Komorebi

A Biophilic Design Concept for Enhanced UX in Autonomous Cars

Duy Long Nguyen

DIVISION OF INNOVATION | DEPARTMENT OF DESIGN SCIENCES
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MASTER THESIS

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Supervisor: Per Liljeqvist
Co-supervisor: Håkan Eftring
Examiner: Per Kristav

Abstract

Autonomous cars have the potential to revolutionize private transportation by allowing occupants to utilize their travel time for other activities. Considering the new opportunities for improved productivity, as well as the increasing demand for constant digital connectivity, reconnecting with nature will be crucial for alleviating cognitive stress and promoting healing and well-being.

In this thesis, an overview of predicted trends in autonomous cars is presented along with the potential risks of prolonged exposure to digital connectivity. The aim is to explore new possibilities of improving user experience (UX) and relaxation in fully autonomous vehicles by incorporating nature-oriented design. Numerous biophilic design patterns are introduced to develop a concept car that provides a restorative and rejuvenating environment.

The design process adopts the Double Diamond Methodology with a focus on UX. An extensive literature research is conducted to investigate the benefits of biophilic implementations on human cognitive performance and well-being. Concept ideas are generated with basis on the biophilic patterns and evaluated throughout the process to consider current and future predictions of customer needs.

The result of the thesis is a nature-oriented holistic concept that combines the design disciplines exterior, interior and user experience. The concept incorporates principles from the Japanese and Scandinavian design philosophies as inspirational sources to give depth to the design and to achieve a harmonious integration of nature and man-made environments. The result is presented as a digitally modeled concept.

Keywords: User Experience (UX), Nature-oriented, Biophilic Design, Concept, Autonomous Cars, Japanese Design

Sammanfattning

Självkörande bilar har potentialen att revolutionera privattrafiken genom att låta passagerare använda sin restid till andra aktiviteter. Med tanke på de nya förutsättningarna till ökad produktivitet, samt den ökande efterfrågan på digital uppkoppling, blir det väsentligt att återfinna anknytning till naturen för att reducera kognitiva belastningar och främja människors välbefinnande.

I detta examensarbete presenteras en översikt över förutsagda trender för självkörande bilar tillsammans med de potentiella risker som finns med långvarig exponering av digital uppkoppling. Målet är att utforska nya möjligheter för att förbättra användarupplevelsen (UX) i fullständigt autonoma fordon genom integration av naturorienterad design. Ett flertal biofiliska designmönster introduceras för att utveckla ett fordonskoncept som erbjuder en miljö för återhämtning och avslappning.

Designprocessen baseras på Double Diamond-metoden med fokus på UX. En omfattande litteraturstudie genomförs för att undersöka fördelarna med biofiliska implementeringar och hur dessa påverkar människors kognitiva förmågor samt välbefinnande. Konceptidéer genereras med utgångspunkt i de biofiliska mönstren och utvärderas under hela processens gång för att beakta nuvarande och framtida förutsägelser av kundbehov.

Resultatet av examensarbetet är ett naturorienterat konceptförslag som kombinerar exteriör, interiör och användarupplevelse. Vidare tar konceptet inspiration från estetiska värden i japansk och skandinavisk design och presenteras slutligen i form av ett digitalt modellerat koncept.

Nyckelord: Användarupplevelse, Natur, Biofilisk Design, Koncept, Japansk Design

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Lund, June 2023

Duy Long Nguyen

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List of Acronyms

AV	automated vehicle
ADAS	automated driver assistance systems
ADS	automated driving systems
ART	Attention Restoration Theory
ICE	internal combustion engine
OEM	original equipment manufacturer
SAE	the Society of Automotive Engineers
SRT	Stress Reduction Theory
SubD	subdivision surface
UX	user experience

1 Introduction

This chapter introduces the context and purpose of the thesis, as well as the aims and delimitations.

1.1 Background

Autonomous cars have the potential to revolutionize private transportation by allowing occupants to utilize their travel time for other activities. This is especially true with the highest level of automation, in which a human driver is unrequired.

Considering the new opportunities for improved productivity, as well as an increasing demand for constant digital connectivity, options for relaxation and for alleviating cognitive stress will be significantly relevant. One such option is by reconnecting with nature.

Having evolved within the natural environment, humans have a strong connection to natural surroundings. Biophilia refers to this biological connection. The concept of biophilia describe the inherent inclination humans have of wanting to affiliate with nature, and that this connection can evoke emotional responses and affect personal well-being (Browning et al., 2012).

This thesis will explore principles for biophilic design, the application of biophilia in design and human built environments, and how these can be implemented into vehicle design.

1.2 Aim

The aim of the thesis is to explore new possibilities of improving user experience (UX) and relaxation in fully autonomous vehicles by incorporating nature-oriented design. Additionally, it will seek to present the principles behind nature-based design philosophy and investigate how reconnecting with nature can reduce cognitive stress and improve human well-being.

1.3 Objective

The objective of the thesis is to present a holistic concept that combines the design disciplines exterior, interior and user experience, that concurrently fulfills the aim. The Japanese and Scandinavian design philosophies will be the main basis for inspiration, where associated principles will act as support for the concept development. The result will be presented as a digitally modeled concept.

1.4 Scope and Delimitations

Automated vehicles (AV), as per NHTSA's definition, are those vehicles *"in which at least some aspects of a safety-critical control function (e.g., steering, acceleration, or braking) occur without direct driver input"* (NHTSA, 2016). The term may thus not only encompass cars but could also include numerous other types of vehicles, e.g., watercrafts, aircrafts, trucks, and buses. Furthermore, these transportation modes can be categorized into private and public transportation services. As a delimitation, the thesis will only discuss autonomous cars as a private transport, i.e., for individual use.

Additionally, there exists 6 different levels of vehicle autonomy ranging from 0 to 5. At the lowest level, *Level 0: Manual Driving*, the vehicle is incapable of autonomous driving and is solely controlled by a human driver. While at the highest level, *Level 5: Full Driving Automation*, the vehicle is capable of driving by itself under all conditions without human involvement (SAE, 2021). The thesis will only consider Level 5 Autonomy, in which there are no driver and the

users are all passengers. Vehicle autonomy will be discussed further in section 3.2.

In relation to cognition, the project will focus exclusively on the emotional impact at a visceral level. While it is important to acknowledge all three levels (visceral, behavioral, and reflective), the latter two will not be the primary focus of this thesis. These terms will be further discussed in section 3.4.

UX is a broad concept, and improving UX can be achieved through various aspects as later discussed in section 2.6. The scope of this thesis is enhancing UX through comfort and relaxation by reconnecting with nature.

As the thesis seeks to present an autonomous car concept, the development will not be limited by current knowledge and technologies. Future technologies may be utilized if they are deemed reasonably feasible. Neither economic aspects, manufacturing restrictions or legal regulations will be taken into consideration, as well as practical limitations, e.g. roof height and wheel size. Nonetheless, the design process will still attempt to balance form, curves, and dimensions to establish coherent proportions and car aesthetic.

In the scope of this thesis, it is assumed that there is no internal combustion engine (ICE) and that the AV concepts are fully electric.

Concept modeling will be entirely digital, thus no physical models will be made. Consequently, no physical user tests will be performed, instead, the evaluation of design decisions will in addition to criteria established from prior research and studies, be based on iterative modeling where discussions with users regarding progression, will be conducted on multiple occasions.

2 Methodology

This chapter outlines the methods and tools employed for planning and executing the thesis.

2.1 Planning

To coordinate and track larger project schedules, a method such as the Gantt chart may be adapted. The chart displays a left-sided list of activities against a horizontal timeline, where each activity is represented by a bar. The length and position of the bar reflect the outset, duration, and deadline of the activity (Ulrich et al., 2012). This gives an expansive outlook of the entire project and helps identifying when each activity is supposed to start, how long they last and if certain activities overlap or must be performed in succession.

The Gantt chart for the project including both planned and actual outcome, is enclosed in appendix A.

2.2 The Double Diamond

The main methodology used for the thesis is the *Double Diamond* design process model, introduced by the British Design Council in 2004 (Design Council, 2023). The framework is a comprehensive and visual description of the design process and has the benefits of versatility and simplicity of use.

The Double Diamond consists of two diamonds separated into the following four phases: *Discover*, *Define*, *Develop*, *Deliver*. These phases are either divergent or convergent in nature; the divergent thinking represented by Discover and Develop, adopting an explorative approach, whilst the convergent thinking represented by Define and Deliver, focusing on taking narrowing action. The process is, however, not linear. Iterative progressions are necessary to spot and

avoid errors early in the process (Design Council, 2023) The objectives of the four phases are further described in the following sections.

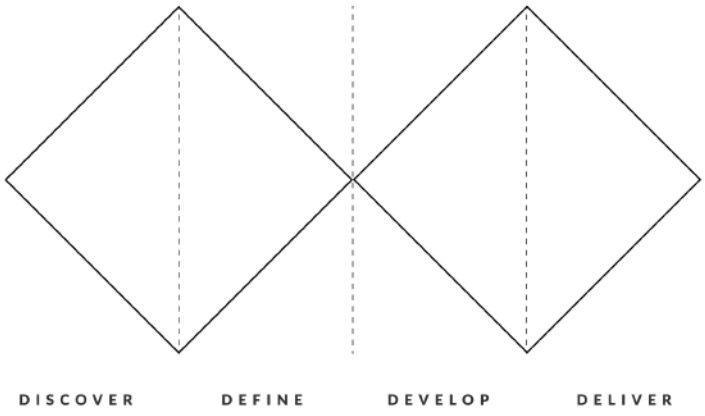


Figure 2.1. Illustration of the Double Diamond framework.

Discover

Discover is the first divergent phase with the purpose of gathering insight into the problem. It helps people understand, rather than simply assume, what the problem is. Methods, e.g., literature studies, interviews, and questionnaires, can be used to gather qualitative or quantitative data. Depending on the project, different methods are often used in combination to gather complementary data (Design Council, 2023).

In this project the Discover phase will consist of literature research about current trends of vehicle autonomy and include the principles and effects of biophilic design. Additionally, the principles behind Japanese and Scandinavian design philosophy will be studied. User research will be conducted to gain practical data and be used for triangulation.

Note that in this phase, no issues are to be solved, the objective is rather to understand the problem before moving on to the next phase.

Define

With sufficient information and knowledge gathered from the Discover phase, the data is sorted to develop a clear brief that frames the design challenge for the thesis. Potential revisions for the aims and objectives can be made, to ultimately serve as guideline for the concept development in the subsequent phase (Design Council, 2023).

Develop

Following the convergent definition phase, comes the divergent Develop phase with explorative grounds based on the definition and criteria established in the prior phase. In the Develop phase, solutions and concepts are created, tested, iterated, and refined until ready for finalization (Design Council, 2023).

Deliver

Deliver is the final phase of the Double Diamond. In this step, the concept developed in the preceding step is evaluated against the issues presented in the first half of the Double Diamond, and ultimately finalized and delivered (Design Council, 2023).

2.3 Ulrich & Eppinger's Design Methodology

Ulrich & Eppinger's design methodology is a generic product development process model which essentially consists of 6 phases: *Planning, Concept Development*, *System-Level Design*, *Detail Design, Testing and Refinement*, *Production Ramp-Up* (Ulrich et al., 2012).

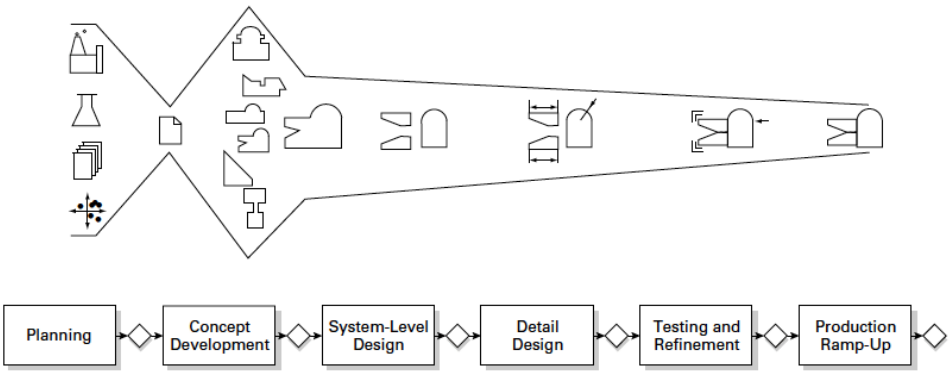


Figure 2.2. Illustration of Ulrich & Eppinger's product development process.

Elements of Ulrich & Eppinger's design methodology will be implemented in the thesis, more specifically from the Concept Development phase. The utilized elements will be further explained in the sections where they appear.

2.4 Interviews

User research is conducted through semi-structured interviews (SSIs) to collect qualitative data.

SSIs are chosen as they provide a flexible framework that allows for a balance between structure and openness. A set of predetermined questions and themes is established to guide the interview process and ensuring consistency across interviews. However, the semi-structured nature also allows the interviewees to elaborate on their experiences and providing unexpected insights and themes. With the project purpose of exploring new possibilities of improving UX, this interview structure was deemed suitable as new perspectives could be provided by the people having first-hand experience with the relevant topics.

2.5 Questionnaire

The evaluation of the final concept is done through an online questionnaire measuring UX.

The questionnaire draws inspiration from the Attrak Diff and UX Questionnaire (UEQ) templates and incorporates additional nature-oriented questions. It follows a similar structure to the UEQ, consisting of pairs of contrasting UX attributes relevant to the concept. These attributes are represented by seven circles indicating gradations between the opposites. Usability aspects are excluded in this test since there is no physical concept to measure. The questionnaire is enclosed in appendix D.

2.6 User Experience

The International Organization for Standardization (ISO) defines UX as follows (ISO, 2019): "*Users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviors, and accomplishments that occur before, during and after use.*"

Another definition of UX is Marc Hassenzahl's model, which conceptualizes it in terms of pragmatic and hedonic aspects. By pragmatic, it is meant how simple, practical, and obvious it is for the user to achieve their goals, and by hedonic, it

is meant how evocative and stimulating the interaction is to them (Preece et al., 2019).

UX essentially refers to the overall experience of a person using a system, product, or service. It encompasses the user's perceptions and feelings during the entire process of interacting with the product, where aspects of central importance are usability, functionality, aesthetics, content, look and feel, emotional appeal. The goal of UX design is ultimately to create a positive experience for the user by evoking satisfactory feelings. Note however that a sensual experience cannot be designed, but only evoked through appropriate design features (Preece et al., 2019).

UX will be a central principle in the thesis together with an implemented user-centered approach, i.e., users are involved appropriately in the development process, and where design decisions are based on explicitly understanding users, tasks, and environments (GSA, 2023).

2.7 Modeling

Digital concept modeling as well as renderings will be produced with *Blender*. *Blender* is a free and open-source software used to create different types of 3D-graphics, e.g., VFX, animations and 3D-modeling. The thesis will predominantly utilize the latter in tandem with the provided render engine.

The modeling technique being used is Subdivision Surface (SubD) modeling. SubD modeling involves creating a rough base mesh with a relatively low polygon count and then applying a subdivision algorithm to subdivide the polygons. This creates a smoother derivative surface with additional levels of detail, which enables efficient editing and manipulation of the model.

3 Discover

In this chapter, the relevant theory and principles are presented and explained. The chapter includes an extensive literature research, benchmarking of related concepts, and user research.

