of controlling the tailgate will be added to today's "unlock trunk" button. By holding down this button or double-clicking it, the user can initiate opening or closing of the tailgate from their current position.



Figure 43 - The car key of the Lynk & Co 01.

The solution feature addresses the following user needs from the "User Needs List":

- **U.N. 1.4** – "Open/close the tailgate without getting dirty."
- **U.N. 1.6** – "To be fully able to operate the tailgate without any greater need for physical effort or perceived discomfort."
- **U.N. 2.1** – "The activity must be comfortable and user-friendly."
- **U.N. 2.3** – "Effortless use of the luggage space without experiencing an extensive process."

Pros:

- Automated features and functions decrease physically demanding activities and physical discomfort.
- A premium impression when features are designed around the user and facilitates the use of the product.
- Intuitive use for all users.

Cons:

- A more complex design of the tailgate to implement the smart opening button will result in a more expensive product and add a risk of failure.
- The system of the revolving opening button must be highly perfected to not create a frustrating and annoying experience.
- All seniors may not appreciate an increase of technical solutions.

9.2.2 Tailgate Close Button Position

Observations showed that some seniors, interacting with Lynk & Co 01, found it difficult and uncomfortable to close the tailgate due to the closing button's current position. In one extreme case, a senior was unable to reach the closing button and required help locating the closing button. Therefore, the car has been equipped with one additional closing button to ensure that all users can close the tailgate comfortably and easily (Figure 44).

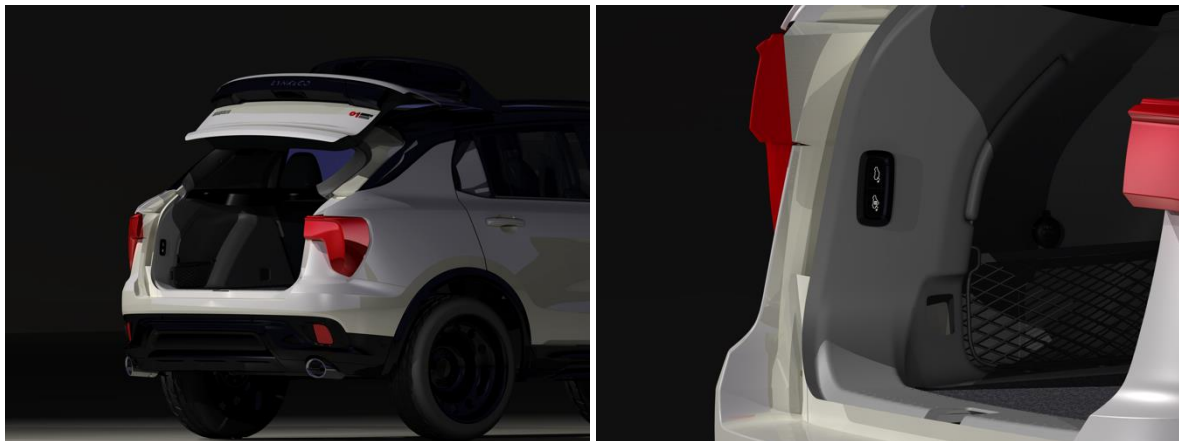


Figure 44 - New tailgate closing button location.

According to CEVT's requirement specification, the height of the closing button must be less than 185cm from the ground, on inspection of three Lynk & Co 01 the average height was 182cm. The added closing button is located 100 cm above the ground (87 cm if air-suspension is implemented, see

Optimized Lift-In-Height – Adaptive Air Suspension).

The button is placed on the left side of the luggage space because the majority of times the tailgate is open/closed it is done by the driver. Given from information gained during looping with seniors, this would be an intuitive and seamless position due to the natural path a driver will have moving towards the driving seat after they have closed the tailgate (Figure 45). However, if the car will be built in a right-hand version, this position might need to be changed to achieve the same level of customer satisfaction.

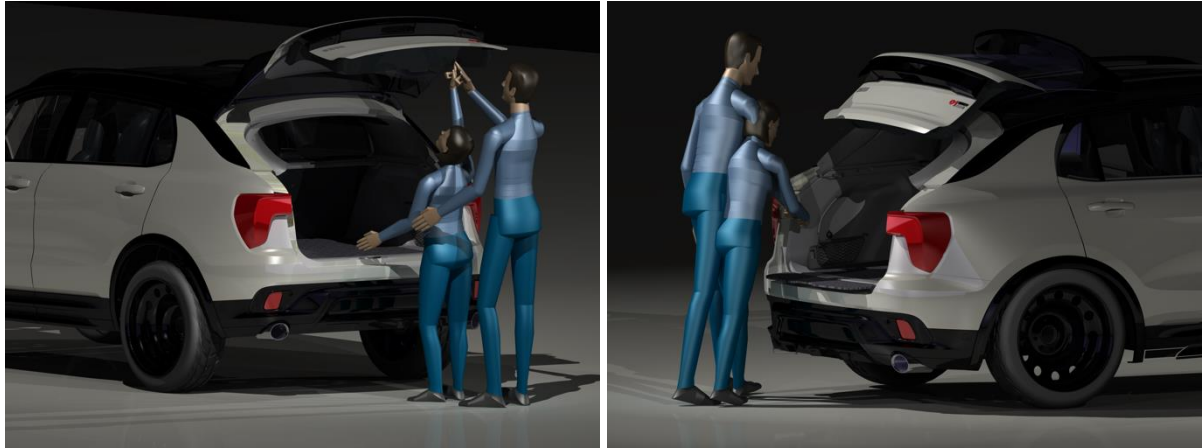


Figure 45 – (Left) shows a 5-percentile woman and 95-percentile man, Europeans, interacting with Lynk & Co 01. (Right) shows a 5-percentile woman and 95-percentile man, Europeans, interacting with the new button position.

The solution feature addresses the following user needs from the “User Needs List”:

- **U.N. 1.6** – *“To be fully able to operate the tailgate without any greater need for physical effort or perceived discomfort.”*
- **U.N. 2.1** – *“The activity must be comfortable and user-friendly.”*
- **U.N. 2.3** – *“Effortless use of the luggage space without experiencing an extensive process.”*

Pros:

- Features are designed around the driver and facilitate the use of the product.
- All users are included in the activity and allowed to choose a method of their preference on how to interact with the car.
- Intuitive use for all users.

Cons:

- Having too many controls might confuse users and give a complicated impression on first sight. To counter this, the old button-position could be removed. However, this might surprise the practiced user who is accustomed to the closing button position on the tailgate.

9.3 Optimized Lift-In-Height – Adaptive Air Suspension

The lift-in-height to the luggage space is recognized to be the most crucial element in the experienced comfort of loading and unloading. This resulted in one of the main targets and priorities of the project to be the development of a feature that enables a lowering of the lift-in-height, without compromising the purity of the design.

A lower lift-in-height feature was achieved by equipping the car with an adaptive air suspension. The feature is designed by replacing the standard use of the steel springs with pressurized air springs. During the loading and unloading activity, the rear suspension decompresses, resulting in the rear section of the car being positioned at a lower height, offering a new decreased lift-in-height with a difference of 125 mm (Figure 46 & Figure 47). The lowering-procedure is executed simultaneously as the tailgate opening procedure, preventing the air deflation from being the bottleneck. If the lowest position of 625 mm from the ground line is perceived as too low, the lift-in-height can be adapted accordingly within the span to the desired height.



Figure 46 - Lift-in-height with inflated air suspension.



Figure 47 - Lift-in-height with deflated air suspension.

The solution feature addresses the following user needs from the “User Needs List”:

- **U.N. 1.1** – “Access to the luggage in the trunk without putting the user’s body into an awkward position.”
- **U.N. 1.3** – “A continuous body motion while loading and unloading the luggage space.”
- **U.N. 1.5** – “A lift-in height that facilitates the loading and unloading of the luggage space and prevents putting the user in any strain.”
- **U.N. 2.1** – “The activity must be comfortable and user-friendly.”

- **U.N. 2.2** – *“An easy way of loading heavy luggage in the car.”*
- **U.N. 2.4** – *“An easy and nonstrenuous loading and unloading of large luggage in the luggage space.”*

Pros:

- An exclusive and premium product feel with a welcoming design that adapts according to the user need.
- Optimal lift-in-height.
- An exciter. A unique feature that will exceed customer expectations and deliver a “wow”-experience.
- Avoids the necessity of a total re-design of the rear of the car.

Cons:

- Weight-increase, which in turn gives a decreased fuel efficiency. Replacing the standard suspension with the added air suspension increases the weight by approximately 45-70 kg.
- Increases cost, relative to the current standard steel springs.
- May enhance the user’s perception of extensiveness when using the luggage space for loading and unloading, resulting in the user using the passenger seats instead. Power-operated and moving parts can have a deterrent effect on the senior user.

9.4 Quick Access – Power-Operated Tailgate Window

One of the reasons why the seniors chose to use the passenger seats for storage of luggage, instead of the designated and appropriate luggage space, was that they considered the opening of the tailgate to be too time-consuming. To counteract this behavior, the user should be able to load or unload the luggage space at the same pace as if using a passenger door. To solve this, a power-operated tailgate window was developed.