3.1 Theory and Literature Research

Literature research is conducted to provide knowledge for understanding the problem space regarding autonomous vehicles. Initially, the chapter defines the term and present prospects for it. The following sections subsequently describe the theory concerning emotional design, biophilia and nature-oriented design, and how these elements can be implemented to improve UX, relaxation and the passengers' overall well-being. Connection is then made to Japanese and Scandinavian design philosophies to conclude the literature research.

3.2 Vehicle Autonomy

Automated vehicles, also referred to as Automated Driving Systems (ADS), as per NHTSA's definition, are those vehicles *"in which at least some aspects of a safety-critical control function (e.g., steering, acceleration, or braking) occur without direct driver input*" (NHTSA, 2016). The continuing evolution of automotive technology aims to deliver even greater safety benefits with the aim that in the future, the system may be able to operate the vehicle independently when human drivers are unwilling or unable to do it themselves (NHTSA, n.d.).

Vehicle safety is one of the biggest anticipated benefits with higher levels of automation (NHTSA, n.d.) As the system takes over the driving tasks, human errors such as distracted driving can be eliminated from the chain of events that can lead to an accident. ADS is expected to offer better protection for drivers

and passengers, as well as other road-users such as pedestrians and cyclists, and may help reduce crash risks, resulting injuries and insurance costs (NHTSA, n.d.; Korkmaz et al., 2022; Fagnant & Kockelman, 2015; Litman, 2023). According to a KMPG report, the implementation of ADS is predicted to reduce the frequency of accidents by nearly 90% (Albright et al., 2017). Although higher levels of ADS have yet to be available to consumers, there already exist advanced driver assistance systems (ADAS) and active safety systems assisting the driver by detecting imminent danger and working to avoid them (NHTSA, n.d.)

With increasing AVs, the potential for automated ridesharing becomes more viable. Not only could this increase independent mobility for non-drivers, seniors, and people with disabilities, with adherence to universal design principles of equitable use and inclusiveness, but it could also increase road capacity, cost savings, and suggest better environmental practices by reducing traffic and parking congestion, increasing fuel efficiency, and reducing pollution (Anderson et al., 2014; Fagnant & Kockelman, 2015; NHTSA, n.d.; Litman, 2023).

Nevertheless, before considerable progress has been achieved in ADS, many of the predicted benefits are still under reasonable uncertainty, with studies suggesting it would require the highest levels of automation, and that autonomous vehicles have become prevalent and affordable before the benefits become apparent (Zmud & Sener, 2017; Davidson & Spinoulas, 2015). Although impacts of ADS are difficult to predict, their transformative potential has certainly been recognized.

3.2.1 Autonomous Driving Levels

The Society of Automotive Engineers (SAE) defines six levels of vehicle automation as depicted in the following figure. As stated in section 1.4, the autonomy being considered throughout the thesis is *Autonomy Level 5: Full Driving Automation*.

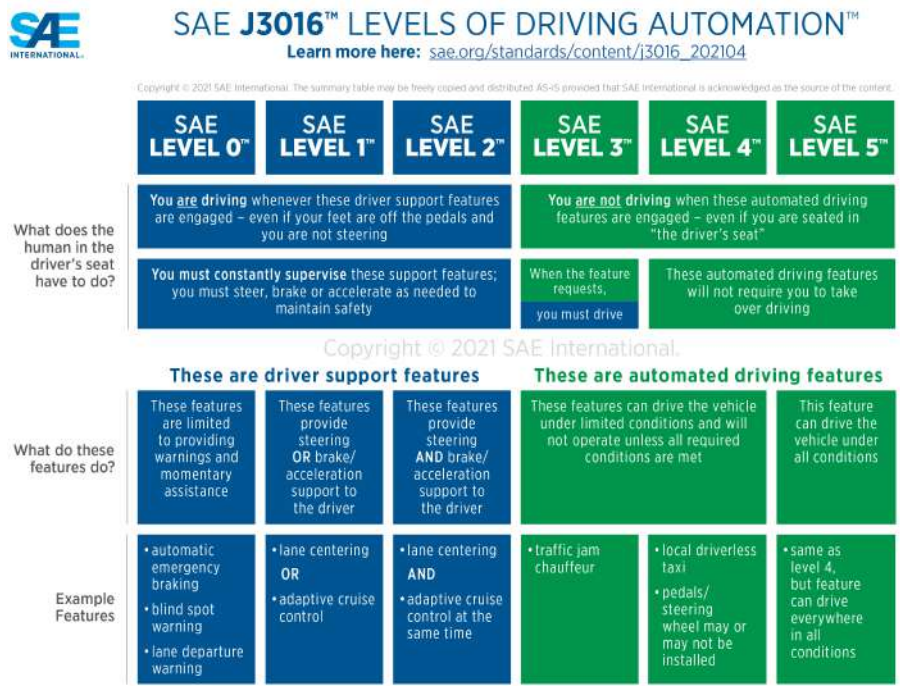


Figure 3.1. Automated Driving Levels by SAE (SAE, 2021).

Level 0: No Driving Automation, the vehicle is incapable of autonomous driving and the driver is fully responsible for controlling the vehicle. The system may provide momentary driver assistance, e.g., automatic emergency braking, forward collision warning, lane departure warning (NHTSA, n.d.).

Level 1: Driver Assistance, the driver is responsible for driving the vehicle, but the system can provide continuous assistance with either acceleration/braking OR steering, e.g. adaptive cruise control, lane keeping assistance (NHTSA, n.d.).

Level 2: Partial Driving Automation, the driver is still responsible for operating the vehicle, however when engaged, the system can control both steering and acceleration/braking, e.g., highway pilot (NHTSA, n.d.).

Level 3: Conditional Driving Automation, the vehicle can drive independently to some extent, although upon request and with advance notice, the driver must be available and ready to retake control of all aspects of the driving task (NHTSA, n.d.).

Level 4: High Driving Automation, a human driver is not required as the system is fully responsible for driving tasks and can operate the vehicle independently,

although only within limited service areas with restricted speed, also known as geofencing (NHTSA, n.d.; SCS, n.d.).

Level 5: Full Driving Automation, human involvement is not required to operate the vehicle, the system is fully responsible for driving tasks and can execute them autonomously in all conditions (NHTSA, n.d.; SAE, 2021).

Note that automated driving provisions of levels 4 and 5 are not yet available on the passenger car market for consumer purchase, and level 3 is only now beginning to enter regular production (Statista, 2022).

3.2.2 Future Direction

Most vehicles in operation as of 2022 are of autonomy level 1-2 (Statista, 2022). The current challenge for OEMs is making the transition into level 3-4 territory, the outset classification for true autonomous vehicles. Although many OEMs may have the technology ready, the matter is beyond that of technological capabilities and more so of their confidence towards their ADS. An OEM must be prepared to take full responsibility for potential accidents involving their ADS before officially claiming Level 3 autonomy, thus making the transition more about liability rather than solely technological improvements (Anderson et al., 2014; Davidson & Spinoulas, 2015). Incidentally, technological advancements are still required, since one of the main concerns for implementation of ADS is that software security is not progressing at the same pace as other technologies in the automotive industry, making them notably vulnerable to cyberattacks (Anderson et al., 2014; Ponemon, 2018). Given that automotive manufacturers are now just as much software companies as they are transportation companies, it is crucial to implement a rigorous cybersecurity strategy to fully realize the benefits of new automotive technologies and maintain quality and safety (Fagnant & Kockelman, 2015; Ponemon, 2018).

In parallel with system developments, OEMs are looking ahead into the transformative potential of the interior in AVs. As human drivers will eventually be unneeded, the vehicle interiors are expected to change dramatically. In contrast to the traditional cabin built around the driver and the steering wheel for optimal control and view of surroundings, the autonomous interior layout will be based on customer needs to improve UX and give passengers the freedom to utilize their traveling time for non-driving activities (Kim et al., 2022; Nelson, 2021). Activities identified to be highly anticipated and desired by users include socializing, working, eating, drinking, relaxation, sleeping, playing games, and

video entertainment, among others (Pettersson & Karlsson, 2015; Wilson et al., 2022; Jorlöv et al.; 2017; Krome et al., 2015).

The following paragraphs will raise three key features of autonomous interiors that will be of discussion in this project for exploring the consumer expectations.

Seating Space

Within autonomous interiors, seating will be a significant aspect which is expected to change. Flexible and adaptable seating arrangements with a great number of adjustment features for higher degrees of movement and rotation, are AV-inspired innovations that are anticipated to expand. One of the challenges, however, is to demonstrate equal or higher levels of occupant safety than what is regulated presently (Visnic, 2022).

Cabin Materials

Sustainability is of central concern within the automotive industry, although with the interior design sector often being neglected (Wellbrock et al., 2020). Efforts have begun to improve recyclability of cabin materials without compromising comfort or quality, with OEMs such as Volvo, BMW and Mercedes taking leading initiative (Visnic, 2022). Volvo's "Concept Recharge", BMW's "i Vision Circular" and Mercedes "Vision EQXX", all display interior designs filled with functional yet aesthetic environmentally responsible materials, both natural and recycled, representing the automakers' visions for sustainability and climate neutrality (Volvo, 2021; BMW, 2021; Mercedes, 2023a; Mercedes, 2023b).

Infotainment Unit

Tesla's introduction of a large touchscreen interface with its Model S in 2012, paved the way for the automotive industry to incorporate more and larger displays in their vehicles. The displays not only reimagine the dashboard by replacing traditional physical buttons and controls for various cabin features, enforcing a cleaner and minimalistic space, they also provide means of controlling media, navigation, and entertainment features, all in a single location (Tesla, 2022). With expanding ADAS capabilities and overwhelming indications of consumer desirability, OEMs continue to adhere to the prospect of connected vehicle interiors being built around larger and more displays, aiming to eventually enable all occupants to be engaged with the infotainment system (Blankenbach, 2018; Visnic, 2022; FutureBridge, 2022).

3.3 Digital Fatigue

Autonomous vehicles have the potential to greatly improve productivity by allowing occupants to utilize their time in transit for other tasks. If given the opportunity, users would prefer actively filling the non-driving time by being productive or use some type of device, rather than doing passive tasks such as looking out the window and at the surroundings (Wilson et al., 2022; Jorlöv et al.; 2017; Large et al., 2017). Whether it is work-related or for browsing internet and social media, this increased productivity may come at the cost of increased cognitive stress and digital fatigue, which is of significant concern especially since there is an expected trend of OEMs implementing more and larger displays.

Mental fatigue in the digital context, i.e., digital fatigue, refers to the sensation of weariness and exhaustion, that results from the constant use of digital devices and the demands of being constantly connected. Weariness, like thirst and hunger, is a biological protective device, that prevent humans from overstraining themselves and allow opportunities for healing and recovery (Grandjean, 1979). As such, recurring stresses over long periods without time for recuperation can lead to symptoms including irritability, difficulty concentrating, sleep deprivation, depression and feelings of anxiety or stress (Grandjean, 1979; Reinecke et al., 2017; Renjith, 2017).

To mitigate the negative effects of digital fatigue, it will be important to allow occupants to disconnect from digital media and alleviating them of cognitive stress, and instead improve UX by promoting overall well-being and relaxation.

3.4 Emotional Design

Adherence to hedonic aspects and evoking positive emotions are key principles to create pleasant user experiences. The concept in which design can evoke emotions in the people who interact with it, is commonly referred to as emotional design. It is a design approach that considers how a product, space, or interface makes people feel, and how that feeling can be used to create a positive, memorable experience.

In his book "Emotional Design", Don Norman explores the role of emotions in design and how designs can elicit certain emotional responses from users, where he divides the concept into three parts, namely: "Visceral Design", "Behavioral Design", and "Reflective Design" (Norman, 2014). As stated in the delimitation section 1.4, although it is important to consider all three levels for an encompassing design, for the scope of this thesis, visceral design will be the central focus.

Visceral Design

A visceral reaction to a design is based on the initial impression of it. This reaction is based on the appearance and feel of the design and is often immediate and unconscious. The visceral reaction is important for creating a positive emotional response to a design, as it creates a sense of trust and comfort.

Behavioral Design

Behavioral design is about the way design functions affect users' emotional responses and equates with traditional values of usability and functionality. Designs that are easy to use, understand, and control will elicit positive emotional responses, while designs that are difficult to use will elicit negative emotional responses. Providing feedback to users is an important aspect, as it helps users understand the results of performed actions and gives them a sense of control.

Reflective Design

Reflective design is about considering the meaning and personal value of a product. Designs that are reflective of users' values and beliefs will elicit positive emotional responses. It is also important to consider the social and cultural context in which a design will be used.

3.4.1 The Four Pleasures

Emotional design is closely related to the 'four pleasures' framework introduced by Patrick W. Jordan in his book "Designing Pleasurable Products", in which he emphasizes that a design should not just be aesthetically pleasing and/or functional, but also evoke emotions through pleasures (Jordan, 2000). With basis on the work of Lionel Tiger, Jordan proposes four distinct types of pleasure that a product can elicit, namely: psycho-pleasure, physio-pleasure, socio-pleasure,

and ideo-pleasure (Tiger, 2017). The thesis will primarily focus on psycho-pleasure.

Psycho-pleasure

Psycho-pleasure refers to the subjective experience of pleasure or enjoyment that relates to psychological or emotional states. Being often tied to positive emotions such as joy, contentment, and happiness, it can be elicited by a wide range of stimuli and experienced differently depending on each individual. One example is Tesla's Romance Mode, which has a virtual fireplace with intentions of creating a comforting and intimate atmosphere (Tesla, 2023).

Figure 3.3. Tesla Romance Mode with a virtual fireplace.

Physio-pleasure

Physio-pleasure refers to pleasures that derive from physical sensations and sensory experiences and are usually associated with comfort and relaxation. It includes pleasures involving touch, sound, and smell and those related to sensual experiences, e.g., the warmth of a hot bath, the relaxation of a massage, or the comfort of a soft, warm bed.

Socio-pleasure

Socio-pleasure refers to relationships and derives from the pleasure associated with activities that involve social connection and interaction, e.g., spending time with friends or family, engaging in cultural experiences or having a sense of belonging to a desired social group. With AVs of the highest autonomy levels, seats could face each other, and fold-down tables could be integrated to provide space for enhanced social interaction. One example that implements this concept is the 360c by Volvo.

Figure 3.4. Volvo 360c interior (Lienhart, 2018).

Ideo-pleasure

Ideo-pleasure refers to subjective ambitions, preferences, and principles. It is a form of psychological pleasure that emerges from experiences aligning with the values and beliefs of the user and contributes to a sense of identity and purpose. For instance, the use of sustainable materials in an interior is likely to elicit ideo-pleasure in an individual who is environmentally conscious.

For this thesis, the approach of implementing emotional design and adhering to the pleasure-framework, will be through nature-oriented design, where the theory behind its principles and patterns will provide guidance for identifying eliciting conditions.

3.5 Defining Nature

'Nature' as a notion, is not easily defined as it can have diverse interpretations. In their publication "14 Patterns of Biophilia", Browning et al. (2014) describe two extreme connotations of nature, the first one referring to living organisms which are unaffected and have not been influenced by human activities. This is an inapplicable perspective as almost everything on Earth has been and will remain influenced by human actions. This definition also excludes aspects such as the sun and moon, home gardens and urban parks.

Another perspective is that everything is considered natural, including man-made objects and designs. This would encompass everything from music instruments to paperback manga and anime.

As a middle ground, the authors define nature as "living organisms and non-living components of an ecosystem", which will be the definition used for this thesis.

3.6 Biophilia

"Biophilia is the passionate love of life and of all that is alive."