The window of the tailgate has the characteristics of a conventional tailgate window, except, it is height-adjustable. The tailgate window can be lowered and heighten, similarly to the passenger door window (Figure 48). The feature can be operated from outside of the car and the position of the window is regulated via the same control consoles that apply to the feature of opening/closing of the tailgate. In practice, this is technically implemented by the window translating downwards into the inside of the lower part of the tailgate, powered by small electric engines. In other words, is the mechanical framework of the tailgate window organized, and works, just as a passenger door window.



Figure 48 - The fold-down process of the power-operated tailgate window.

The solution feature addresses the following user needs from the “User Needs List”:

- **U.N. 2.3** – *“Effortless use of the luggage space without experiencing an extensive process.”*
- **U.N. 2.5** – *“The required effort of loading and unloading the luggage space, should not be perceived as overwhelming for the considered luggage.”*
- **U.N. 2.6** – *“Fast access into the luggage space.”*

Pros:

- Enables efficient, quick, and easy loading & unloading.
- It provides stressed users an incentive to use the luggage space instead of the passenger seat.

Cons:

- Complex to implement with the current design of the tailgate and the window.

9.5 Easy Access – Power-Operated Luggage Space Floor

Leaning into the luggage space of the car to load/unload, was an action that the seniors often experienced as uncomfortable, painful, or in another way cumbersome. To prevent the users from putting themselves in this position a solution has been created where the action of leaning into the trunk has been minimized.

By mounting a power-operated luggage space floor within the trunk, which can translate in X-direction, the distance of which the user needs to lean is decreased (Figure 49). Since cars today have rather large bumpers that users need to lift their luggage over, as well as lean past to reach further into the trunk, the solution of transporting the floor towards the user and past the bumper would address the problems caused by the bumper. The floor will be translated to the point where the edge of the floor is flush or extended slightly over the bumper. This would ensure that the users will benefit and there will be no risk of the floor extending towards any object that might be positioned behind the car. The user study also showed that it was undesirable to have objects coming towards the users, which might result in an impulse to move out of the way or otherwise feel distressed. The idea of *“what you see is what you get”* is used so that the users early on can see the boundaries of the product and know that there will be no surprises that extend past these boundaries.

The power-operated floor also fulfills customer needs regarding the use of the product without getting dirty, *U.N. 1.2*, and *U.N. 1.4*. Since a lot of the dirt users have contact with is from the bumper, minimizing any contact with its surface will decrease the contact with dirt immensely.



Figure 49 – Power-Operated floor positioned in its extreme translations.

However, the solution will result in higher complexity of the product, resulting in a higher manufacturing cost and a higher risk of failure. An FMEA-analysis would most likely show that its severity would only be of minimal impact since the result of a malfunctioning power-operated floor would be a standard, non-power-operated floor.

There might also be a risk of objects gets jammed in-between the backside of the rear seats and the inner edge of the power-operated floor. If this happened the tailgate would not be able to close and the user must remove the object, which would add an uncomfortable action. To prevent this, a design where some kind of cover that hinder objects from reaching this position could be created. However, this has not been taken into consideration within this project but can be seen as a development suggestion, for future work.

Further, it is questionable how feasible this solution is together with today's design where small storage space is placed beneath the top floor, as well as a spare wheel. If these are of high demand from the standard customers, then this solution might not be ideal since it may hinder or make the process of reaching this concealed compartment. However, the looping process with seniors showed that they rather exchange the spare wheel with a tire repair kit, if it enabled the power-operated floor. (Several different variants of a tire repair kit are available on the market, but the general function is to inflate the tire with a foam that hardens which allows for a quick and easy repair of the tire)

The solution feature addresses the following user needs from the "User Needs List":

- **U.N. 1.1** – *"Access to the luggage in the trunk without putting the user's body into an awkward position."*
- **U.N. 1.2** – *"Access to the luggage in the luggage space without getting the user dirty."*
- **U.N. 1.3** – *"A continuous body motion while loading and unloading the luggage space."*
- **U.N. 2.1** – *"The activity must be comfortable and user-friendly."*
- **U.N. 2.2** – *"An easy way of loading heavy luggage in the car."*
- **U.N. 2.4** – *"An easy and nonstrenuous loading and unloading of large luggage in the luggage space."*

Pros:

- Prevents dirt on the loading/unloading user.
- Avoid uncomfortable positions, e.g. leaning into the luggage space.
- Supplies a premium and welcoming feel.

Cons:

- Brings complexity to the product.
- Feasibility with other luggage space floor solutions is questionable.
- Risk of objects getting jammed in-between moving parts.

9.6 Luggage Space Personalization – Customizable Luggage Space Floor

Shared mobility, with carsharing and peer-to-peer services, is evolving to be more and more established in today's mobility society. With Lynk & Co striving to be a pioneer in the market, the car used in the development concept may periodically be used by several different users simultaneously. However, as stated in the theory, and confirmed in the empirical study, the seniors tend to adapt slowly to change and may still appraise product ownership.

For the senior user to still feel a personal connection to its car, the characteristics of it have to be customizable and adapt according to the senior user's needs and manner of usage. The feature of having a customizable luggage space floor results in a dynamic luggage space that offers the desired flexibility, without being permanent and/or having an effect on other sharing users. This feature is achieved by a foldable floor (Figure 50). The solution was inspired by a similar feature discovered in a competitor's solution.



Figure 50 – (Left) Luggage space floor in its familiar appearance. (Right) Luggage space floor in its adapted appearance.

Furthermore, it was stated in the empirical study that the seniors experience that their luggage space is too voluminous for their luggage in question, and it feels unnecessary to concern themselves with opening the tailgate and place the luggage in its proper position. The customizable luggage floor offers a new volume that is not perceived as overwhelming and is more suited for smaller luggage that otherwise would have ended up in the rear seat. When the floor is set in its folded mode, it provides hooks to be used for safe, sturdy, and reliable storage of bags Figure 51.



Figure 51 - Luggage space floor in its adapted appearance storing grocery bags.

The solution feature addresses the following user needs from the “User Needs List”:

- **U.N. 2.5** – *“The required effort of loading and unloading the luggage space, should not be perceived as overwhelming for the considered luggage.”*

Pros:

- Customizable, adaptive, and personalized.
- It offers a convenient and appropriate space for small luggage.
- Dynamic and flexible and can be idle if the user so desires.
- Simple yet effective solution.

Cons:

- The integration and combination with the translating power-operated floor might be mechanically complex.

9.7 Visual Assistance for the User – Environmental Illumination

As stated in the theory, the eyesight of the senior user deteriorate with age and become extra vulnerable in a dark setting, e.g. when it is dark outside or parked in a darkened garaged. This results in, as stated in the empirical study, that some seniors can find it difficult to orient and locate their luggage when performing the activity in dark surroundings. To make it more comfortable for the senior, not only the physical ergonomic need should be considered. To include more users, as many of the human senses possible were taken into consideration in this development project. This feature addresses the sense of sight.

To solve this problem, the luggage space is equipped with interior and exterior lighting to illuminate the environment and surroundings to aid the senior user in its loading and unloading. The interior lights aid the user to orientate in the luggage space, and the exterior lights aid the user to orientate in the workspace and the surroundings, e.g. locating luggage to be loaded.

Luggage space illumination already exists on the market today; however, they are too dim and inadequate for the visually impaired senior user. The developed lights are amplified and also exteriorly operative Figure 52.



Figure 52 - Luggage space with amplified interior and exterior illumination.

The solution feature addresses the following user needs from the “User Needs List”:

- **U.N. 1.7** – “To be guided by visual means.”

Pros:

- Address and aid the senior's impaired sense of sight.
- It generates a welcoming and inviting feeling.
- Establishes a pleasant user experience set up.

Cons:

- The light may be perceived as too bright and generate a discomfort presence, due to that some seniors with impaired vision might have obtained photosensitivity in parallel.

9.8 Guided User Attention & Intuitive Use – Illuminated Controls

Like the previous feature, this feature also addresses the senior user's sense of sight. As mentioned in the theory section, the seniors experience problems with attention ability, e.g. visual search, recognition, and attention switch, leading to the inhabitation of irrelevant information. Insignificant info, that does not affect the intended output of the performed activity, can easily be filtered out by a young user, but for a senior, it can be misleading and difficult to understand what action is required.

To aid the senior users in their cognitive progress, the controls of the luggage space should be illuminated and visually discernible from the contrasting environment that will draw their attention legitimately Figure 53. The purpose of the feature is to guide the senior user through the activity and lead their attention towards the next required action in the loading and unloading process. Sometimes, in a complex product such as a car, is going back to basics the most efficient approach. Illuminated controls guide in the most intuitive way possible, make it childishly simple, cannot be misinterpreted, and avoids misuse of product intention.



Figure 53 – Illuminated tailgate operation control, approaching vehicle.

The innovation concept recommends that visual guidance of attention should be applied to all crucial controls included in the seniors' car usage. The closing button (Figure 54) is essential in the loading and unloading activity and should not be perceived as demanding and strenuous to locate and use.



Figure 54 - Illuminated tailgate operation control, close-up view.

The solution feature addresses the following user needs from the "User Needs List":

- **U.N. 1.7** – "To be guided by visual means."

Pros:

- Distinguishable, obvious, and visually noticeable.
- It does not compromise aesthetics.
- Clear and intuitive.

Cons:

- More expensive than a standard closing control button.
- It requires electronic components that may break or malfunction and require maintenance.

9.9 Visual-Haptic Feedback Features

In today's car systems, a lot of invisible work is done beneath the surface, which the user never is exposed to, which is an intentional design to avoid the user being bothered with unnecessary information. However, with the digital and automated functions, the seniors may not be aware of what is going on, which generates a feeling of being out of influencing control and create discomfort. This can be prevented with a visual or/and a haptic feedback feature that addresses the impaired senses of the seniors. The senior user should be receiving feedback that a process has started due to a performed action, so that the user is aware of that the system has responded to the given signal and that the process for the intended outcome has been either implemented or terminated.

In the innovation concept, awareness is achieved through visual feedback via the luggage space's interior and exterior lights, and the illuminated controls, described in section 9.8. When an action is performed, the lights change characteristics to inform the user that there has been a change in the system. For instance, in the situation when the senior is done loading or unloading and presses the closing button (Figure 56), initiating the closing of the tailgate, the interior light of the luggage space change color to alert the user of what occurs and instruct the user to keep away from the luggage space (Figure 55). However, the external environment lighting is maintained active, to assist the senior moving away from the rear of the car.



Figure 55 - Visual feedback by changing the light's characteristic (Tailgate closing).

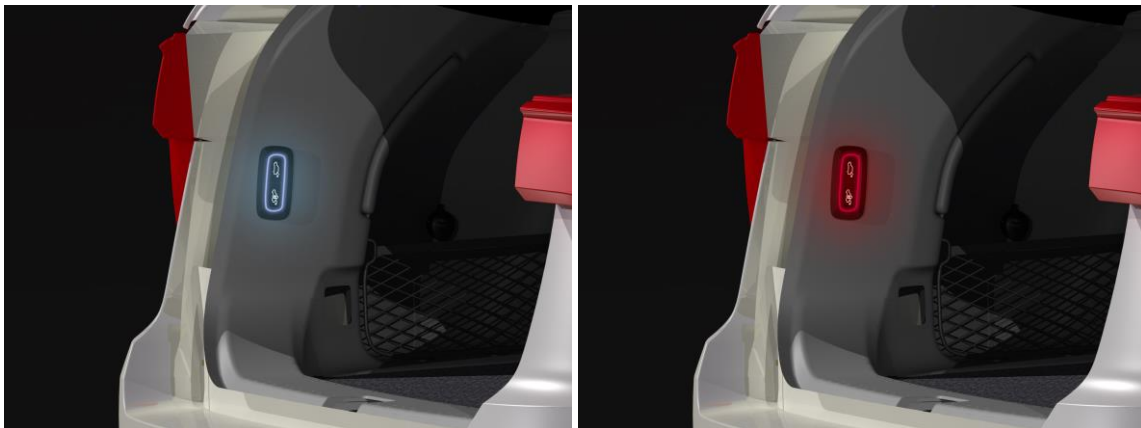


Figure 56 - Visual feedback by changing the light's characteristic (Tailgate closing).

The visual feedback feature will also be integrated into the tailgate opening control button; when the button is pressed, the light changes to the color green to inform the user that the opening procedure has been initiated (Figure 57).



Figure 57 - Visual feedback by changing the light's characteristic (Tailgate opening).

Feedback features can also be achieved through a haptic function, creating an experience of touch by applying forces, vibrations, or motions to the user, often used in smartphones. For example, when locking the car, in addition to the exterior lights flashing and the car horns, the key vibrates to confirm that the intended action was successful.

The solution feature addresses the following user needs from the *"User Needs List"*:

- **U.N. 1.8** – *"To be assisted by visual and haptic feedback."*

Pros:

- Designed to address the cognitive ability, uses multiple senses to enhance the product experience.
- Simple, intuitive, and effective design approach.
- Cool, exciting feature that generates a perceived "wow"-factor.

Cons:

- May be perceived as an annoying standard feature by those who experience it as unnecessary. Even if the feature can be deactivated, the action still demands initiating effort from the user to manually switch off the setting.

9.10 Safety – Obstacle Detection Sensors

When using a product, the user should never be exposed to danger or experience a feeling of being unsafe. To increase safety in the use of this product, and its system reliability, the innovation concept is equipped with so-called "obstacle detection sensors". The sensors are mounted on the object in motion to stop it before contact with the obstacle (Figure 58). For instance, the moving tailgate's sensors prevent it from hitting the vulnerable senior user in the head, or other parts of the body. In today's tailgate solution (Figure 59), the sensors are located inside the power-operated tailgate's motors and do not respond until they receive a resistance signal of momentum, i.e. in collision with an obstacle, which is not a sufficiently fast reaction time for the product to be considered safe and can cause relatively great damage to the fragile senior user.



Figure 59 - Lynk & Co 01 current tailgate in contact with object.



Figure 58 - Tailgate equipped with obstacle detection sensors, stopping at a safe distance to the object.

The solution feature does not address any of the stated needs from the user needs list, however, it is an important safety aspect that addresses an unspoken need that must be considered in the product development process.

Pros:

- Ensures a safe usage of the product.
- Feels exclusive with no contact.

Cons:

- Expensive hardware and software.
- Brings complexity to the product system.

9.11 Prevention of Dirt on User – Optimized Aerodynamics & Repellent Materials

The user study showed that while loading and unloading, users found it highly annoying to get dirt on themselves while interacting with the vehicle. In some cases, this led to the users opting to use another storage option where they could avoid any contact with the dirt. Since the outside of the car is constantly in contact with a contaminated environment, the car will inevitably become dirty. To ensure that the user will not be in contact with dirt there are two solutions: Eliminate the dirt from the surface of the car, or remove/alter the actions where contact with the dirt is located. The following feature is presented with top-view and generally defined. i.e. the recommendations are approximate and can be interpreted ambiguously.

Focusing on the first possible solution, to eliminate the dirt, the solution today would be to clean the car manually as an additional action. However, the user study stated that it is preferable to not add further activities, and therefore are the solutions created to work passively during regular use of the car.

By a thorough redesign of the car's aerodynamics, the flow of air could be in such a way that dirt and other particles are removed, or redirected, away from desired surfaces. For instance, wind deflectors have been used by car manufactures to keep the rear window clean.

Another option is to use special materials or coatings on desired surfaces which will allow a low coefficient of friction. This will result in a repellant surface, of which dirt and other particles will "glide" off/not attach to, supplying a clean and dirt-free surface.

These solutions could be implemented alone or together to reach a higher grade of fulfillment.

The solution features address the following user needs from the *"User Needs List"*:

- **U.N. 1.1** – *"Access to the luggage in the trunk without putting the user's body into an awkward position."*
- **U.N. 1.2** – *"Access to the luggage in the luggage space without getting the user dirty. "*
- **U.N. 1.4** – *"Open/close the tailgate without getting dirty."*

Pros:

- No or less dirt/particles where the user might be in contact with the car.
- The change in design will not result in any additional actions for the user.
- Decrease the need for manual washing and give the user an impression of a cleaner car.

Cons:

- Might have a negative impact on fuel efficiency.
- Restricts the freedom of the design of the car.
- Lack of success in previous implementations. Feasibility is questionable.
- Might have to re-apply and maintain the material/coating to uphold its function.

10 DISCUSSION

The master thesis project studied the seniors as a target group and the disabilities they inhabit, and its consequences, from a general perspective through theoretical literature study and market analysis. However, the major part of the project consisted of a specific endeavor focusing on how cars can be designed to be more inclusive, through an empirical study, followed by the development of a product concept. The objective pivoted to be facilitating the loading and unloading activity of the luggage space for seniors. The result was an innovative conceptual luggage space that aims to be used as inspiration for future work at CEVT.

10.1 Scope

The scope of the project was initially relatively wide, and the topic within *ergonomics* and *inclusivity of the disabled* was undefined for the project to be self-interpreted and adjustable according to members' self-interest. The project adapted to fit the members with a background in product development. This entailed that knowledge in areas of relevance, and previously unrecognized, increased as the project progressed, and delimitations were formed to fit the time frame and the competence possessed by project members, e.g. focusing on seniors, limiting the product development to only consider the luggage space, and disregarding prototyping and testing. In retrospect, a more definite and defined project deliverable would have been preferable. Even though it was understandable that CEVT did not want to limit the project development, a definite and clear goal to pursue would prevent time and energy spent on deciding the course of the project. Time and energy that could have been spent differently, as the complexity of the initial phase may very well have affected the quality of the generated results in sequential phases.

10.2 Research

The project was initiated by exploratory research that aimed to grasp and describe the whole picture, as it was crucial for understanding what the topics of ergonomics, inclusivity, and disability entailed in this project case. The process was challenging, and it required continuous contact and communication between CEVT stakeholders and project team members. The exploratory research was carried out with a data collection of different kinds; an examination of published theory in the sub-topics, and a market analysis of the current market. There were some uncertainties regarding which marginalized group with a disability the project should target, and in turn which relevant car activity to focus on, leading to time-consuming questioning of the relevance of certain data. These uncertainties were handled by a discussion with people who were well versed and possessed relevant knowledge in the subject. This caused some minor project delays since people with relevant knowledge were quite tricky to get in contact with, and not always in a position available to share information.