- Erich Fromm (1973)

Biophilia refers to the innate biological connection that humans have towards nature. The term was first introduced by social psychologist Erich Fromm who described it broadly as an instinct (Fromm, 1964). Biologist Edward O. Wilson later popularized the term by proposing the *biophilia hypothesis*, suggesting that humans have an inherent tendency to affiliate with life and lifelike processes as a fundamental aspect of biological evolution (Kellert & Wilson, 1993).

Having evolved within the natural environment, humans have a strong connection to these natural surroundings. Our interactions and experiences with nature have shaped our growth and behavior, imprinting sensory and spatial relationships with different natural landscapes (Kellert & Wilson, 1993).

The concept of biophilia implies that humans are inclined to affiliate with nature on a visceral level, and that this connection can evoke emotional responses and affect personal well-being (Browning et al., 2012).

3.6.1 Effects of Biophilia

Building on the concept of biophilia, there has been two major theories describing how connecting with nature might affect human health and well-being, namely the *Attention Restoration Theory* and *Stress Reduction Theory*. Extensive studies have increasingly been conducted, supporting these theories in implying that nature can serve as a positive assistive platform for e.g., stress management and in promoting psychological as well as physiological health and well-being.

Attention Restoration Theory (ART)

ART suggests that nature serves as a positive restoration environment for humans and the limited capacity of directed attention (i.e., to focus on a specific task or stimulus, or the requirement for many repetitive tasks). By viewing or engaging with nature that provides a sense of extent, being away, fascination, and compatibility - mental fatigue and concentration can be improved as this would impose less demands on cognitive resources and allow the attentional capacities to recover and replenish (Kaplan & Kaplan, 1989; Kaplan, 1995).

Stress Reduction Theory (SRT)

SRT suggests that because of the innate evolutionary connection humans have to nature, exposure to nature and natural environments can evoke affective and aesthetic responses that influence feelings of stress and comfort. With affective it is meant the innate emotions of humans, whereas aesthetic is the preference affect associated with pleasurable feelings elicited by visual encounter with nature (Ulrich, 1983).

Psychological Health and Well-being

Psychological responses encompass adaptability, alertness, attention, concentration, and emotion. Included are reactions to nature that affect stress management as well as cognitive and emotional restoration (Browning et al., 2014). Empirical studies have reported that exposure to natural environments compared with urban environments, is associated with alleviated feelings of stress (Grahn & Stigsdotter, 2010), improved attention and attentional restoration (Berman et al., 2008), as well as enhanced cognitive performance and mood (Berman et al., 2008; Bratman et al., 2015),

Shinrin-yoku

Shinrin-yoku, or "forest bathing", is a Japanese-originated field of research which examines the human interactions with natural environments, specifically the presence within a forest setting (Ohtsuka et al., 1998). The concept of shinrin-yoku resides in making contact with and taking in the atmosphere of the forest to promote psychological and physiological health (Browning et al., 2012). Forest environments have been proven to evoke positive emotions and feelings of relaxation, while also displaying a connection to reduced feelings of anxiety, depression, and hostility (Park et al., 2010; Morita et al., 2007).

Figure 3.5. A forest setting (DobelMann, 2019).

There is a growing body of research regarding the effects biophilia and biophilic design can exert on human health, performance, and well-being, only some of which are referenced in this thesis. For an extensive overview on the function and supporting research of biophilic design patterns and biological responses, see "14 Patterns of Biophilic Design" (Browning et al., 2014).

3.7 Biophilic Design

Biophilic design can be defined as the application of biophilia in the design and development of the human built environment (Kellert, 2018). Although the practice of biophilic design has thus far been predominant in architecture and urban planning, because it is a philosophical approach to design there are no physical boundaries to its adoption (McLennan, 2004). Therefore, it may be applied to any product or project under design, including automotive exterior and interior.

Successful biophilic designs adhere to a wide range of biophilic values, which are represented by the biophilic patterns described later in this section. The more values a design embodies, the higher the possibility of numerous benefits being generated. However, this does not imply that designers should apply a thoughtless checklist approach attempting to satisfy every pattern. The practice of biophilic design should rather be cautiously and appropriately adapted to the specific uses, conditions, and circumstances (Kellert, 2018).

A similar approach must be applied regarding the human senses. Although the visual is the most dominant sense having evolved from humans being largely reliant on sight to perceive opportunities and threats in natural environments, the remaining senses of touch, smell, sound, time, and movement are still significant in establishing effective biophilic designs and in promoting human well-being. Even if a certain attribute of biophilic design is more likely to yield considerable benefits the more senses it stimulates, it does not however equate to forcing the inclusion of unsuitable biophilic design strategies for that specific circumstance and use (Kellert, 2018).

Biophilic design can be represented by three categories in the fundamental ways people experience nature: "direct experience of nature", "indirect experience of nature", and the "experience of space and place" (Kellert, 2018). As the thesis will adopt the framework introduced by Browning et al. (2014) in their publication "14 Patterns of Biophilic Design", the terms "Nature in the Space", "Natural Analogues", and "Nature of the Space" will be used instead to describe the same experiences. These categories will be further described in the subsequent sections, including the 14 patterns which they encompass. Images will be provided for each pattern to give context and illustrative examples of what the patterns could encompass. The patterns are also not exclusive to the aforementioned categories and there may occur overlaps. When presented below, the order does not signify any priority of importance.

When working with biophilic design patterns it is important to recognize that they are not absolute formulas albeit being supported by considerable research, but rather guidelines providing information and assistance in the design process (Browning et al., 2014).

3.7.1 Nature in the Space

"Nature in the Space" refers to the actual contact with elemental features and characteristics of the natural environment, which include naturalistic aspects such as water, light, air, as well as animals, plants, sounds and scents (Browning et al., 2014; Kellert, 2018).

Visual Connection with Nature

A visual connection with nature is a view to elements of nature, living systems and natural processes, which can include coastal, forested, and mountainous landscape features, as well as calm harmless animals and flowering plants (Browning et al., 2014; Kellert, 2018). Views of these types have been indicated to evoke aesthetic responses, triggering pleasurable receptors in our brain leading to prolonged interest, stress reduction and improved cognitive functioning. (Orians & Heerwagen, 1992) The psychological benefits are suggested to increase with biodiversity and not necessarily because of access to greater land area, allowing the pattern to be applied even in built environments and dense urban settings (Fuller et al., 2007).

The objective of this biophilic design pattern is to allow individuals to alleviate cognitive stress and relax eye muscles by providing visible biodiversity and a quality view of the natural environment and naturalistic elements (Browning et al., 2014).

Figure 3.6. Quality view of nature with biodiversity (Aedrian, 2022).

Non-Visual Connection with Nature

Non-visual connection with nature refers to the auditory, haptic, olfactory, or gustatory stimulation that induces positive experiences with nature, living systems and natural processes (Browning et al., 2014). For instance, not only are humans drawn towards the sight of water, but also to its sound, texture, movement, taste and even smell, with studies suggesting an especially strong connection between the visual and auditory sensory systems (Jahn et al., 2011; Hunter et al., 2010).

The objective of this biophilic design pattern is to help promote well-being and mitigate feelings of stress by engaging the senses of sound, scent, touch and possibly even taste, either separately or simultaneously. Although an experience of multi-sensory stimulation is more likely to exert increased positive health responses (Browning et al., 2014).

Figure 3.7. Non-visual connection with nature on beaches include the touch of sand, feeling the wind breeze, sounds and scents of the ocean (Hasanbekava, 2020).

Non-Rhythmic Sensory Stimuli

Non-rhythmic sensory stimuli are the stochastic and ephemeral connections with nature that are statistically observable although not accurately predictable because of their irregular nature (Browning et al., 2014). Non-rhythmic stimuli are continuously experienced when being immersed in nature, and include instances of leaves rustling, sudden breezes and birds chirping. These dynamic natural scenes are generally perceived as positive and pleasurable as they are processed more effortlessly by the brain and create opportunity for recovery and replenishment of cognitive capacity (Biederman & Vessel, 2006).

The objective of this biophilic design pattern is to generate momentary experiences of stochastic and unpredictable movements to allow the attentional capacity to replenish from mental fatigue and physiological stressors (Browning et al., 2014).

Figure 3.8. Stochastic movements of clouds, flying birds and ocean waves (Jason, 2017).

Thermal & Airflow Variability

The pattern of Thermal & Airflow Variability refers to the subtle changes in air temperature, airflow, relative humidity, and surface temperatures that simulate natural scenes (Browning et al., 2014). People usually prefer moderate levels of sensory variability in the environment, conversely, an environment lacking in sensory stimulation and diversity may lead to feelings of boredom and apathy (Heerwagen, 2006).

The objective of this biophilic pattern is to provide users with a sensory experience of thermal and airflow variability. Since thermal comfort is inherently subjective and could vary with diverse circumstances, it should also enable occupants to control thermal conditions to a certain degree (Browning et al., 2014).

Figure 3.9. Visual representation of thermal & airflow variability (Hoefler, 2019).

Presence of Water

The Presence of Water relates to the enhanced spatial experience of providing access to the visual, auditory, and haptic aspects of water (Browning et al., 2014). Incorporating large bodies of water is not a requirement, although it can also induce affective and aesthetic responses if the water is clean and unpolluted (Orians & Heerwagen, 1992). As our level of interest for water remains practically unaffected even after repeated exposure over time (Biederman & Vessel, 2006), a smaller water feature may be adequate in providing the desired health benefits of e.g., reduced stress and restorative responses (Browning et al., 2014).

The objective of this biophilic pattern is to utilize the multi-sensory attributes of water to enhance the spatial experience in evoking emotional and restorative responses.

Figure 3.10. Presence of water (Wilson, 2014).

Dynamic & Diffuse Light

Dynamic and Diffuse Light includes the time-dependent variations of light and shadow intensities that occur in nature. These light fluctuations can affect eye functions and visual comfort, as well as the circadian rhythm and the daily cycle of hormonal activity (Browning et al., 2014). Sunlight is such an example, which changes color from yellow in the morning, to blue at midday, and red in the evening. This daylight color transition balances the levels of produced serotonin and melatonin which can be associated with mood, sleep quality, alertness, depression, and other health conditions (Kandel et al., 2000).

The objective of this biophilic design pattern is to provide opportunities for illuminance fluctuation, light distribution and light color variability that help maintain circadian system functioning, induce visual comfort and other positive psychological or physiological responses. Conversely, uniform light distribution and glare discomfort should be avoided. Additionally, utilizing accent lighting and layering of other light sources can create depth and interest for a pleasurable visual environment and improved quality of UX (Browning et al., 2014).

Figure 3.11. Evening sunlight (Brodard, 2020).

Connection with Natural Systems

Connection with Natural Systems refers to the awareness of and connection with natural processes, such as weather changes or the seasonal and temporal changes of nature (Browning et al., 2014). The application can range from simply viewing the course of change in a healthy ecosystem, to complex integration of systems such as utilizing rainwater in the hedonic aspect of design or for regulating household activities during rain events.

The objective of this biophilic pattern is to raise the awareness of naturally occurring life cycles and systems, e.g., weather, and seasonal changes, to induce enlightening, relaxing, and nostalgic experiences.

Figure 3.12. Seasonal change in Japan (Hirayama, 2019).

3.7.2 Nature Analogues

"Nature Analogues" refers to the indirect experience of nature through images or other representations of the natural environment. This includes e.g., textures, colors, geometries, processes, and patterns found in nature, as well as mimicry of the appearance, biology and behavior of living systems and organisms. Natural materials such as wood, wool, and metal, that have been processed or extensively transformed from their original state also provide a connection with nature although in an analogous manner (Browning et al., 2014; Kellert, 2018).

Biomorphic Forms & Patterns

Biomorphic Forms and Patterns refer to the symbolic references to patterns, geometries, textures, and numerical arrangements occurring in nature. These include e.g., the Fibonacci series (0, 1, 1, 2, 3, 5, 8, 13, 21, 34...) and the Golden Ratio of 1:1.618, both frequently appearing in living forms such as with the spacing of tree branches and flower petals, or the spiral of seashells (Browning et al., 2014).

Biomorphism is closely related to biomimicry in the way they both take inspiration from nature and provide an indirect experience of it, however there are key differences between the concepts. While biomorphism focuses on the visual or aesthetic resemblance of natural elements, biomimicry instead considers the structural and functional aspects (Vincent et al., 2006). Both design approaches can however be used in tandem to enhance the biophilic experience.

The objective of this biophilic design pattern is to establish an indirect connection with nature through representational design elements of the natural environment. Biomorphism can be utilized to create a more visually preferred environment that enhances cognitive performance reduces stress. Excessive use of the pattern should however be avoided as that may lead to visual discomfort (Browning et al., 2014).

Figure 3.13. Naturally occurring pattern and numerical arrangement (Spratt, 2015).

Material Connection with Nature

A Material Connection with Nature is the indirect contact with nature through naturalistic materials and elements that have been processed or extensively transformed from their original 'natural' state, e.g., wood and stone. Included is also the impact of colors and natural color palettes, although the body of research is still limited (Browning et al., 2014). Natural materials possess visual and tactile properties that are difficult to replicate and should therefore be preferred over synthetic variations whenever possible to claim the most out of the biophilic benefits (Kellert, 2018). Not only can natural materials be used for aesthetic and decorative purposes, but they are also functional and possess distinctive thermal, mechanical, and acoustical properties (Tsoumis, 1991).

The objective of this biophilic design pattern is to utilize the various qualities of natural materials as an indirect experience with nature, to induce psychological and physiological responses. Depending on the intended use, e.g., restorative versus stimulating environment, the quantity should also be considered as the ratio could affect the physiological responses (Tsunetsugu, 2007). Additionally, variability of materials and applications is preferred over the extensive use of any one material or color (Browning et al., 2014).

Figure 3.14. Various materials giving a connection with nature (Oetelaar, 2020).

Complexity & Order

Complexity and Order refers to sceneries with rich sensory information of the symmetries, spatial hierarchies, and irregular geometries found in nature. These "fractal" patterns appear in complex shapes and repeatedly at different scales, which can be seen in e.g., snowflakes, stone or wood grain patterns, the reflections of rippling water and the branching of trees and rivers (Browning et al., 2014).

Fractal patterns of nature are processed more effortlessly by the brain, and exposure to such geometries can induce pleasurable and relaxing responses (Hagerhall et al., 2008; Salingaros & Masden, 2008). Conversely, overly complex environments may result in confusion, discomfort, or psychological stress. The challenge is to identify a balance between an alluring and restorative environment, and a surrounding that has an abundance of sensory information (Browning et al., 2014). By imposing order, complexity can be made more accessible and comprehensible (Kellert, 2018).

The objective of this biophilic pattern is to provide an environment rich in detail and diversity while simultaneously being perceived in an organized and meaningful manner. Experiences of visual coherence and balance can be elicited through symmetries and fractal patterns, inducing positive psychological or cognitive responses. Conversely, spaces that are uniform and lack distinct features should be avoided as they could often be perceived as monotonous and boring (Kellert, 2018).