The scope screening also contributed to that the theory data and market variables identified and presented do not necessarily capture all details of interest and some assumptions had to be made which might have had an effect on the validity of the project result. An example of assumptions made was that the project team members wanted to scope the project according to where action could generate the greatest impact relative to team capacity but still chose to focus on the Swedish market. This choice was because of that the Swedish market was the most accessible for an investigation of quality, highly relatable, and most uncomplicated to maintain close contact with the users in the feedback-loop. However, it can be discussed if a focus on a larger market in question, such as China, where Lynk & Co has its roots and already has been launched, would have generated a more comprehensive and influential result.

Furthermore, since the project had a product development approach to the topic and not a scientific exposition, the pilot study pinpointed data that would be useful and beneficial in the development of an eventual product. Also, in this case, it can be discussed if a more thorough and extensive mapping of the topic would generate a greater impact by highlighting the topic and encouraging public awareness.

10.3 User Study

The empirical study was carried out by observations and supplementary interviews to gain a general perspective of the seniors' car usage, considering all possible problem areas. The empirical study was planned to advance, after the initial phase, into a detailed examination of a specific problem area, e.g. *"Loading and Unloading"*. However, due to the circumstances at the time of the project (spring of 2020), during the Covid-19 pandemic, the empirical study was not able to proceed when the problem area screening was performed and the detailed observation of the loading and unloading activity was due. This led to that the project team members had to settle with the data they managed to collect up till then, and the concept generation had to make use of the general data from the initial phase of the empirical study. A deeper user study could have given a greater understanding of the user and cause a positive effect on product development. This would perhaps generate a different result, depending on the data collected. In any future research, a more extensive and problem area-specific observation would be recommended to ensure that senior user's opinions and preferences are justified.

Also, to gain a more justifiable comparison between the presented theory and practice, more observation objects would be needed, for example seniors with other disabilities mention in the theory but not inherent by the objects observed in the empirical study. The greater disability diversity, the better. Another action that would have justified the empirical study result more is if all the observed objects used a car model, with equal characteristics as the considered Lynk & Co 01, i.e. a modern SUV, during their observation. Some of the experienced problems in the observations, due to the older car model, have already been addressed and solved with features of modern cars and are thereby irrelevant when developing new cars today.

10.4 Development

The different approaches in product development are many, have lots of pros and cons depending on the circumstances, vary greatly, and ought to be discussed and reflected upon. In this project, to prevent subjectivity in the decision-making process of the concept generation, the project team members relied on objective engineering methods, e.g. the Kesselring matrix. When using the matrix in the decision-making process, some of the following reflections are important to consider: Are the evaluation criteria relevant and complete? What about the weights on the evaluation criteria, can they be motivated and accounted for? What about the significance of the scoring, is the difference between the total merit values big enough to determine that an alternative with a higher value is better than an alternative with a lower value? However, the judging was made that the usage of the Kesselring matrix as a decision-making tool was not development perfection, but it was a scientific and objective approach in the strive to achieve it.

10.5 Results

The resulting concept was a general concept of innovative solution ideas with overall estimations of how the technical functions beneath the surface would be designed and constructed. This results in the concept being material of inspiration for future development, more than an actual product. Validation and proof of concept are needed to conclude a rate of success for the project, but it was difficult to perform with the characteristics of the developed concept. A produced prototype, and valuation, would have been more applicable to a detailed developed ship-ready product.

The innovation concept was designed with a focus on fulfilling the established user needs. The results depended on the prevailing circumstances, for instance it became evident that the lift-in-height of the luggage space was a decisive attribute for the perceived comfort of loading and unloading. With this in mind, it makes it rather contradictory to focus the development to consider an SUV as the Lynk & Co 01. Having an SUV as a development object was attractive because of its increase in popularity jointly with the project team member's objective to place focus on the greatest potential for impact. However, an SUV is not optimal for shorter users, which the seniors in the user study happened to be. With another car as a product reference, the final concept might have had another appearance.

It is also worth discussing where the line of inclusivity and adaptability should be drawn in the development of specific sub-solutions. Some solutions could be developed even further to ensure the facilitating of loading and unloading of the luggage space. For example, could the "*Visual & Haptic Feedback*"-feature be extended with sounding feedback to alert a user with impaired sight during the closing of the tailgate. However, this added feature could be exceeding the bounds of what is perceived as attractive for the user. A user of the norm would maybe consider it as an unnecessary and unwanted drawing of attention. Some of the seniors may feel that they are being pointed out as old and unfairly identified by their disability, which the market analysis concluded that they do not want to be. The absolute goal of inclusive design is to include, and adapt for, the marginalized users, without deterring other users and thus excluding.

10.6 Ethical Aspects

The project was conducted towards a marginalized group who are not included in a normal product development concerning cars. Since the mobility a car offers are closely linked to a person's sense of freedom and their social life, it would be considered a social responsibility to give all persons the same prerequisite in this aspect. From this, it is apparent that further development efforts must be carried out with marginalized groups so that everyone has the choice of using a car that is designed for them.

Statistics clearly show that seniors have more accidents than younger people. This would argue that seniors might be a danger towards other people and raise the question whether or not they actually should be driving at all. The point is valid in some aspect in the situation we have today. One solution would be to enable the same level of mobility in a different way/product. However, the argument if seniors should drive or not only highlights the problem of additional designs with an exclusive character. The focus should be to assist the seniors by creating solutions around the different problems that seniors face when interacting/driving a car, and in some cases resulting in crashes. This is the main idea of inclusive design, to design for all in order to include everyone, and not exclude users on the basis of their abilities or means.

10.7 Sustainability Aspects

In a project carried out in an industry such as the car industry, the aspects of sustainability are of high importance to consider and discuss. As mentioned earlier, the possibility to stay mobile is a key factor in the individual's quality of life. Especially for the senior population, where mobility is something that they value highly and is considered to be substantial to gain independence, the ability to be mobile plays a huge part to live and thrive in a sustainable way.

However, it can be discussed if a car as a product is the appropriate approach to offer mobility as a service, from an environmental sustainability perspective. By implementing the presented final concept that was developed during this project, cars will increase in attractiveness amongst seniors and the newly discovered target group will contribute to the purchase, production and usage of more cars. Due to the product attributes of cars, an increased consumption will lead to higher material consumption and contribute to the greenhouse effect, amongst other negative effects on the environment.

A more sustainable efficient way would be to shift the focus of users towards public transportations, e.g. buses or trains. The special needs of the disabled senior users should be taken into consideration, included and adapted for in a more comprehensive development of shared mobility services. However, the public transportations of today is somewhat limiting the user's flexibility, which is highly valued by the senior generation, and contradicts a sustainable independence.

11 CONCLUSIONS

The world population is aging, and the car industry must adapt to the future market. To be able to meet the needs of the growing user segment of senior users, the car manufacturers must gain knowledge of how to adapt according to the seniors' preferences. Even though the health of the seniors has improved over the past few decades, disabilities of different kinds will still be common in this user segment. These disabilities have a direct effect on their daily life usage of the car, limiting their mobility, which is a significant factor in the quality of life and independence. In this product development project, it was confirmed that a mindset aligned with inclusive design was a beneficial approach to address the marginalized group of seniors and to fulfill their needs regarding their car usage, explicitly the loading and unloading of the luggage space. The fulfillment of the seniors' needs was achieved by performing three distinct phases; exploratory research, empirical study, and concept development.

- The exploratory research consisted of a theoretical literature study and a market analysis. The theoretical literature study highlighted that the most common disabilities that the seniors inhabit, are musculoskeletal impairments and deterioration in the sensor, motor and cognitive functions. These disabilities have a negative effect on their car experience. However, the experienced issues can be managed, and their car usage can be facilitated, without the need of an extensive radical re-design. Minor, yet effective, inclusive customizations of the car will accommodate the seniors and enable them to thrive in their car experience.

The market analysis displayed that there are potential benefits for car manufacturers of including the seniors in their customer portfolio, due to the considerable market size of senior users, which is predicted to keep on growing. Resulting in a large potential market share to conquer. Additionally, the analysis showed that in mature markets, the purchasing power increases with the age of the individual.

- The empirical study was intended to embody the findings of the theoretical study. This was achieved by observations and interviews carried out with senior participants from the local region, resulting in an establishment of a user needs list that mediates the problems that the observed seniors experience when interacting with cars. In conclusion, the user study confirmed that the seniors perceive the loading and unloading of the luggage space so strenuous that they rather use the passenger seats as storage space for luggage.

Due to findings of the empirical study, the research questions "*What problems do seniors experience when interacting with cars?*", and "*What special needs are important to focus on when including seniors?*" are answered.

- The concept development had the objective to ensure that the usage of the luggage space is so attractive, and so comfortable and easy to use, that the senior user indeed chooses to use the luggage space for its intended purpose. The objective was achieved by the development of an innovative concept of the luggage space that facilitates the procedure of loading and unloading the Lynk & Co 01. The resulting concept, and its included sub-solutions, facilitates the loading and unloading procedure on several different levels by fulfilling all the stated needs in the user needs list. The sub-solutions of the concept can be viewed separately, or be combined into an improvement package, that can be implemented to reach the desired level of inclusiveness. Due to the characteristics of

inclusive design, the concept was designed towards an extreme user. However, the concept did not result in a lessened experience for a norm user but increased product satisfaction without compromising the purity of the design, nor the quality of the product.

With the sub-solutions of the developed innovative concept, the research questions *“How can these needs be addressed in the design of the luggage space?”*, and *“What new features and solutions can be developed to enable an effortless loading and unloading of the car?”*

Due to the comprehensive and general characteristics of the two base research questions *“How can cars be more inclusive for seniors with natural disabilities caused by age?”*, and *“How can the procedure of loading and unloading the Lynk & Co 01 be facilitated for seniors with natural disabilities caused by age?”*, they are answered by the achievements of the three separate phases of the project: The gained knowledge of inclusive design and disabilities in the exploratory research, the obtained insight of the senior user’s car experience in the empirical study, and the resulting concept in the concept development.

11.1 Recommendations

As an action plan, CEVT should implement the sub-solutions of the innovative concept with the highest feasibility, simplest design, and cheapest production. By applying these features, a high level of inclusivity can be obtained despite an uncomplicated implementation. Other features that require major changes should be preceded by proof of concept and validation, using prototypes for testing the fulfillment of product intention.

To increase CEVT’s competence within inclusiveness, further research should be conducted within the problem areas defined but neglected during the empirical study. Additionally, they should examine other marginalized groups other than seniors.

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13 APPENDICES

13.1 Appendix A – Specification of Requirements

Table 11 - Specification of Requirements.

Requirements Specification									Additional comments for the team
ID	Criterion	Derived From	Unit	Target Value	Justification	Evaluation	R/D	Degree Of Fulfilment	
1	Elderly User Loading/Unloading Car								
1.1	User Physical Requirement								
1.1.1	Access to luggage in luggage space	U.N. - 1.1	REBA - score	≤ 3	User	REBA	R		
1.1.2.1	Comfort loading/unloading luggage space, <10kg	U.N. - 1.1	RPE-D - scale	≤ 1	User	RPE-D	R		
1.1.2.2	Comfort loading/unloading luggage space, >10kg	U.N. - 1.1	RPE-D - scale	≤ 3	User	RPE-D	R		
1.1.2.3	Comfort loading/unloading luggage space, >10kg	U.N. - 1.1	RPE-D - scale	≤ 2	User	RPE-D	D3		
1.1.3.1	Comfort loading/unloading luggage space, <75dm3	U.N. - 1.1	RPE-D - scale	≤ 1	User	RPE-D	R		
1.1.3.2	Comfort loading/unloading luggage space, >75dm3	U.N. - 1.1	RPE-D - scale	≤ 3	User	RPE-D	R		
1.1.3.3	Comfort loading/unloading luggage space, >75dm3	U.N. - 1.1	RPE-D - scale	≤ 2	User	RPE-D	D3		
1.1.4	Dirt on user loading/unloading luggage space	U.N. - 1.2	Yes/No	No	User	Prototype	D3		
1.1.5	Dirt on user opening/closing tailgate	U.N. - 1.4	Yes/No	No	User	Prototype	D4		
1.1.6	Motions loading/unloading luggage space	U.N. - 1.3	Number of motions	≤ 2	User	HTA	R		
1.1.7.1	Lift-in height, luggage space	U.N. - 1.5	mm	< 700	User	CAD/Catia V5	R		
1.1.7.2	Lift-in height, luggage space	U.N. - 1.5	mm	< 600	User	CAD/Catia V5	D4		
1.1.8	Enable usage of tailgate	U.N. - 1.6	Yes/No	Yes	User	CAD/Catia V5	R		
1.1.9	Comfort using tailgate	U.N. - 1.6	RPE-D - scale	≤ 1	User	RPE-D	R		
1.1.10.1	Time open/close tailgate	U.N. - 2.5	sec	≤ 5	User	Prototype/Simulation	R		
1.1.10.2	Time open/close tailgate	U.N. - 2.5	sec	≤ 4	User	Prototype/Simulation	D5		
1.1.11	Time loading/unloading luggage space	U.N. - 2.2	sec	≤ other alternatives	Development Team	Prototype	R		
1.2	User Behavioral Requirement								
1.2.1	Overall experience loading/unloading of car	U.N. - 2.1	RPE-D - scale	0	User	RPE-D	R		
1.3	External Requirements								
1.3.1	Comfort should not jeopardize safety	Safety Department	Yes/No	No	CEVT	Observation	R		Observation will regard a test where users will be situated with a number of scenarios. They must always choose the safest alternative by themselves, without any external influences.
1.3.2	Safety of stored luggage	Safety Department	Yes/No	Yes	CEVT	Observation	R		Verification method Objective evaluation Used for requirements that easily can be evaluated objectively if they are fulfilled or not. Can be used to verify requirements containing specific measurements or values. Objective evaluations doesn't need to be performed by the Lead Ergonomist.
1.3.3	There shall be no sharp edges or rough surfaces in the storage area that could damage the loaded item or the loading user during loading/unloading	Safety Department / Customer Attributes	Yes/No	Yes	CEVT	CAD/Catia V5	R		System Weaver ID: 130423. Legacy ID: VCC TCr 021155
1.3.4	Tailgate/trunk lid - Opening/closing force	Safety Department	N	Max 50N between -30° to +20° Max 70N for closing, above +20° to +70° and for opening at temp -30 and colder.	CEVT	Observation	R		System Weaver ID: 130487. Legacy ID: VCC TCr 021118

13.2 Appendix B – Lift-in-height of a Car’s Luggage Space

Lift-in-height = The maximum distance (“X” in Figure 60), normal to ground, that must be overcome to place items in/on the luggage, or cargo, compartment floor surface from outside the vehicle with the rear closure(s) in the open position. Measured at vehicle centerline, between the highest portion of the lower opening, including strikers, locking mechanisms, or any other obstruction and ground.

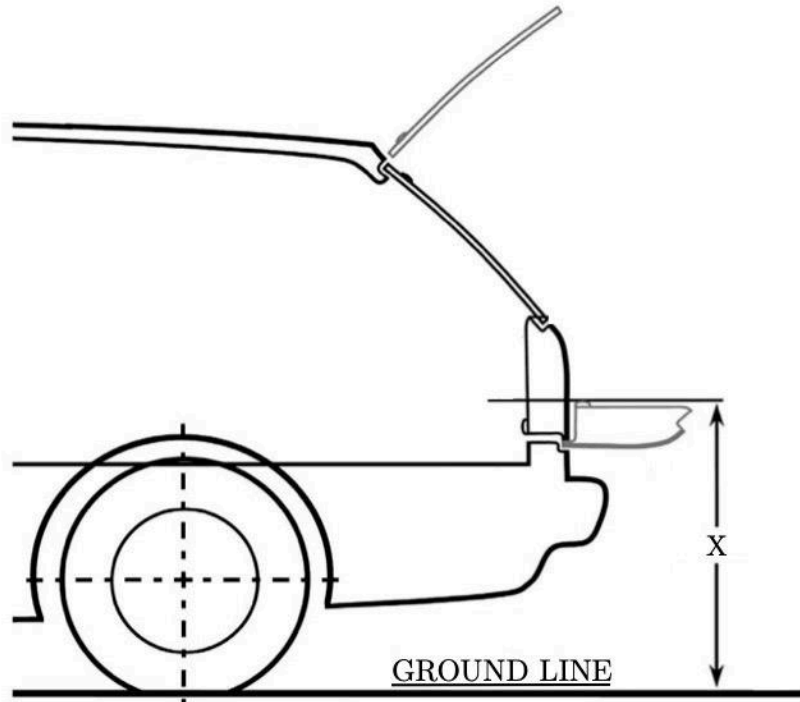


Figure 60 - Compartment loading metrics, two-closure-system.

13.3 Appendix C – Function-Means-Tree: Load Luggage

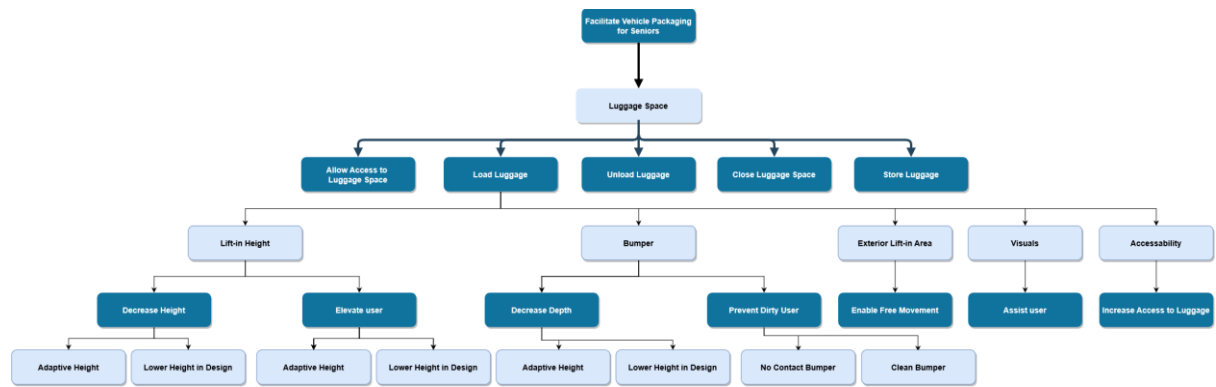


Figure 61 - The hierarchal function-means structure of the subtask "Load Luggage".