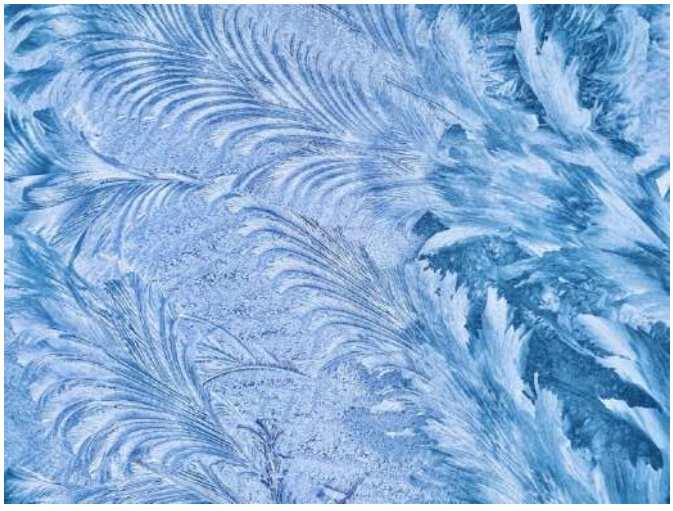


Figure 3.15. Fractal patterns in frost and snowflakes (Golovesov, 2022).

3.7.3 **Nature of the Space**

"Nature of the Space" refers to the spatial features and characteristics of nature, which includes our inherent and acquired desire to discern long distances beyond the immediate surroundings, as well as the allure towards the obscure and unknown, and sometimes even the peril and fear-evoking when there is a familiar and trusted element of safety included (Browning et al., 2014).

Prospect

Prospect refers to the evolutionary preference of vast unobstructed views for discerning opportunities and dangers (Browning et al., 2014). Distances of 6 meters minimum should be provided, preferably a distant prospect of over 30 meters, to yield the greatest benefits of a sense of awareness and comfort (Herzog & Bryce, 2007). When alone or in unfamiliar settings, such views can also reduce feelings of stress and anxiety (Petherick, 2000).

The objective of this biophilic pattern is to enhance visual connections by providing spatial conditions that are expansive, unimpeded, and open to perceive the immediate and distant surrounding for opportunities and hazards. Prospect must, however, be balanced with refuge, i.e., more enclosed spaces that offer protection and privacy. This balance is often more significant than the magnitude and frequency of the experience (Browning et al., 2014).

Figure 3.16. A vast unimpeded view giving a sense of prospect (Lenaerts, 2019).

Refuge

Refuge refers to enclosed spaces of retreat and withdrawal that offer protection and moments for rest and recovery. Rather than being entirely confined and disengaging, a place with good refuge condition feels separate while still providing contact with the surrounding environment. Balancing refuge with prospect is, as discussed in the previous section, key in creating places that provide openness and privacy at the same time. The principal spatial condition is protection from behind and overhead (Browning et al., 2014).

The objective of this biophilic pattern is to create a setting that is protective and restorative while concurrently providing privacy by limiting visual access into the space. The refuge condition typically improves with increasing number of protective sides, however, protection from behind and overhead is usually adequate, with three protective sides being the preferable amount; complete refuge, i.e., protection on all sides, is not necessarily the optimal solution as it disengages with the larger surrounding (Browning et al., 2014).

Figure 3.17. Point of view with refuge (Milo, 2017).

Mystery

Mystery is the anticipation of revelation and describes spaces or features with partially obstructed views or unknown elements, that engage a sense of curiosity and excitement (Browning et al., 2014). The mystery pattern builds upon our inherent desire to understand and explore and can evoke strong pleasurable responses to anticipatory situations (Kaplan & Kaplan, 1989). A poor mystery condition however, evokes unpleasant surprise such as fear. The distinction centers around the visual depth of field, where typically an obscured view with greater visual access of a medium (>6 meters) to high (>30 meters) depth of field is preferable (Herzog & Bryce, 2007).

The objective of this biophilic pattern is to create an environment with great visual access that encourages exploration and curiosity in a way that enhances cognitive restoration and alleviates feelings of stress. Conversely, a shallow depth of field to partially obstructed views should be avoided as that could induce experiences of unpleasant surprise and fear. The mystery pattern also implies movement and the inclination of wanting to further investigate the space, beyond the often stationary experience encountered in other biophilic patterns (Browning et al., 2014).

Figure 3.18. A foggy obstructed mountainous view (Kjellvestad, 2015).

Risk/Peril

While risk generally imply the possibility of a negative consequence, peril refers to the immediate and imminent danger. The Risk/Peril pattern describes the deliberate interactions with these dangers when a reliable element of safety is included (Browning et al., 2014). The distinction between Risk/Peril and fear lies within the extent of perceived danger and perceived control (Rapee, 1997). Having an awareness of a controllable risk unable to cause any harm, can produce dopamine and evoke positive and pleasurable responses, enhancing motivation, memory and problem-solving. Examples of Risk/Peril include testing the limits of the spatial attributes: heights, gravity, or water, with the perceived risks of falling, losing control, getting hurt or getting wet (Browning et al., 2014).

The objective of this biophilic pattern is to provide the experience of risk and peril while including elements of safety, protecting the user from actual harm. Short-term exposure to Risk/Peril conditions can induce positive experiences and improve cognitive performance, whereas long-term exposure may result in detrimental responses of over-production of dopamine, e.g., depression and mood disorders (Browning et al., 2014).

Figure 3.19. A sense of Risk/Peril (Shannon, 2018).

3.8 Biophilic Design versus Sustainable Design

Biophilic design and sustainable design are related concepts, however, it is important to note that they do not have equivalent meaning although the terms are occasionally used synonymously depending on context. A biophilic design can resemble nature yet be unsustainable, likewise, a completely sustainable design does not necessarily have to mirror a nature-like image.

There are many interpretations and misconceptions regarding sustainable design, even within professional fields (McLennan, 2004). Sustainability in the broadest sense, is defined by the Brundtland Commission as "meeting the needs of the present without compromising the ability of future generations to meet their own needs", which encompasses all aspects of society including e.g., transportation, economy, and human welfare (Imperatives, 1987). Based on this definition, sustainable design could involve the growth and prosperity of the human species, in which it could be used interchangeably with biophilic design. However, to discuss sustainable design in the context of built environments and for the scope of this thesis, boundaries to the definition need to be established for a common understanding of the term.

In his book "The philosophy of sustainable design: The future of architecture", Mclennan (2004) defines sustainable design as "a design philosophy that seeks to maximize the quality of the built environment, while minimizing or eliminating negative impact to the natural environment."

Thus, while biophilic design has a human-centered approach aimed at well-being and reconnecting people with nature, sustainable design is more focused on promoting environmental sustainability. A holistic approach to design, however, is to employ both principles in tandem to create built spaces that are both healthy for people and good for the environment (Wijesooriya & Brambilla, 2021).

3.9 Architecture versus Automotive

With urbanization, more people are living in cities and spending less time in nature. Buildings become a significant factor for human health and well-being, considering that we spend approximately 90% of our time indoors according to a study by The National Human Activity Pattern Survey (NHAPS) (Klepeis et al., 2001).

In the same study by NHAPS, (Klepeis et al., 2001), an observable average time of roughly 1,5 hours is spent daily in enclosed vehicles. Although it is not a considerable amount of time in comparison to the time people spend inside buildings, it is a noticeable part to consider as AVs are rapidly developing and car interiors are beginning to parallel workspaces and living rooms.

Despite the numerous arguments for beneficial implementation, the automotive industry has not seen a similar level of adoption of biophilic design as in architecture. A probable reason could be a matter of different priorities.

The automotive industry has traditionally been focusing on the critical issue of sustainability and the reduction of overall environmental impact of vehicles worldwide. OEMs have been pressured to develop solutions that mitigate negative effects on the environment, and thus prioritized technological innovation with respect to sustainable design, energy-efficiency and electrification while simultaneously ensuring performance and safety (Mayyas et al., 2012).

One key factor is the different time frames. The lifecycle of a building can be much longer than a car, so the benefits of biophilic design may be more apparent over the long term. In contrast, the benefits of biophilic design in the automotive industry may not be as easily quantified or apparent in the short-term.

3.10 Technological Nature

Technological nature is defined by Peter Kahn in his book *"Technological Nature: Adaptation and the Future of Human Life*", as “technologies that in various ways mediate, augment, or simulate the natural world” (Kahn, 2011). Essentially it refers to the intersection of technology and nature, in which technology is utilized to support, enhance, or alter and replace natural systems. Examples of technological nature include robotic pets designed to mimic the appearance and behavior of pet animals, audio recordings of the rain, sea or forest sounds, VR that simulate natural environments offering users immersive experiences through exploration and interaction with virtual nature.

Although, the integration of technology into natural processes and environments has yielded beneficial influences, e.g., biomimicry and biomorphism, Kahn argues that technology could diminish the depth of human life and weaken our connection with nature. He introduces the term “environmental generational

amnesia", which describes the phenomenon where with each generation, individuals become increasingly detached from nature and start to view degraded conditions in the environment as normal. If allowed to continue, adapting to the gradual loss of nature and the increase of technological nature could eventually lead to humans losing their fruitful connection with nature (Kahn, 1999; Kahn et al., 2009; Kahn, 2011).

While Kahn does conclude that there is a possibility of humans adapting and thriving as a technological species in relation to nature, and that having technological nature is better than no nature at all, technological nature should be viewed as a supplement to real nature and not entirely a replacement for it. As humans are increasingly dependent on technology for survival and growth, it is necessary to keep actual nature relevant and to recognize the importance of preserving and embracing natural systems (Kahn, 2011).

3.11 Japanese Design

A culture with deep historic connection with nature is that of the Japanese. Living with the periodical and unpredictable occurrence of e.g., earthquakes, floods, typhoons, and volcanic eruptions, nature have instilled respect and reverence within the Japanese (Koren, 2008).

While the grand aspects of nature are revered it can also appear intimidating and threatening. The natural objects and phenomena being endorsed in the Japanese visual arts are therefore often the small, gentle, and intimate aspects of nature (Asquith & Kalland, 1997). Embracing these sensible characteristics along with the unpredictable variations of nature, the Japanese has developed a distinct sense of aesthetic and appreciation for natural beauty (Keene, 1969). Describing it in one word is not possible, rather the Japanese aesthetic must, beyond being appreciated in the visual sense, be spiritually participated in and experienced (Kempton, 2018). Particular words exist however, to describe the emotional quality of experiencing these different forms of beauty found externally as well as beneath the surface. The diverse terms depicting different aspects of this are many, some of which overlap in meaning. The aesthetics included in this thesis are '*wabi-sabi*', a rustic and desolate beauty; ' *mono no aware*', an ephemeral, varying beauty; '*ma*', an empty or formless beauty (Davies & Ikeno, 2011); four principles of Zen aesthetic, namely '*yūgen*', '*kanso*', '*fukinsei*', and '*seijaku*', which will be further discussed in section 3.10.1.

Wabi-Sabi

Wabi-sabi is a traditional Japanese aesthetic principle that embraces the beauty of imperfection, impermanence, and incompleteness. It represents a way of life and a worldview that values simplicity, naturalness, and humility (Koren, 2018).

The concept of wabi-sabi is a combination of wabi and sabi, two complementing and closely related aesthetic terms that together emphasizes rustic or aged beauty, and the incorporation of organic elements with a human touch. It integrates flaws found in various materials such as wood, stone, fabric, and clay, and values the patina and signs of age that give objects history, depth, and authenticity (Prusinski, 2012).

Wabi is the inward, and subjective philosophical construct which originally had a negative connotation associated with secluded living and a discouraged emotional state. However, it later evolved into a more positive aesthetic, emphasizing spiritual richness through self-imposed isolation and voluntary simplicity (Koren, 2018).

Sabi on the other hand, is the outward expression communicating a deep and tranquil beauty that emerges with the passage of time. It encompasses the visual aspects of patina, weathering, and tarnishing, while also invoking emotional responses such as wistfulness, melancholy, pensiveness, and longing (Kempton, 2018).

Wabi-sabi encourages us to appreciate the beauty in the imperfect, transient, and incomplete aspects of life, developing a deeper connection with the natural world and a sense of gratitude for what already exists.

Figure 3.20. Wabi-sabi is deeply rooted in Japanese tea ceremony (Oriento, 2018).

Mono no Aware

Beyond the preference for simplicity and naturalness lies one of the most distinctive ideals of Japanese aesthetics, mono no aware, which can be translated to "the empathy toward things" and depicts an awareness of impermanence and perishability (Keene, 1969). Rather than trying to achieve artistic immortality, mono no aware emphasizes an ephemeral and fragile beauty that cannot be specified to a single moment but instead must be enjoyed and fully appreciated within a specific timeframe (Prusinski, 2012).

While mono no aware and wabi-sabi share certain similarities, there is one distinct difference. Mono no aware focuses on the beauty itself, particularly its imminent disappearance, while wabi-sabi focuses on the reflections on life that the beauty evokes. Japanese people often use metaphors to describe these concepts, with the delicate pink cherry blossom on the verge of falling representing mono no aware, and a fallen autumn leaf symbolizing wabi-sabi (Kempton, 2018).

Figure 3.21. Cherry blossoms on the verge of falling (Tchebotarev, n.d.).

Ma

Ma represents negative space and a beauty in voidness and formlessness. Although it is a void, the meaning is less equivalent to "empty space" and closer to "open space".

In Japanese design, ma is often used to create a sense of balance, harmony, and simplicity, allowing the observer to appreciate the beauty of individual objects in relation to their surroundings. Ma often referring to the spaces between objects, is therefore considered just as important as the objects themselves as it prompts the observer to participate in the scene and complete the voidness. The ambiguity and difficulty in depicting ma is where its beauty and timeless quality lies.

Figure 3.22. Ma instance in the sky (Ajith, 2018).

3.11.1 Zen Aesthetic Principles

The most influential and commonly used identification of the zen aesthetic principles is described seven in total by philosopher Hisamatsu (1971) in his book "Zen and the fine arts". These principles have become so influential on Japanese culture that they are commonly known as "Japanese aesthetics" rather than exclusively Buddhist aesthetics (Keene, 1969). In this thesis, four of the principles will be discussed briefly, as previously stated. The order does not reflect any priority of importance; each of the five is of equal significance.

Yūgen

Yūgen, although a difficult concept to define and express in words, can be understood as a form of suggestion that depends on acknowledging that there are meanings beyond what is visible or described. For instance, Japanese aesthetics have had a preference for the monochrome, because although the use of colors can be expressive, it does inevitably restrict the extent of suggestion. While a flower painted in red is bound to that color, a black contour of a flower on white paper can be imagined by the observer in whatever color (Keene, 1969).

Yūgen can also take form in the beginnings and ends, with beginnings suggesting what is to come, or ends suggesting what has been. For instance, the buds of cherry blossoms and the crescent moon, suggest the full flowering and full moon (Keene, 1969).

Figure 3.23. A monochromatic image of a twig suggesting sprout or wither (Gawand, 2021).

Kanso

Kanso represents simplicity and the values of being sparse and devoid of clutter. It is a sense of abandon and eliminating the non-essential to focus on what matters within a space. It refers to both the outward appearance or arrangement of material phenomena in space and time, and the underlying concepts or abstract ideas that are expressed or symbolized by those material phenomena (Hisamatsu, 1971).

Figure 3.24. Japanese garden with careful arrangement for balance and harmony in simplicity (Lu, 2020).

Fukinsei

Fukinsei can be associated with the outward attributes of being asymmetrical, incomplete, uneven, unbalanced, or irregular, while rejecting regularity as well as perfection as these are thought to limit the suggestive range of yūgen (Hisamatsu, 1971). Leaving something incomplete adds an intriguing element, evoking a sense of curiosity and potential for growth.

It's important to note that fukinsei is not about creating chaotic or disordered designs, but about creating a sense of balance and harmony using asymmetry and irregularity.

Figure 3.25. Asymmetrical display of a "bunjin" bonsai. (Fields, 2022)

Seijaku

Seijaku emphasizes the concept of stillness or tranquility and is often associated with a sense of silence or peacefulness; sei, referring to an absence of turbulent emotions, and jaku, referring to the resulting peaceful state of mind. The intentions of evoking seijaku are to enter a special state of consciousness of calmness and mindfulness and invoking feelings of peace and quiet (Lomas et al., 2017).

Figure 3.26. Visual representation of seijaku (Wong, 2018).

3.12 Scandinavian Design

While Scandinavian design and Japanese aesthetics have their own unique cultural influences and expressions, the philosophies resemble each other in many ways. They both seek to establish a strong connection with nature and share a mutual appreciation of simplicity, and a focus on creating harmonious and mindful designs that enrich the human experience. Skillful craftsmanship is celebrated in both philosophies, where the attention to detail and high-quality craftsmanship are considered essential aspects of creating long-lasting and timeless designs.

The use of natural materials, such as wood, leather, and textiles, is deeply emphasized. These materials are valued for their warmth and durability as well as the authenticity in their imperfections, and often reflects the connection to the region's natural environment.

One of the core principles that separates Scandinavian design, however, is its pragmatic approach. Pragmatism in Scandinavian design emphasizes functionality and practicality as essential elements in creating well-designed objects and spaces. It values the idea that design should serve a purpose and improve the user experience through both present and long-term functionality. This pragmatic approach is reflected in the focus on efficient use of space, the use of sustainable and durable materials, and the integration of practical features into the design.

There is a tendency to misinterpret and misuse minimalism as a core principle of Scandinavian design. While minimalism shares similarities with Scandinavian design, it is not synonymous with it. Minimalism could rather be seen as a natural evolution or product of the original Scandinavian design principles, where the pursuit of clean lines, uncluttered spaces, and efficient use of resources inherent in Scandinavian design has led to the emergence of minimalism.

3.13 Benchmarking

3.13.1 **Jaguar Manta**

Figure 3.27. Jaguar Manta Concept by Ningbo Zhang (Zhang, 2020).

The "*Jaguar Manta*" as suggested by its name, takes inspiration from underwater and mirrors the distinctive shape and movements of the marine creature. Even the lack of conventional wheels and implementation of "maglev" (magnetic levitation), resembles how mantas drift underwater, with the vehicle seemingly floating on the surface. The concept displays a combination of biomorphism and biomimicry through a resembling aesthetic to the manta while also embracing aerodynamics forms, making it both visually and functionally like nature.

3.13.2 Mercedes-Benz BIOME

Figure 3.28. Mercedes-Benz BIOME concept by Mercedes-Benz Advanced Design Studios in Carlsbad, California (Mercedes, 2020a).

The *Mercedes-Benz BIOME* is a concept designed to be fully integrated into the ecosystem and in complete symbiosis with nature. Through genetic engineering, the vehicle can adhere to specific customer requirements and grow in a completely organic environment from seeds sown in a nursery. The interior grows from the Mercedes star in the front, whereas the exterior develops from the star in the rear. The wheels are grown separately from four other seeds (Mercedes, 2020a).

On the road the Mercedes-Benz BIOME acts as a moving plant, producing pure oxygen and contributing to improved air quality, and at the end of its lifespan it can simply be composted or used as building material, blending seamlessly into the ecosystem (Mercedes, 2020a).

3.13.3 **Mercedes-Benz Vision AVTR**

Figure 3.29. The Mercedes-Benz Vision AVTR.

The *Vision AVTR* is a nature-oriented concept designed in collaboration with the team from the movie AVATAR (2009) which merges the interior and exterior to create an immersive and unique experience where passengers can communicate with the vehicle and the surrounding environment (Mercedes, 2020b).

With adapted elements inspired by the world of AVATAR, such as the wheel design portraying woodsprites and the "bionic flaps" on the back mimicking avatar gestures, the vehicle itself comes alive and blends harmoniously into the environment. Not only are the elements visual features of biomorphism, but they also provide functional biomimetic qualities in terms of aerodynamics and angular maneuverability. Due to the front and rear axles being separately controllable, the Vision AVTR can move sideways by approximately 30 degrees, mimicking crab-movement (Mercedes, 2020b).

3.14 User Research

User research is conducted to gather information about current and expected trends and customer needs in the automotive industry regarding UX, as well as to gain insights from people who frequently spend time in nature. The research is conducted through semi-structured interviews (SSIs) to collect qualitative data.

SSIs are chosen as they provide a flexible framework that allows for a balance between structure and openness. A set of predetermined questions and themes is established to guide the interview process and ensuring consistency across interviews. However, the semi-structured nature also allows the interviewees to elaborate on their experiences and providing unexpected insights and themes. With the project purpose of exploring new possibilities of improving UX, this interview structure was deemed suitable as new perspectives could be provided by the people having first-hand experience with the relevant topics.

3.14.1 Interviews with car dealerships

Interviews are conducted at three different car dealerships with brand philosophies related to the thesis themes of UX, nature, Japanese and Scandinavian design. The brands visited are Mercedes-Benz, a leading premium automobile manufacturer recognized for its sophisticated design, and in delivering premium quality UX that blends superior comfort with advanced technology; Toyota, a renowned Japanese automobile manufacturer known for its commitment to reliability and efficiency; Volvo, a Swedish automobile manufacturer celebrated for its integration of Scandinavian design principles and a deep connection with nature.

Salesmen at the car dealerships are chosen for interviews due to their unique position as frontline representatives of the automotive industry. Possessing extensive firsthand experience interacting with customers and individuals from various backgrounds, they understand the customers' preferences and needs, and know the current trends of the automotive industry. Their regular exposure to a wide range of customer feedback makes them well-suited to provide practical insights for the project.

Main topics for the interviews are regarding UX, comfort, customer customization, implementations of nature, and autonomy. The documentations are transcribed during and immediately after the interviews to ensure that findings had been documented properly. The identified patterns and key findings after organizing the data are presented in the following paragraphs.

UX

When questioned about the UX in their vehicles, all the brands are quick to highlight and emphasize the provided technology and functionalities provided to the users. Screens are becoming larger and wider as they replace physical

buttons and controls, whilst integrating all the functionalities within the software. Automakers like Mercedes-Benz and Volvo believe that this integration allows for a more intuitive user experience within the vehicle's interior while also contributing to a simplified and minimalist appearance.

The focus is on seamlessly integrating new technology into the interior design as the technological features are already many and still increasing. Mercedes-Benz, for instance, must provide a comprehensive walkthrough of all the existing functionalities during the delivery process. This is because many people may own their cars for several years without even being aware of certain functions.

Still, technology will continue to be relevant to users as there is an ongoing expectation and customer need for new and modern technology in cars.

UX in cars also extends beyond the screens and interior features, starting from the initial encounter with the outward appearance. The exterior design plays a crucial role in establishing an emotional connection, with companies like Mercedes-Benz and Volvo recognizing the significance of exterior design in creating a positive UX. Surfacing, expressions, proportions, and the overall design language contribute to the initial visual impact and appeal of the vehicle. Examples of features where these aspects are commonly expressed are in the large wheels and rims, and through the exterior lights which could display an ability to greet the users when they unlock or approach the car.

Moreover, the exterior design can also incorporate functional aspects that enhance the overall user experience. Aerodynamics, for instance, can contribute to improved performance, efficiency, and reduced wind noise. The design of the doors, handles, and entry points should be intuitive, providing ease of access. Smooth and effortless opening and closing mechanisms, along with thoughtful ergonomics, contribute to a positive first impression and a seamless transition into the interior.

Comfort

Seating comfort is a highly valued factor for the premium brands, as they cater to a target demographic that often includes slightly older individuals and customers who utilize the cars as company or family vehicles.

In the case of company cars, the occupants often spend long hours on the road, thus there are options of seat heating, ventilation, and massage functions to provide a comfortable seating experience. For family cars, the comfort of all occupants, including children and elderly people, is of utmost importance to

ensure a pleasant and safe journey. The latter is especially applicable to the ideologies of Volvo, with safety being a fundamental aspect of comfort.

For Toyota on the other hand, comfort is only a relevant topic first after the customers have decided to buy a car.

Their vehicles aim for simplicity starting with only the most essential functionalities, which shows in their compact package and standardized seating.

Customer Customization

During the ordering process of a new vehicle, customers often can customize various features and select optional add-ons and packages to tailor the car to their preferences. However, once the vehicle has been received, the options for customization are very limited, particularly in terms of physical modifications. While physical customization may be limited, software-related customization is becoming more prevalent. Modern infotainment systems can be customized to a certain extent, allowing users to personalize settings, select preferred display layouts, and configure various software features according to their preferences.

Premium brands often provide a greater range of customization options, with brands such as Mercedes-Benz and newer Polestar models (Polestar being an automotive brand under Volvo), including features like seat memory and customizable ambient lighting, enabling drivers to personalize the interior atmosphere by selecting different colors and intensity levels.

The brands are expecting this trend of customization to increase as cars are increasingly becoming a space frequently resided in and would need more personalization for long-term comfort.

Nature

The closest connection to nature is described to be through the windows, with a focus on allowing natural light to illuminate the interior environment. Car manufacturers offer various options to enhance this connection, one being the inclusion of a panoramic roof.

Among the interviewed brands, Volvo stands out as the one valuing the direct connection between nature and user the most. With a nature-based identity rooted in Scandinavian design, both in design and production, the company utilizes natural wood as accents in the interior as well as synthetic fabric made from recycled material for its newer seating. By maximizing interior space and extensively utilizing natural light, the visibility is also improved with occupants gaining a better view of the surroundings.

Their nature-based identity is also subtly apparent in for instance the Volvo C40 and XC40. The graphics on the Volvo C40's dashboard and front door panels are directly inspired by the Abisko national park in Sweden, while the engraved decor in the XC40 is an overview of central Gothenburg.

Mercedes-Benz is beginning to touch upon this area, although currently only through their future concepts. The company's most notable connection to nature is still only on production level where they, like Volvo, are following the trend of electrification. From the interviews, there is a clear bias of customers opting for EVs rather than ICEs.

Mercedes-Benz and Toyota are, however, both acknowledging that there are limitations to EVs, especially considering range and available infrastructure. With a big market in Asia where charging boxes, charging stations and EVs as a whole are not yet widespread, there is skepticism of an all-electric approach. Currently Toyota see larger benefits in hybrids and are looking at fuel alternatives such as hydrogen and synthetic fuels.

Autonomy

Recently, there has been a significant increase in the number of autonomy functionalities being introduced, with all the interviewees expecting the trend to continue at a rapid pace in the near future. Previously considered advanced technology is quickly becoming the norm, with autonomy features such as lane assistance and self-parking becoming a standard in many vehicles.

While Volvo has been actively focusing on electrification, they have also recognized the transformative potential of autonomy in the future of transportation. While advanced technologies in the field of autonomy are said to exist, they are chosen to be released gradually, because of legal and liability considerations. They believe however, that developments will happen much quicker than anticipated which is apparent through the release of novel technologies with each new car model.

3.14.2 Interview with backpacker

An interview was conducted with a seasoned backpacker with the purpose to gather first-hand information about their experiences in outdoor settings and to understand the preferences and incentives of them seeking contact with nature through such experiences.

During the interview, the seasoned backpacker was given the opportunity to share their personal experiences through their commonly visited destinations and expand upon what attracts them to those places. He mentioned a strong affinity for exploring mountainous regions and experiencing vast scenery as these natural landscapes provide a stark contrast to the urban environment. They offer a tranquil and serene atmosphere with a feeling of freedom; having control over your own time and schedule, and not being influenced by others or the pressures of everyday life.

The duration of the trips usually depends on the routes and destination. When traveling a beautiful road, he appreciates the ability to travel both day and night, as traveling during nighttime also offers a distinct alluring experience. As such, his preferred mode of transportation has transitioned from a motorbike to traveling by car. This change allows for more convenience and comfort, especially when covering long distances.

Seasonal differences also affect the traveling experience, with each season having its own distinctive charm. Having traveled multiple seasons in the southeastern parts of Asia, one particular experience he seeks is foreign mountainous areas during the snowy season as it would be a completely novel experience.

Upon returning home, there is a sense of fulfillment and rejuvenation. Occasionally, there will be moments of longing and regrets about missed opportunities during a trip, such as not being able to enjoy the sea of clouds due to bad weather. These feelings do, however, create a motivation and desire to return to nature.

The comments from the backpacker predominantly align with the patterns of prospect and the visual connection with nature. In this way, nature acts as a medium for detachment from the hectic environment of everyday activities and provide an experience of freedom. The notion of change, whether temporal or seasonal, makes for an interesting variety and attraction when traveling in natural environments. The constant changes and unpredictability of nature can create both a sense of comfort and fulfillment but also curiosity and longing.

4 Define

In this chapter, the research and data gathered from the Discover phase are compiled to define a brief that frames the design challenge.

4.1 Aim and Objective

The aim and objective remain as stated in section 1.2 and 1.3; developing a nature-oriented concept to explore new possibilities of improving UX and relaxation in fully autonomous vehicles. The concept should therefore exhibit novelty and innovation through appropriate considerations to nature-based principles.

Having presented the principles and patterns behind biophilic design, as well as the resulting impacts it can have on human well-being and cognitive performance, an argumentative foundation has been built regarding the beneficial aspects of implementations of nature. Adhering to these principles as a framework for the concept development, the concept will have the objective of attempting to evoke positive emotional responses and yielding the said effects, although on a visceral level.

The interpreted trends and user needs from the user research are also evaluated and included in defining the design requirements. From the interviews with the car dealerships, it is evident that advancements in technology will see continuous developments and incorporated into vehicles in the future. From the current perspective, the desire for it from customers will most likely remain and therefore technology will have to be seamlessly integrated when utilized. However, it is important to make the distinguishment between technology and digital screens. Although they may be closely connected, there is not an equivalency between the terms and new technology can therefore be implemented without the use of screens. Technological elements can thus be incorporated without inciting digital fatigue.

The lack of customization after having received the vehicles is also an interpreted need that many brands believe are expected to increase. AVs are incrementally changing the layout of car interiors and the space is becoming more like a third space between home and work. The need for personalization is therefore a relevant topic and should be explored in a concept of future autonomous vehicles as this would also impact the user experience.

For a deeper and more sincere connection with nature, the identified principles in Japanese and Scandinavian philosophy should also act as guidance in the design process. These philosophies emphasize the visceral aspects of the connection to nature and are appropriate for this project with their historical recognition and empirical validation.

4.2 The Design Challenge

The concept should:

- exhibit a holistic view of exterior, interior and UX.
- seamlessly integrate technology if utilized.
- adhere to the biophilic patterns.
- offer customization.
- evoke positive emotional responses.
- exhibit novelty and innovation.
- incorporate values from Japanese and Scandinavian aesthetics.

The biophilic patterns are summarized below for ease of finding:

Nature in the Space	Nature Analogues	Nature of the Space
• Visual Connection with Nature	• Biomorphic Forms & Patterns	• Prospect
• Non-Visual Connection with Nature	• Material Connection with Nature	• Refuge
• Non-Rhythmic Sensory Stimuli	• Complexity & Order	• Mystery
• Thermal & Airflow Variability		• Risk/Peril
• Presence of Water		
• Dynamic & Diffuse Light		
• Connection with Natural Systems		

Table 4.1. The 14 biophilic design patterns.

5 Develop

In this chapter ideas and concepts were generated based on the established biophilic values. A chosen concept was then selected for further development and modeling in Blender.

5.1 Ideation

During the initial idea generation phase, brainstorming sessions are conducted with a focus on established biophilic patterns. The aim is to identify various natural phenomena that could potentially be incorporated into the concept. The approach of having nature as an origin is thought to create a more natural and authentic development process.