13.4 Appendix D – Function-Means-Tree: Unload Luggage

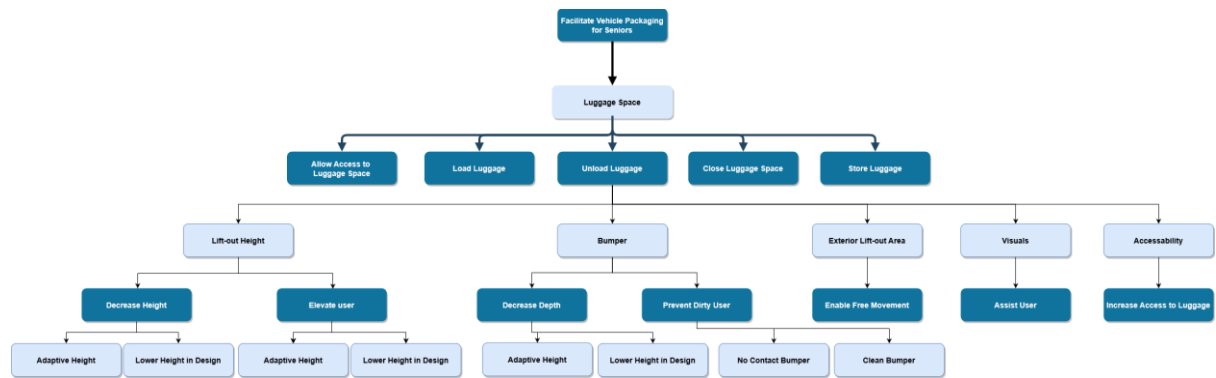


Figure 62 - The hierarchal function-means structure of the subtask "Unload Luggage".

13.5 Appendix E – Function-Mean-Tree: Close Luggage

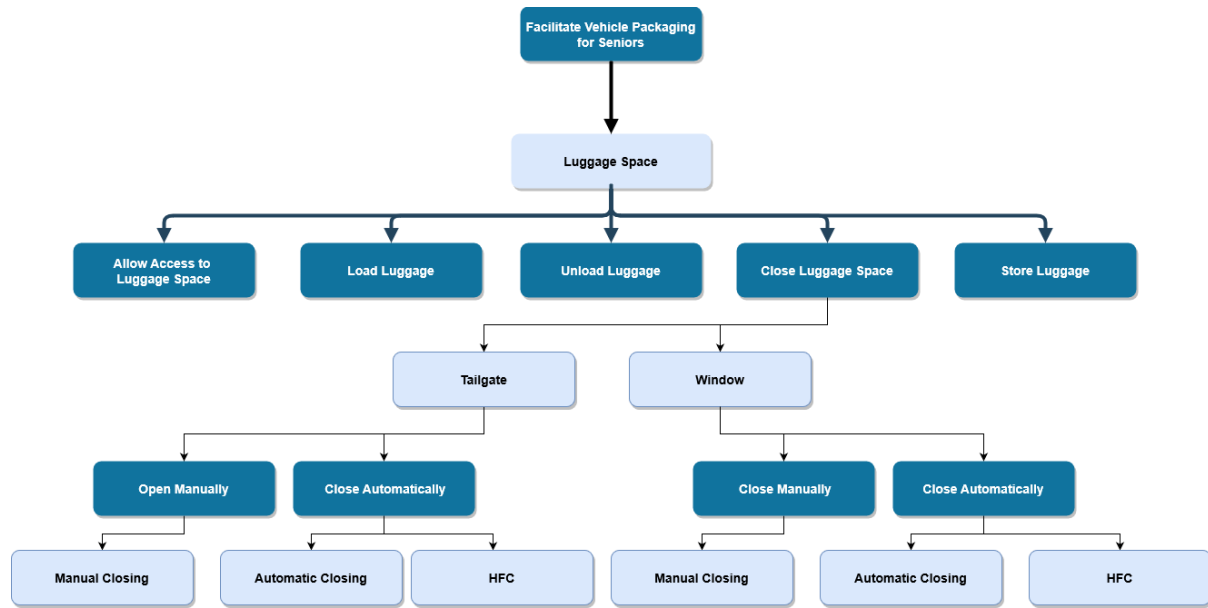


Figure 63 - The hierchal function-means structure of the subtask "Close Luggage".

13.6 Appendix F – Function-Means-Tree: Store Luggage

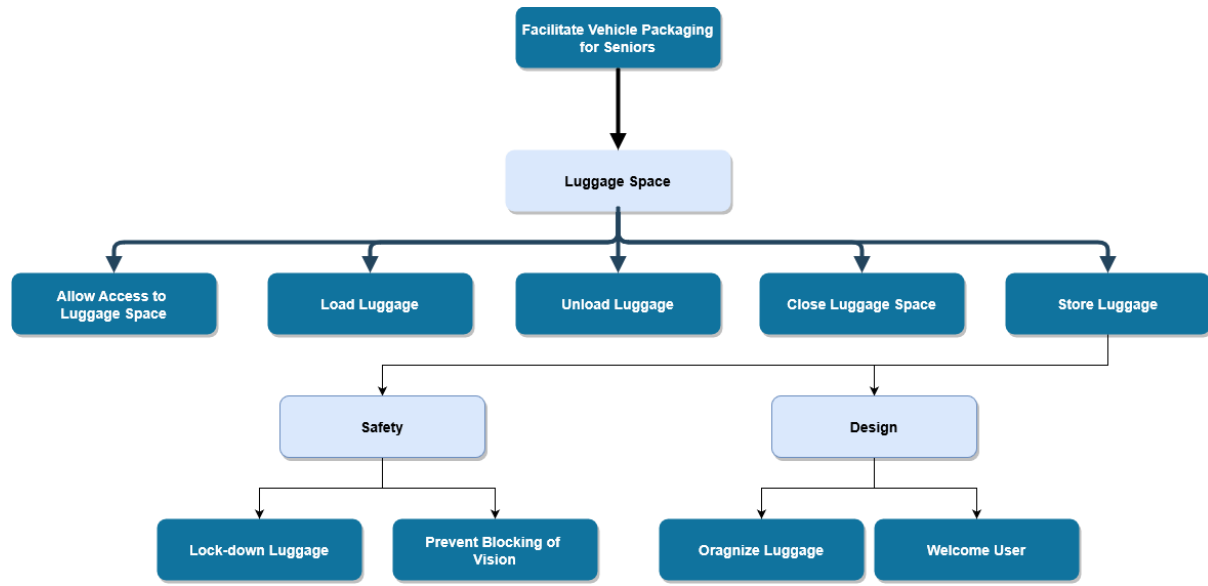


Figure 64 - The hierarchal function-means structure of the subtask "Store Luggage".

13.7 Appendix G – Kesselring Matrix

Table 12 - Kesselring matrix.

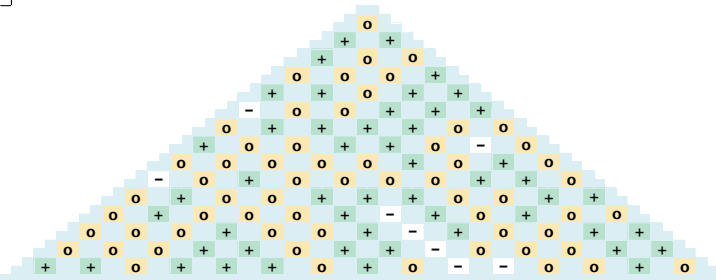
UN.No	Evaluation Criteria	WL	Remarks	IDEAL		Existing Solution		Automatic		Bare/Minimum		The Manual		Mechanical		Big/saligate		Kitchen/Cabinet		Low/NP	
				Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted
1.1	Access to the luggage in the trunk without putting the user's body in a backward position.	5	Give in a score of 5 for backward position	5	25	2	10	5	15	3	15	5	25	5	25	4	20	4	20	3	15
1.2	Access to the luggage in the luggage space without getting the user dirty.	4	All our users mention dirt as a problem. Extreme users have spoken	5	20	2	8	5	20	3	12	5	20	5	20	5	20	3	12	3	12
1.3	A continuous body motion when loading/unloading the luggage space.	3	It is more important to have a comfortable motion than a continuous	5	15	3	9	4	12	3	9	4	12	4	12	3	9	3	9	3	9
1.4	Open/close the luggage without getting dirty.	4	All our users mention dirt as a problem. Extreme users have spoken	5	20	3	12	5	20	5	20	4	16	5	20	5	20	3	12	5	20
1.5	A lift-in-height that facilitates the loading/unloading of the luggage space and prevents putting the user in any strain.	5	The most determining factor is comfort for loading/unloading	5	25	3	15	5	25	4	20	4	20	5	25	5	25	4	20	5	25
1.6	To be fully able to see the luggage without any greater physical effort perceived or discomfort.	5	Enable/deny access in the luggage space should not be demanding	5	25	2	10	4	20	3	15	2	10	4	20	4	20	4	20	2	10
1.7	To be guided by visual means	3	To be able to see here or put/grab things	5	15	3	9	4	12	4	12	4	12	4	12	4	12	4	12	4	12
1.8	To be assisted by visual/haptic feedback	3	To get feedback and intuitive instructions	5	15	1	3	4	12	4	12	4	12	4	12	4	12	4	12	4	12
2.1	The activity must be comfortable and user-friendly.	5	A general mindset	5	25	3	15	5	25	4	20	3	15	5	25	4	20	4	20	3	15
2.2	Analysis/way of loading heavy luggage in the car.	3	It will be a way to restrain the load heavy luggage in the matter of packaging concept	5	15	2	6	4	12	3	9	3	9	4	12	3	9	3	9	4	12
2.3	An effortless use of the luggage space without experiencing an extensive process.	4	To be able to see something to be easy in the define	5	20	2	8	3	12	2	8	4	16	3	12	2	8	5	20	3	12
2.4	Analysis and strenuous loading/unloading of the luggage in the luggage space.	3	It will be a way to restrain the load heavy luggage in the matter of packaging concept	5	15	2	6	4	12	3	9	3	9	4	12	3	9	3	9	3	9
2.5	The requirement for loading/unloading of the luggage space should be perceived as a service for the specific luggage.	4	It should not be "unnecessary" to be set the luggage space	5	20	2	8	4	16	3	12	3	12	2	8	2	8	5	20	4	16
2.6	All access to the luggage space.	4	It should be managed to open quickly this is irrelevant	5	20	1	4	4	16	1	4	5	20	1	4	1	4	5	20	1	4
SCORE				275	8	123	1	239	7	177	4	208	2	219	5	196	3	215	6	183	