The concepts and findings from the ideation process are decided to be communicated through moodboards, a visual tool that uses a selection of references to effectively capture the desired atmosphere, feelings, and design direction.

Moodboard i aims to reflect the transparency of glass, the natural complex reflections and refractions of light bouncing through the glass and water surfaces and creating striking fractal patterns and shadows.

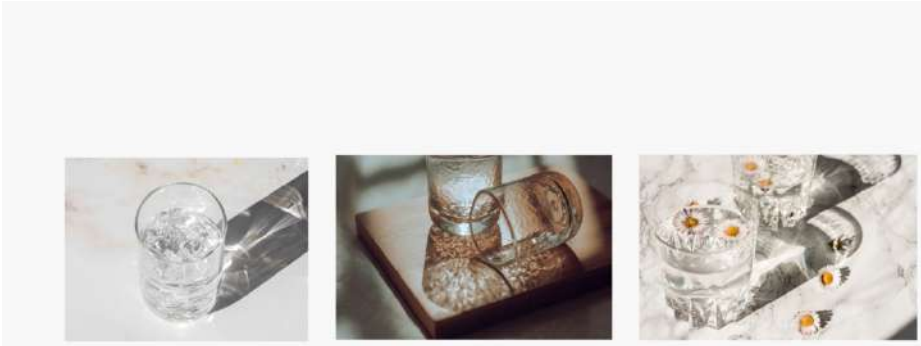
Moodboard ii gives the spatial feeling of being underwater in an enclosed space. The main features to be examined are the caustics effect, an interplay between light and water which creates alluring fractal patterns.

Moodboard iii conveys the openness and boundlessness of a clear sky. The feelings connected to summer are of interest, this includes the perceived warmth and heat but also the cool shade and refuge from the sun under a roofing.

Moodboard iv explores the nighttime setting and the darkness and mystery that it entails, as well as circular geometries and the faint presence of a distant illuminating object such as the moon.

Moodboard v encapsulates the feelings of shinrin-yoku. It depicts the subtleties of illumination in a forest environment with an interplay of gentle, diffused sunlight and varying, soft shadows, casting a soft and dynamic ambience.

Moodboard i



Moodboard ii

Moodboard iii



Moodboard iv



Moodboard v

5.1.1 First Concept Evaluation

Using the moodboards, a test is conducted to identify how well the ideas are being mediated, what the images convey for the testers, and whether there are any uncertainties or preferences for certain concepts.

The tests are conducted with a sample size of 7 random individuals, where images are shown without context to achieve objectivity and ensure that their initial impressions are received. For the convenience and quick nature of the test, the backgrounds of the test individuals are not considered as it is the visceral impressions that are being evaluated. As the images are shown without context, the test individuals are not required to have any prior knowledge regarding neither form nor design.

The test employs a word association methodology, where each tester is asked to relate the images to multiple words, feelings, or thoughts, both individually for each image, and each moodboard. The purpose is to explore the common themes or patterns that emerge from their interpretations. The test is done quickly and thus do not include many participants. More interpretations could be collected with more participants as the word association methodology being used depends on past experiences and individual preferences of testers.

One interesting finding was that most of the testers associated the images with specific places, seasons, and different times of the day. This suggests that the

images resonated with their memories and experiences, evoking a sense of location and temporal context.

Moodboard i prompted associations related to refreshing experiences, summer vibes, transparency, complexity, and cleanliness. Meanwhile, Moodboard iv evoked a sense of a serene evening atmosphere during autumn, with testers associating it with the experience of strolling under the night sky of cities like Paris or Tokyo.

Moodboard ii, however, was described as confusing and unclear by multiple testers, with too much going on. The abundance of sensory information without any context may have overwhelmed their interpretations.

Moodboard iii and v were favored by many testers as they reminded them of the relaxed warmth of a summer days' vacation in Bali or the Mediterranean's, as well as the peacefulness of traditional Swedish deep forests. These moodboards conveyed a sense of calmness and easiness, with the subject in moodboard v reminding a few testers of family and taking walks together.

The feedback from the test was evaluated based on how they aligned with the established biophilic values, and the preference for each concept was considered in the subsequent concept generation phase.

5.2 Concept Generation

The different concepts presented in the moodboards were combined to generate three different concept directions. Apart from fulfilling the established requirements of displaying biophilic patterns and considering the feedback from the first evaluation, another common guideline was to achieve a holistic approach that merged the UX with both the exterior and interior.

The concepts are described in more detail in the following sections.

5.2.1 **Direction A**

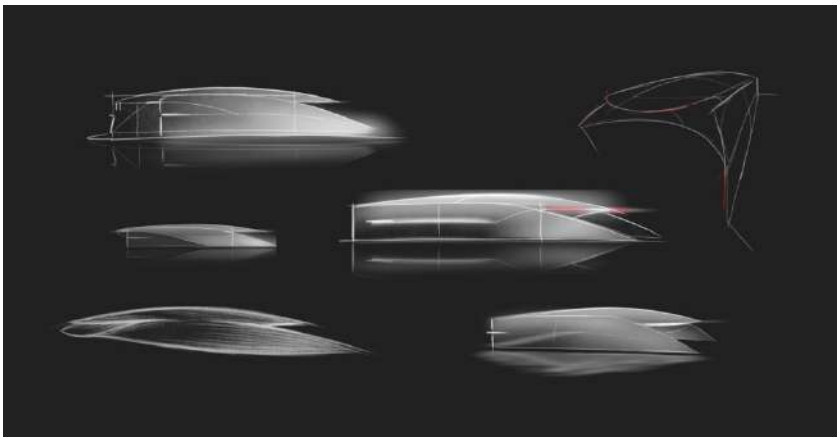
Figure 5.1-5.2. Images inspiring Direction A (Owens, 2017; Trovato, 2021).

This concept embraces biomorphism and biomimicry, drawing inspiration from the flowing and convex forms of turtles. The design embodies the gentle curves and rounded edges found in their body structure as to exhibit the appearance of a living exterior whilst also emphasizing functional fluidity.

The greenhouse-arch mimics the protective shells of turtles and continues around to enclose the interior space as a bodyshell made entirely out of glass. The large glass surface allows plenty of natural light to enter the interior.

With the use of layered glass, water is sealed between the layers to create a wall encapsulating the interior, thus offering a sense of refuge. When light passes through a glass, the refraction creates shimmering patterns on the surrounding surfaces, adding a sense of complexity and intrigue. These so-called caustics are fractals and non-rhythmic stimuli that change with the movements of the vehicle.

Intrigue is heightened by the perceived risk/peril. The presence of water surrounding occupants, creates a thrilling yet controlled sense of danger.



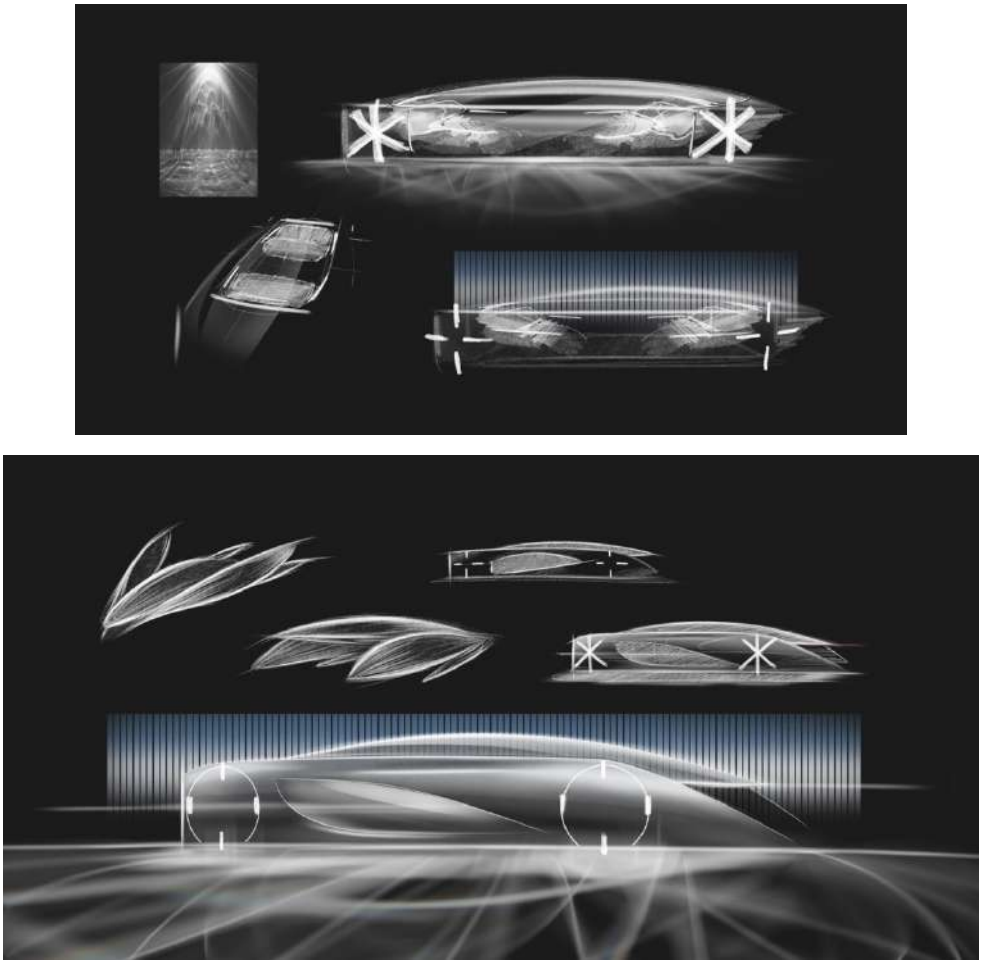


Figure 5.3-5.5. Sketches of Direction A.

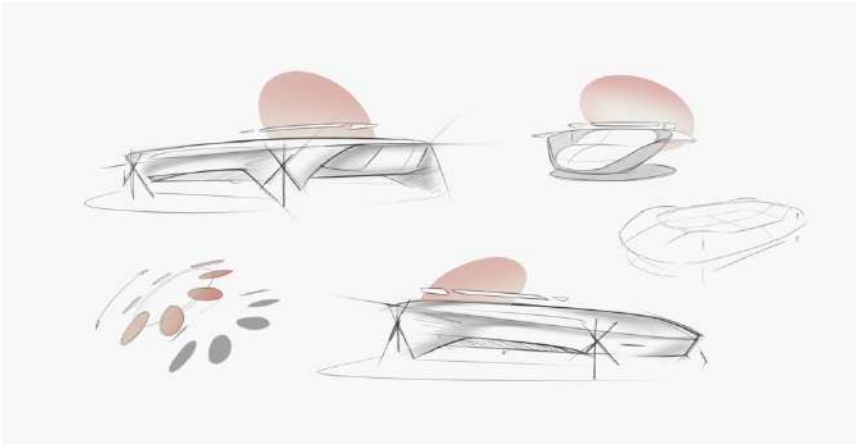
5.2.2 **Direction B**

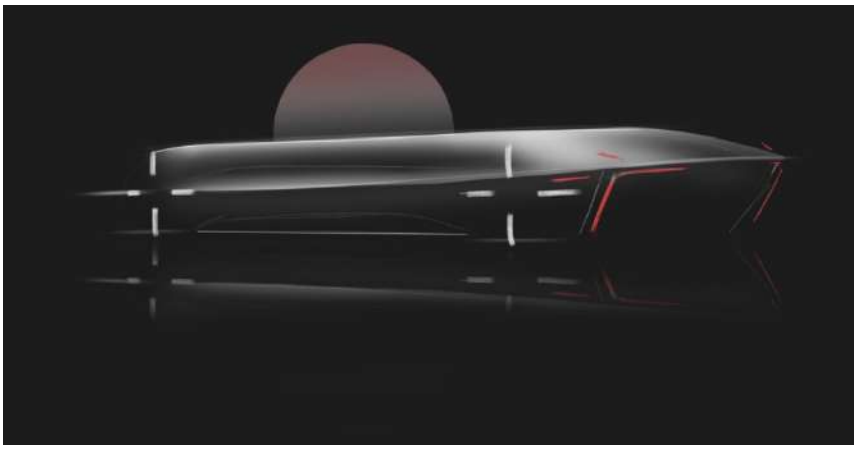

Figure 5.6-5.7. Images inspiring Direction B. (Nguyen, 2022)

This concept emphasizes the biophilic patterns of prospect and connection with natural systems. The concept takes inspiration from walking in an open natural environment under the shade of a *wagasa*, a Japanese umbrella often seen as a protective object, shielding against negative energy and impurities.

The notable feature of this concept is the absence of a traditional greenhouse. Instead, the design enables direct contact with nature, allowing occupants to fully experience the thermal and airflow variability of the environment. It also includes both visual and non-visual connection with nature, as there are no obstructing walls that separate the occupants from their natural surroundings. This unobstructed view enables a seamless integration of the interior and exterior spaces.

The concept also incorporates the idea of refuge, offering angular adjustability through a rotating disc. Located behind the occupants' seating by default, the disc provides a protective side to the back. The transparency of the disc can be adjusted, creating partially obstructed views which engage a sense of curiosity and mystery. The way the shadows are created by the disc, which can be reminiscent of an umbrella, parasol, or even the moon, adds to the experience in the space. The adjustable transparency also allows it to be synced with the phases of the moon, enhancing the biomorphic qualities.





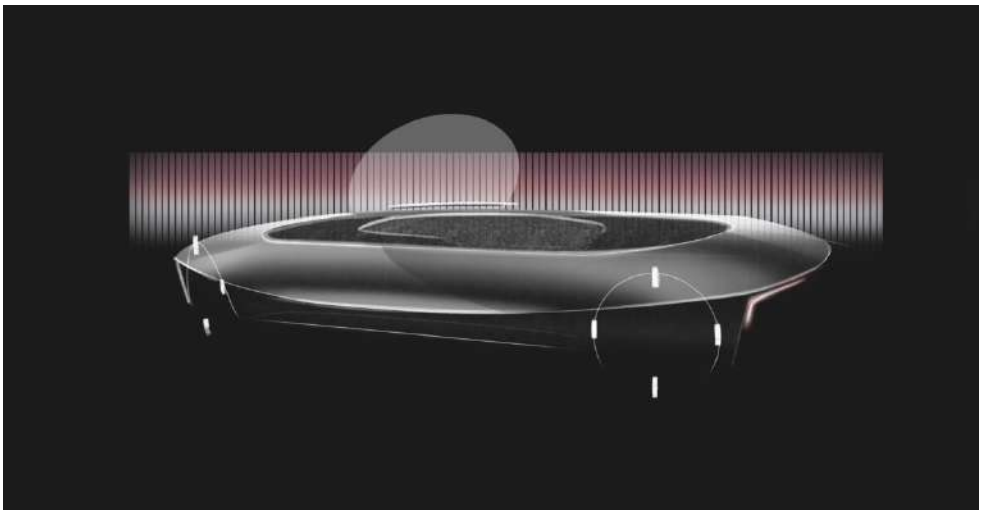


Figure 5.8-5.10. Sketches of Direction B.

5.2.3 **Direction C**


Figure 5.11-5.12. Images inspiring Direction C.

The final concept draws inspiration from the Japanese concept of "kōyō," which celebrates the autumn foliage and the changing colors of leaves during the fall season. This concept incorporates biomorphic forms that resemble a tree with branching leaves in the roof and connects to the natural system of seasonal change. The changing colors of the leaves serve as non-rhythmic stimuli, adding visual interest and dynamism.

The tree trunk serves as a material connection to nature, and emphasizes the complex textures and patterns found in wood. The tree canopy evokes a sense of mystery by hinting the sky above and creates a dynamic and diffuse play of light and shadow through the vacant spaces between the leaves. This non-rhythmic occurrence emphasizes both temporal changes as the sun moves across the sky, and momentary changes caused by the movements of the vehicle.

The concept aims to create a sense of calmness and tranquility, reminiscent of sitting under a tree, and provides a feeling of refuge where occupants can find relaxation. However, there is also a subtle sense of risk/peril, for instance when dramatic shadows are cast by the awe-inspiring and sometimes intimidating nature of trees.

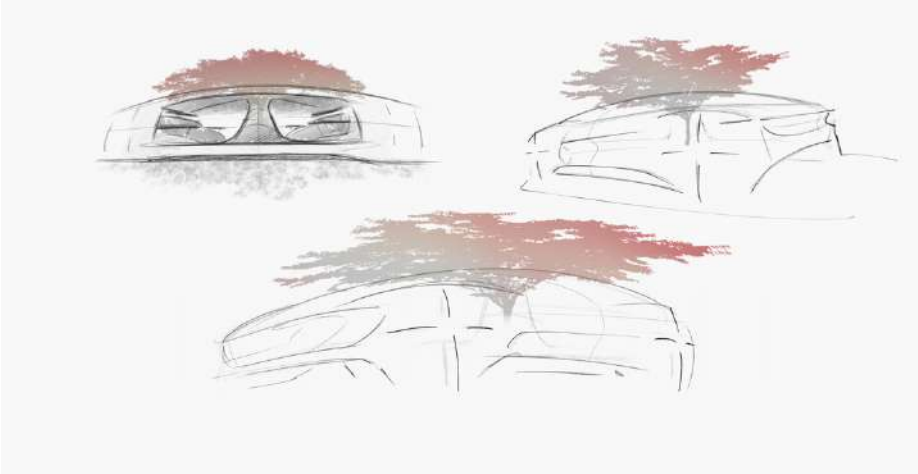


Figure 5.13. Sketches of Direction C.

5.2.4 Second Concept Evaluation

Prior to Concept Selection, a second evaluation is conducted to gather more detailed feedback on the concept ideas. This time, the concepts are presented in a contextualized manner, allowing the participants to better understand and visualize the potential implementations.

The evaluation involves individual meetings with four salesmen from different car dealerships. Salesmen are chosen for similar reasons when user research was conducted. Their regular experience with customers and knowledge about the current needs and trends in the automotive market, make them valuable contributors to the evaluation process.

During the evaluation session, the focus is on gathering feedback and comments on the concept directions. The discussions revolve around various aspects of UX, practicality, the degree to which nature is integrated, and the potential desirability for customers. The key takeaways are presented in the following paragraphs.

Privacy concerns is a common topic raised during the discussions. If the interior of the car is too exposed, occupants might feel discomfort. People value their personal space and want to feel secure and comfortable while traveling. Finding the right balance between openness and privacy is key.

Participants voices some concerns about direction A, feeling that the concept of caustics could be a bit overwhelming and potentially even distract or disrupt the

overall UX. While arguably visually appealing, they could interfere or cause inconveniences for the passengers through excessive glare or reflections.

There are some doubts regarding Direction B as well, with concerns of it not being that practical in adverse weather conditions. This limitation could impact the market appeal, as customers expect their vehicles to be adaptable and reliable in various conditions.

Despite compromising on interior space, participants embrace the idea of Direction C incorporating seemingly living elements into the vehicle interior with possibilities of creating an immersive natural atmosphere during travel.

5.3 Concept Scoring

	Concept Scoring								
			*	Concept					
				Direction B (Reference)		Direction A		Direction C	
	Criteria	**Weight**		**Rating**	**Weighted score**	**Rating**	**Weighted score**	**Rating**	**Weighted score**
Nature in the Space	Visual Connection with Nature	12%	***	3	0,36	1	0,12	3	0,36
	Non-Visual Connection with Nature	8%	**	3	0,24	2	0,16	3	0,24
	Non-Rhythmic Sensory Stimuli	8%	**	3	0,24	5	0,4	3	0,24
	Thermal & Airflow Variability	8%	**	3	0,24	1	0,08	1	0,08
	Presence of Water	8%	**	3	0,24	5	0,4	3	0,24
	Dynamic & Diffuse Light	8%	**	3	0,24	3	0,24	3	0,24
	Connection with Natural Systems	0%		**0**	0	0	0	0	0
Nature Analogues	Biomorphic Forms & Patterns	4%	*	3	0,12	5	0,2	5	0,2
	Material Connection with Nature	0%		**0**	0	0	0	0	0
	Complexity & Order	8%	**	3	0,24	5	0,4	4	0,32
Nature of the Space	Prospect	12%	***	3	0,36	1	0,12	1	0,12
	Refuge	12%	***	3	0,36	3	0,36	5	0,6
	Mystery	8%	**	3	0,24	2	0,16	4	0,32
	Risk/Peril	4%	*	3	0,12	4	0,16	4	0,16
		100%							
	Totalscore			3		2,8		3,12	
	Rank			2		3		1	
	Continue?			No		No		Yes	

Table 5.1. Concept scoring matrix.

The concept selection is conducted through Ulrich & Eppinger's Concept Scoring matrix. The method provides a structured approach to evaluate and compare different concepts based on predetermined criteria and weights.

Each criterion is assigned a weight that mirrors its relative importance. The concepts are then rated for each criterion on a numerical scale, 1 to 5, with one of the concepts as a reference. The ratings are then multiplied by the corresponding weights to calculate weighted scores, which are summed up

across all criteria to obtain a total score for each concept. The concept with the highest score from the concept scoring is selected for further development.

In this case, the developed concepts are rated against the biophilic patterns with the weights depending on how much research have been conducted for each pattern. This is based on the conducted literature research and in accordance with (Browning et al., 2014). The asterisks indicate the quantity and quality of empirical data supporting each biophilic pattern and are marked with up to three asterisks (***). The absence of an asterisk indicates a lack of extensive research supporting the connection between health and design. However, despite the limited research on two patterns, the anecdotal information is sufficient to assume their potential impact and significance as distinct patterns. The information in question is in reference to the data provided in (Browning et al., 2014).

The total weight is distributed over the criteria to yield a 4% weight of importance for each asterisk.

Direction B is used as reference for comparison of Direction A and C, wherein the comparisons are based on the concepts' relative connection to each biophilic pattern and what was discussed in the previous evaluations.

Direction A is an enclosed space with similarities to a water tank. The visual connection with nature is thus, mostly with water and the reflections of it created by light shining through the cabin. Although the transparency could provide views of the surroundings, this is not the focus of this concept direction. The criteria "Visual Connection with Nature" and "Prospect" are therefore ranked lower for Direction A in comparison to Direction B. The fractal patterns and irregularities of water connected to Direction A, however, create more complex and stochastic stimuli which gives it higher scores in terms of the patterns "Non-Rhythmic Sensory Stimuli", "Presence of Water" and "Complexity & Order". The perceived risk of getting wet while in the cabin also add to the "Risk/Peril" pattern giving it a higher score than the reference concept.

Direction A similar to Direction C, adopt biomorphic patterns to a higher degree and more conspicuously which consequently yield higher scores than Direction B. Direction C emphasizes the presence of a tree and the sense of refuge of sitting under the protection of a canopy. While letting light dynamically shine through the canopy branches of leaves, concurrently, the concept displays a greater sense of mystery of what is behind the canopy as well as a perceived danger of a tall tree falling. These considerations contribute to Direction C

receiving higher scores in the following criteria: “Complexity & Order”, “Refuge”, “Mystery”, and “Risk/Peril”.

As Direction B eliminates the greenhouse, occupants are directly getting in contact with nature and the thermal and airflow variabilities in the air. This gives Direction B a higher score regarding the associated biophilic pattern criterion in relation to the other directions, as these in contrast, have enclosed cabins.

Because of the limitations of the project and the lack of time for thoroughly examining the relative importance of the patterns, the scoring system is selected despite its apparent flaws. More developments can be made regarding the establishment of the weights and chosen criteria in the selection process. This is especially relevant for the criteria with weights chosen as zero, which were chosen because of limitations and for facilitating the selection process with regard to these boundaries.

5.4 Concept Development

5.4.1 **Form Development**

The main purpose of form development is to find a good balance on the stance of the vehicle and connecting key volumes to get a good proportion. Proportions are especially important when designing for simplicity, and are significant for establishing an emotional connection and in creating a positive UX.

Inspiration is taken from "shakan", a slanting bonsai style that features fukinsei through its asymmetrical form. Despite it seemingly being unstable, it manages to maintain a feeling of balance and stability through a properly grown root system. The shakan is selected as it evokes dynamism and a sense of forward movement through its asymmetry. It also displays strength, with the slanted trunk often being interpreted as a representation of resilience and adaptation. It suggests that the tree has endured external forces such as strong winds or natural challenges and has adapted by growing at an angle.

The top part of the concept mirrors the organic structure of the bonsai and adds a sense of fluidity and natural form to the overall design. In contrast, the lower part reflects the bonsai pot and instead adopts a static and geometric approach by incorporating straight and angular lines to convey stability and solidity. This

geometric foundation provides a visual anchor and adds a sense of structure to the design.

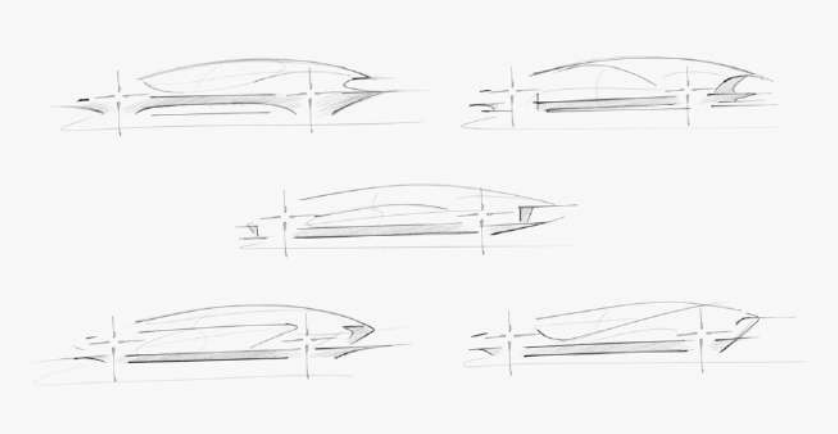


Figure 5.14. Sketches of form development.

Figure 5.15. Slanting “shakan” bonsai style (Yu, 2019).

5.4.2 **Exterior**

With regards to kanso, the exterior is defined by few but purposeful lines, focusing on creating a clean and deliberate appearance.

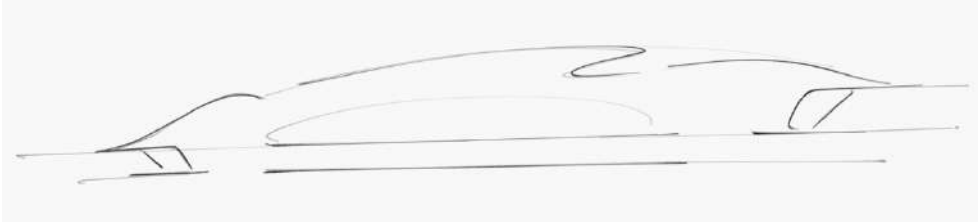


Figure 5.16. Minimal sketch of key lines defining the concept.

In terms of packaging, assuming that there is no ICE and instead having a battery package located beneath, allows for greater design freedom in the upper parts of the vehicle. The bonnet can be significantly lowered to allow more natural light to enter the cabin, improving visibility and openness within the interior.

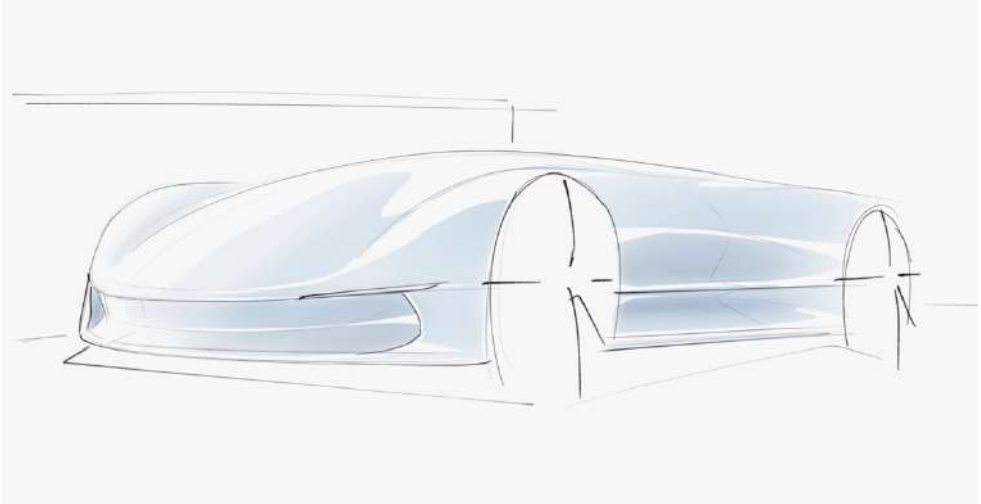


Figure 5.17. Front sketch of the concept.

To maximize the intake of light even further, the side windows are extended all the way to the floor, essentially eliminating conventional doors. This not only serves an aesthetic purpose but also contributes to the overall volume and functionality of the vehicle.

The volume of a car is an important consideration to optimize passenger comfort. Interior volume refers specifically to the passenger space within the car, encompassing legroom, headroom, seating and storage space. A large

wheelbase, minimizing overhangs and utilizing form efficiently maximizes the available interior space.

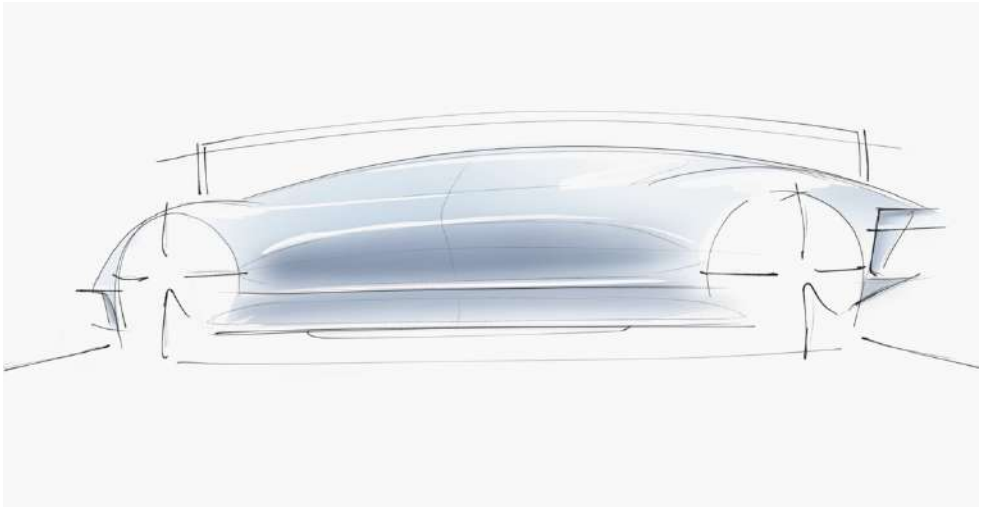


Figure 5.18. Side sketch of the concept.