13.8 Appendix H - House of Quality

Table 13- House of Quality

QFD: House of Quality	
Project:	Car Ergonomics: Inclusive design for seniors
Revision:	3
Date:	04-22-20

Correlations	
Positive	+
Negative	-
No Correlation	o
Relationships	
Strong	●
Moderate	○
Weak	▽
Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



Row #	Weight Chart	Relative Weight	Importance (1-5)	Maximum Relationship	Customer Requirements (Explicit and Implicit)	Technical Requirements																Customer Competitive Assessment					
						1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	1	2	3	4	5	
1	9%	5	9	9	Access to the luggage in the trunk without putting the user's body into an awkward position.	●	▽	▽	▽	●	▽	●	●	●	●	o	●	▽	o	o	▽	3	4	4	4		
2	5%	3	9	9	Access to the luggage in the passenger seats without putting the user's body into an awkward position	●	▽	▽	▽	●	▽	●	●	●	▽	o	●	▽	▽	o	o	▽	3	3	3	3	
3	5%	3	9	9	Access to the luggage in the luggage space without getting the user dirty	o	●	▽	o	●	●	o	▽	o	▽	o	o	o	▽	o	o	o	2	4	4	4	
4	5%	3	9	9	Access to the luggage in the passenger seats without getting the user dirty	o	●	▽	o	●	●	o	▽	o	▽	o	o	o	o	o	o	o	2	2	2	2	
5	7%	4	9	9	A continuous body motion when loading/unloading the luggage space	●	▽	o	▽	▽	o	o	o	●	o	o	o	o	o	o	o	o	3	4	4	3	
6	7%	4	9	9	Open/close the tailgate without getting dirty.	▽	●	▽	o	●	●	o	o	o	o	o	o	o	o	o	o	o	2	5	5	5	
7	9%	5	9	9	A lift-in height that facilitates the loading/unloading of the luggage space and prevents putting the user in any strain.	●	▽	o	▽	▽	o	o	o	o	o	o	o	o	o	o	o	2	4	4	3		
8	7%	4	9	9	To be fully able to use the tailgate without any greater need of physical effort or perceived discomfort.	▽	▽	▽	▽	●	▽	●	o	o	o	o	o	o	o	o	o	o	3	5	5	4	
9	4%	2	9	9	To be guided by visual means	▽	▽	o	●	o	o	o	o	o	o	o	o	o	o	o	o	o	1	4	4	4	
10	4%	2	9	9	To be assisted by visual and haptic feedback	▽	▽	●	●	o	o	o	o	o	o	o	o	o	o	o	o	o	o	1	4	4	4
11	9%	5	9	9	The activity must be comfortable and user-friendly	●	▽	▽	o	●	●	o	o	o	o	o	o	o	o	o	o	o	3	4	4	4	
12	5%	3	9	9	An easy way of loading heavy luggage in the car	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	2	3	3	2	
13	7%	4	9	9	An effortless use of the luggage space without experiencing an extensive process	▽	▽	●	▽	o	o	o	o	o	o	o	o	o	o	o	o	o	2	3	3	4	
14	5%	3	9	9	An easy and nonstrenuous loading/unloading of large luggage in the luggage space	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	2	3	3	2
15	4%	2	9	9	The required effort of loading/unloading the luggage space, should not be perceived as overwhelming for the specific luggage	▽	▽	●	▽	▽	o	o	o	o	o	o	o	o	o	o	o	o	2	4	4	4	
16	7%	4	9	9	A fast access into the luggage space	▽	▽	▽	▽	o	o	o	o	o	o	o	o	o	o	o	o	o	o	1	3	1	4
Product Targets						Lift in Height: 600mm	No Contact With Dirt	Able to Customize Luggage Space	Visual Assistive Guidance	Automatic Opening	Smart Door-handle for Tailgate	Low entrance line and effort into luggage space	No Movement Restrictions	Enable Good Reach Within the Luggage Space	No Perceived Awkwardness / Inconvenience	Enable the Sparty Design	Easy to Reach Luggage within Luggage Space	Appropriate Resistance for Intuitive Use	No Perceived Discomfort	PMMA score & No User Injuries	Perceived Quality						
Max Relationship						9	9	3	9	9	9	9	9	9	9	3	9	9	9	9	3	9					
Technical Importance Rating						457.14	242.86	264.29	210.71	528.57	364.29	685.71	385.71	489.29	371.43	246.43	432.14	203.57	253.57	214.29	192.86						
Relative Weight						8%	4%	5%	4%	10%	7%	12%	7%	9%	7%	4%	8%	4%	5%	4%	3%						
Weight Chart						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■							
Lynk & Co 01						2	1	2	2	3	2	2	4	3	5	4	3	2	2	4	4	4	4	5			
Sliding to Roof						5	5	4	5	5	4	3	4	4	5	3	3	4	5	4	4	4	4	6	7		
Cabriolet						3	5	4	5	5	4	2	5	4	5	3	4	4	4	4	2	4	4	6	3		
Kitchen Cabinet						4	4	3	5	5	4	4	3	4	4	3	3	3	3	2	3	3	3	5	6		
Technical Competitive Assessment																											

13.9 Appendix I – Observation Protocol: Object X1

Observation object: A

Observed in Kungälv, 2020-02-18

Personal data

Sex - Male

Age - 78

Height - 166 cm

Weight - 68 kg

BMI - 24.7

Profession - Retired/Clerk

Car used during observation

Toyota Aygo 1.0, 2013



About

Spirited and healthy for his age, with a positive mindset and attitude towards life. Lives with his wife in a calm suburb to Gothenburg. He spends his spare time socializing with friends and family and takes care of a dog a couple of days during the week. He uses his car almost every day.

Disabilities

- Previously had sciatica.
- Minor age-related motion reduction.
- Impaired vision, using correction aid.

Motion ability

Self-perceived

Highly impaired
mobility

No mobility
problem



Observer-perceived

Highly impaired
mobility

No mobility
problem



Observation

Performs his general tasks around the car without any major difficulties. However, since the used car model is slightly smaller and rather low, the ingress/egress activity post a challenge. The luggage space is also poorly designed, which is noted in the habits of use.

Quotation

"The threshold to the trunk is too high".

"While getting in, I fall into the seat and use my arms to lift in my left leg. When getting out, I have to use my arm strength to pull myself out".

"When storing luggage, I usually use the passenger seats. I only use the luggage space when I'm carrying a larger suitcase".

Likes

- The clear and standardized control panel and infotainment system of the car.
- The car is easy to park.

Dislikes

- The mirrors don't supply enough information about the surroundings of the car, would appreciate a feedback system.

13.10 Appendix J – Observation Protocol: Object Y1

Observation object: B

Observed in Kungälv, 2020–03–03

Personal data

Sex - Female

Age - 78

Height - 162 cm

Weight - 81 kg

BMI – 30.9

Profession - Retired/Dental Nurse

Car used during observation

Skoda Octavia 1.6, 2000



Observation

Performs the general tasks around the car with some effort. Due to her lack of movement in her right arm, many actions are somewhat hindered and solutions to work around her disabilities have been constructed. The manually managed tailgate was not at all comfortable to use and a high lift-in height made it difficult to deposit heavier luggage in the luggage space. If possible, she avoided the luggage space and placed luggage in the passenger seat instead.

Quotation

"I would like to receive some feedback regarding my surrounding when I reverse".

"I have no idea how I actually set up my seat, as long as it's comfortable I'm good to go".

"It's such a large process to get into the luggage space and lift everything in, much easier and quicker to just put it in the passenger seat".

Likes

- The robust and spacious design of her old Volvo 850 estate.

Dislikes

- To get dirty when handling a car
- To reverse into a parking lot.

About

Positive mindset with some major disabilities due to several different causes. Lives together with one person and their dog in a calm suburb to Gothenburg. She enjoys the company of others and go to painting classes every week, she also visits Gothenburg occasionally. She uses her car daily.

Disabilities

- Macula of retina.
- Some age-related cognitive disability.
- Osteoarthritis of the right knee, uses a cane to support her walking.
- Due to shingles, major locomotion disability in her right hand.
- Impaired vision, using correction aid.

Motion ability

Self-perceived

Highly impaired mobility

No mobility problem



Observer-perceived

Highly impaired mobility

No mobility problem



13.11 Appendix K – Observation Protocol: Object Y2

Observation object: C

Observed in Kungälv, 2020-02-24

Personal data

Sex - Female

Age - 76

Height - 163 cm

Weight - 75 kg

BMI - 28.2

Profession – Retired

About

Bright and sharp in mind, but age has taken its toll on her body. Lives together with one person and their dog in a calm suburb to Gothenburg. Prior retirement, she drove several types of vehicles for the military. She uses her car daily.

Disabilities

- Knee-protheses in both legs. Uses a cane to support her walking.
- Right knee injured for 6 months, is now under treatment.
- A whiplash damage causing pain and stiffness in upper part of body.

Motion ability

Self-perceived

Highly impaired mobility

No mobility problem



Observer-perceived

Highly impaired mobility

No mobility problem



Car used during observation

Mazda Demio 1.5, 2000



Observation

Does not experience any major problems when interacting with the car. However, her stiffness and reduced motion ability has a negative effect on her driving skill, for example the incapability of changing body position while reversing. The cars height is optimal for the observed person, both regarding ingress/egress and loading/ unloading luggage.

Quotation

"I prioritize the driving experience higher than car brand".

"It would be nice to be able to rotate the driver's seat while exiting".

"Since I can't turn around, I find it hard to get an overall view of the cars surrounding environment".

"It's strenuous to put on the seatbelt".

Likes

- The "boxy" look of her car, a lot of space and comfortable height.
- A reliable car, stable functionality.

Dislikes

- The mirrors don't supply enough information about the surroundings of the car.
- That the seat controls to change the seat position is difficult to access.

13.12 Appendix L – Observation Protocol: Object Y3

Observation object: D

Observed in Kungälv, 2020–03–11

Personal data

Sex - Female

Age - 76

Height - 156 cm

Weight - 59 kg

BMI - 24,2

Profession - Retired/Preschool Teacher

About

A somewhat pessimistic mindset with typical age-related disabilities. Does not drive herself, but her husband does. They live together in a calm suburb to Gothenburg. Enjoys reading and knitting at home, as well as cooking and baking.

Disabilities

- Muscle impaired on the right side of the body, due to a stroke.
- Age-related cognitive disability and motion reduction.
- Impaired vision, using correction aid.

Motion ability

Self-perceived

Highly impaired mobility

No mobility problem



Observer-perceived

Highly impaired mobility

No mobility problem



Car used during observation

Lynk & Co 01, 2018



Observation

Performs general tasks with the car with some difficulty, for instance, car doors are heavy, and the ride is too high for her stature. Due to the cars height several problems emerge: unable to close the tailgate since she cannot reach it, packing luggage is extremely uncomfortable, ingress/egress requires lots of effort.

Quotation

"How do I close the tailgate? Oh, I cannot reach that button".

"I would need a ladder to climb up in this seat".

"This door is really heavy".

Likes

- Like the automatic opening of the tailgate.
- A luxury impression inside a car.

Dislikes

- To get reminded of her height and excluded in the design because of it
- To load/unload luggage in a car.

13.13 Appendix M – Empirical Study: Observation Scenarios

To ensure that all observation objects went through the same procedures, movements, and actions a list of scenarios was created. This scenario list was used as assistance during the observation to ensure all data was gathered. Due to the characteristics of the observations, where it was desirable to create fully natural and non-staged situations, there was not a specified order of which the scenarios were to be performed. They were performed in most order that was the most natural for the specific observation object.

To further assist the observer, hypotheses of problems that might arise during the scenarios based on previous literature had been noted. These notations could help to guide the observers' attention and ensure that no data remained unnoticed.

Table 14 - Observation Scenarios.

Scenarios	Scenario	Hypothesis		
S.1	Opening/Closing of door	Shoulder Position	Leg position	Grip Technique
		Approach to door		
		Over all Strain		
S.2	Ingress	Spine position	Leg movement	Arms support
		Sliding movement when sitting	Supporting actions	RLF
		Head/Neck position	General strategy	
S.3	Egress	Left Leg First?	Both Legs Out?	
		Spine position	Head/Neck position	
		Drag/Push support with arms		
S.4	Seat Adjustment	Enter an altered car	Reach?	
		Uncomfortable positions		
S.5	Position while seated	Legs	Leaning	Arms resting
S.6	Grocery Shopping	Effort to open trunk	Lifting technique	
		Bodyposition filling trunk		
		Bodyposition lifting groceries		
S.7	Heavy Package	Weight of object	Lifting technique	
		Bodyposition filling trunk	Fold seats	
		Bodyposition lifting groceries		
S.8	Using Backseat	Ingress/Egress	Usage of backseat	
		Comfort in backseat		
		Riding position from backseat		
S.9	Using infotainment system	While stationary		
		While driving		
		Eye sight		

13.14 Appendix N – User Personas

SENIOR WITH NATURAL DISABILITIES CAUSED BY AGE

Definition of persona:

A persona depicts an envisioned user.

These personas are “critical” persona that represents the customer needs.

“Personas may be easily used in inclusive design because they present synthetic characteristics and do not stigmatize individual limitations. However, they should be carefully designed in order to avoid reinforcing stereotypes of disability and people with disabilities. Thus, a large range of user characteristics, attitudes and interests should be included rather than focusing strongly on the user’s limitations induced by a disability.”

- (HaptiMap, 2009)

Leif



Figure 65 - Persona picture of the fictive character "Leif" (The Sun, 2016).

QUOTATION

“I use my car on a daily basis, and it works sufficiently, but somedays I have so much back pain that I barely can get out of it!”

BACKGROUND

- Swedish
- 78 years old white male
- Worked as a construction worker for the full extent of his working life
- Retired for 10 years
- Married, 2 children and 4 grandchildren's
- Lives in a small village, 40km from a large town.
- Babysits his grandchildren twice a week, 50km one-way.
- Uses the car a few days a week for grocery shopping
- Just needs the car to function.
- Not really fussed about all the fancy extra things.

ATTRIBUTES

- Older
- Male
- Ordinary wealth for the age group – working class
- Less experience with computers and the internet of things
- Prioritizes comfort
- Does not want to compensate functionality for other attributes, e.g. design
- Above average interest in cars.
- Demanding if things goes wrong with the car
- Do not want to appear ignorant/stupid when handling the car or learning the car
- Reduced:
 - Eyesight
 - Hearing
 - Balance
 - Reaction
 - Cognitive skills to and the ability to consume information
 - Movement
 - Pain in knees, lower back and neck.
- A bit overweight, has BMI of 34.
- Loves food and would like to eat a steak of red meat every meal.

CUSTOMER NEEDS

- As owner:
 - Simplicity
 - Good service when needed.
 - Trustworthy product
 - Buy it and it's working, no extra installations.
 - The ability to bring up to 4 extra persons
 - Easy controls, both visuals and self-explanatory.
 - High storage ability
- As other user:
 - High comfort
 - Easy access in and around the car
 - Comfortable ingress/egress movement

Agda

Figure 66 - Persona picture of the fictive character "Agda"(Culturacolectiva, 2017).

QUOTATION

"Without a car I would not be able to visit my friends and relatives, but other than those occasions it is rarely used... well I also use it when I go shopping for groceries."

BACKGROUND

- Swedish
- 84 years old white female
- Worked as a teacher for the full extent of her working life
- Retired for 24 years
- Married
- Love cats
- Lives in an apartment in a large city, a bit outside the city-center
- Lives an active life and enjoys water aerobics once a week and often participates in senior training at the gym.

ATTRIBUTES

- Older
- Female
- High wealth regarding the age group – Upper middle class
- Poor skill and interest in computers and the internet of things
- Prioritizes comfort
- Would like to have a good-looking car.
- Reduced:
 - Eyesight
 - Hearing
 - Balance
 - Reaction
 - Cognitive skills to and the ability to consume information
 - Movement
 - Pain in Shoulders, and
- Minor rheumatism, some pain in joints and reduced grip strength

CUSTOMER NEEDS

- As owner:
 - Easy to keep clean.
 - Simplicity.
 - Good service when needed.
 - Trustworthy product.
 - Buy it and it's working, no extra installations.
 - Easy controls, both visuals and self-explanatory.

- As other user:
 - High comfort.
 - Easy access within the car.
 - Comfortable ingress/egress movement.

Average pension in Sweden before tax:
All: 17 600 SEK / month (2018)
Women: 14 500 SEK / month (2018)
Med: 21 000 SEK / month (2018)
(Pensionsmyndigheten, 2020).