The aerodynamic body features streamlined and flowing lines that not only have a visual purpose but also serve function. The defined and prominent shoulders enhance the visual appeal while creating a more dynamic and sculpted appearance, helping in managing airflow along the sides, reducing turbulence and drag for improved performance.

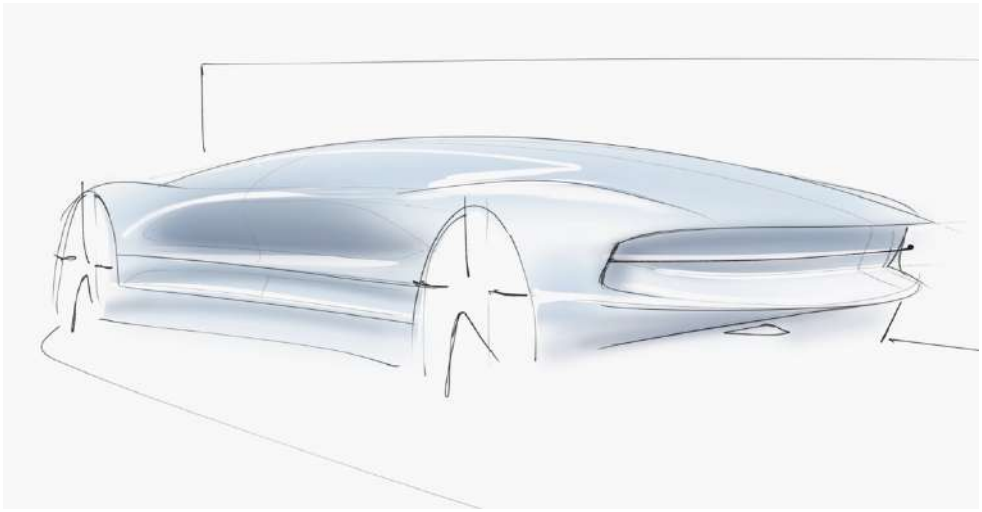


Figure 5.19. Rear sketch of the concept.

5.4.3 **Interior**

With EVs, flat floor design becomes possible, further enhancing the interior space. The absence of a traditional transmission tunnel and other mechanical components associated with ICEs allows for a more spacious and versatile interior. The electric motors and other essential components associated with EVs are given general consideration, allowing for flexibility in their placement within the free space behind the backseats in the rear and under the lowered bonnet at the front. Additionally, with no need for traditional instrument panels or controls, there is an opportunity to reimagine the interior layout. Stripping away excess and focus on creating a warm and comforting space like being at home.

The flat floor design increases legroom and enables easier configuration of seating arrangements. The seating is inspired by *zaisu* seating, or floor chairs, which is a type of seating furniture without legs commonly found in Japanese homes. Zaisu seats bring the user closer to the ground which could represent a way of getting closer to the earth and nature.

The initial idea was to incorporate an organic and similar appearance to a real tree trunk. However, this attempt felt too artificial and unnatural. Instead, the woodframe is intended to symbolize the trunk through a biomorphic approach, which is depicted in the renderings in section 6.1.2.

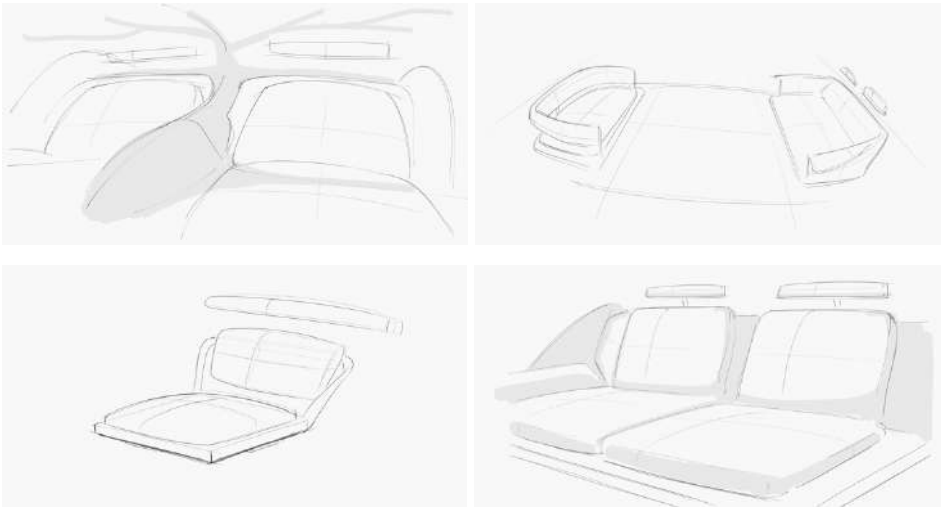
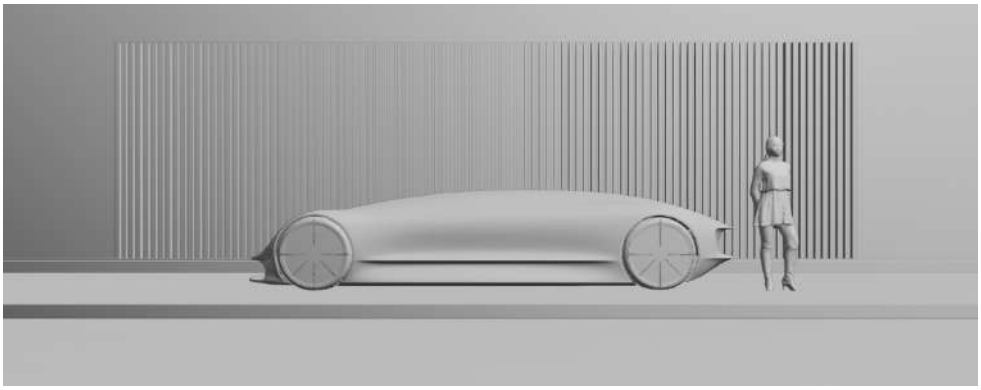
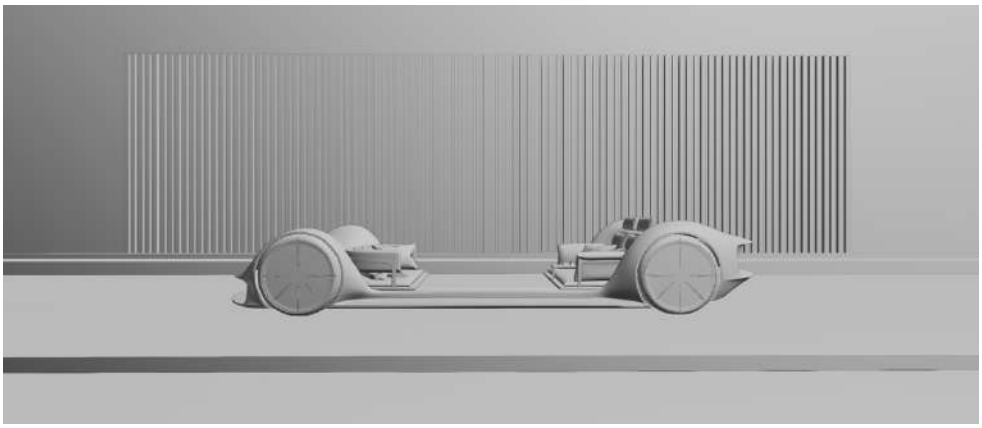


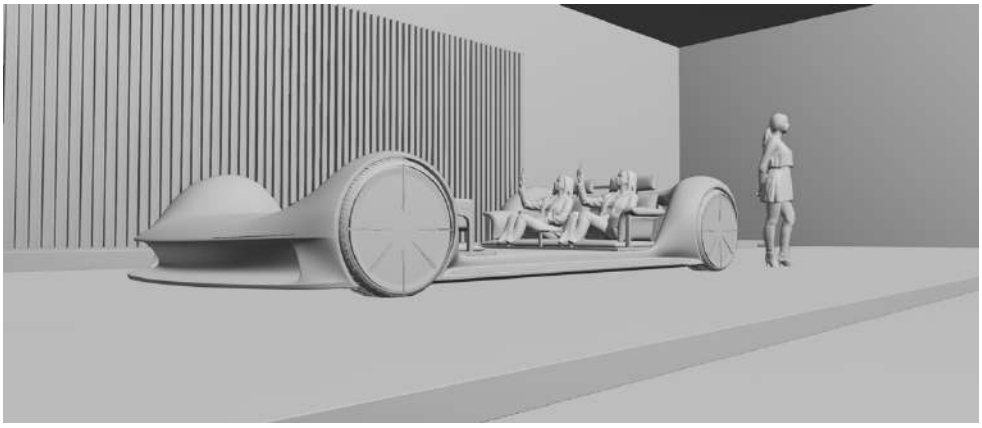
Figure 5.20. Sketches of the interior.

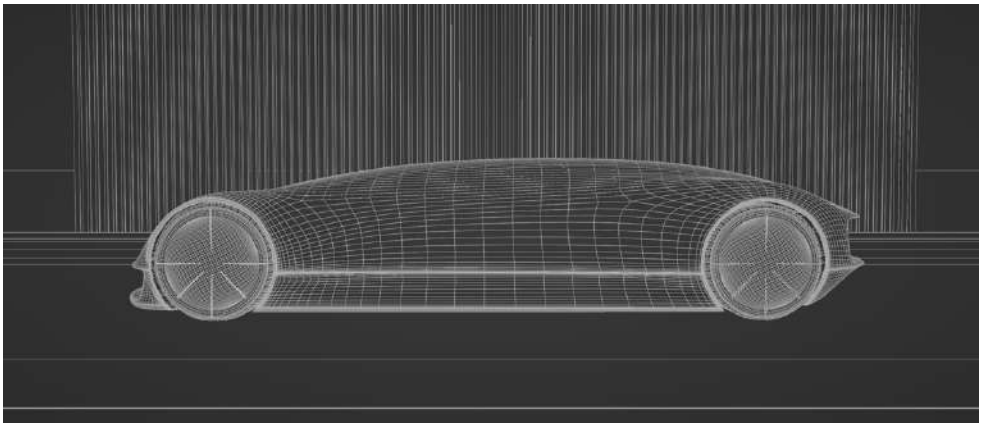
5.4.4 **Modeling**

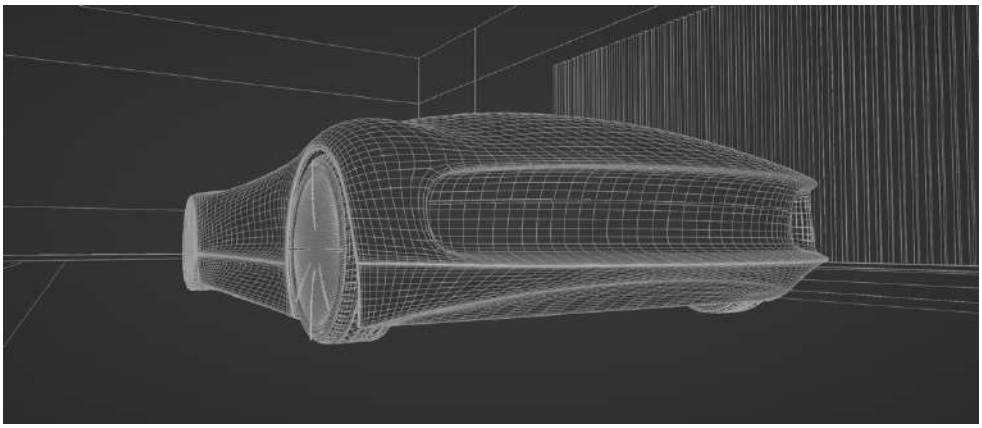
The forms and proportions having been established through the sketches, were used as reference for the following modeling phase. The 3D-modeling of the concept was conducted in Blender and applied the method of SubD modeling. SubD modeling involves creating a rough base mesh with a relatively low polygon count and then applying a subdivision algorithm to subdivide the polygons. This creates a smoother derivative surface with additional levels of detail, which enables efficient editing and manipulation of the model. The rough base mesh included the overall volume and proportions of the vehicle with defining lines and surfaces as visualized through the sketches in section 5.4.2. For the dimensioning of the vehicle, 3D-modeled people were used as a reference with the height of 180 cm. Only free human models were utilized which is why the seating position of the models are slightly awkward. In this case, it is the height of the seating position that is of significance.

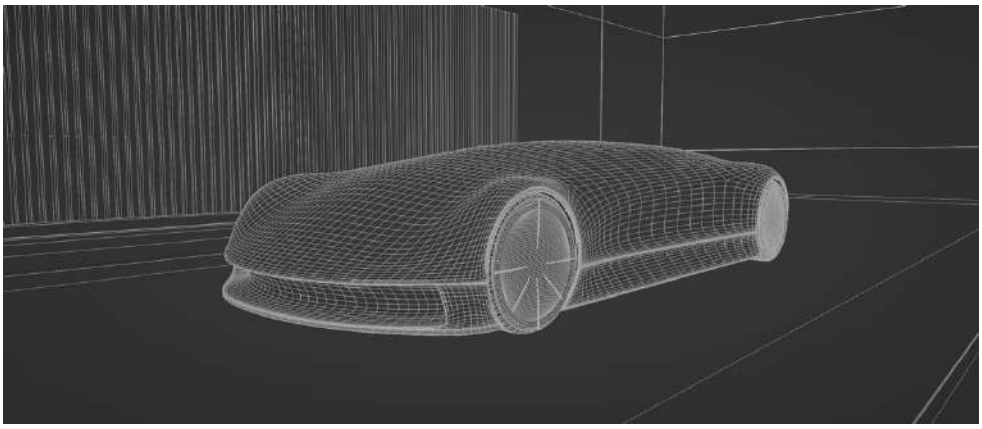


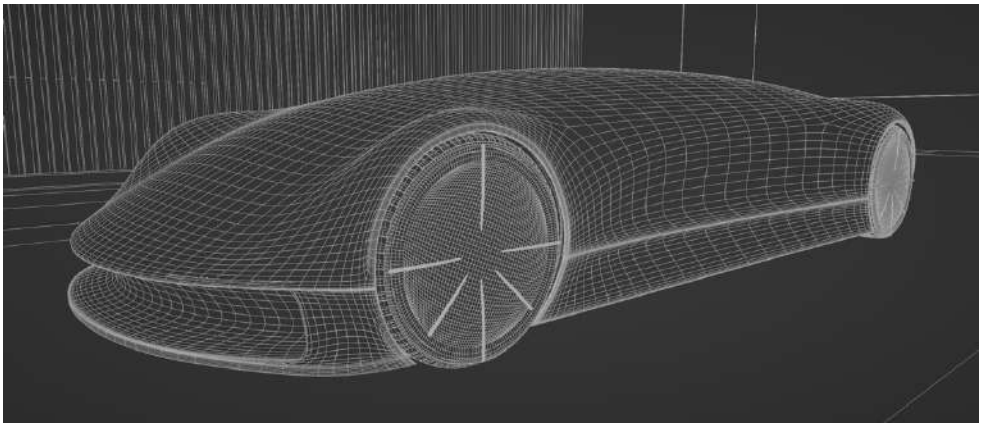












6 Deliver

This chapter presents the final deliverables of the thesis project in the form of renderings. A final concept evaluation is ultimately conducted.

6.1 Final Concept

6.1.1 **Exterior**

The UX begins right at the moment of encounter with the exterior. The inspiration from a “shakan” bonsai gives the concept a balanced asymmetry with a sense of forward movement and dynamism.

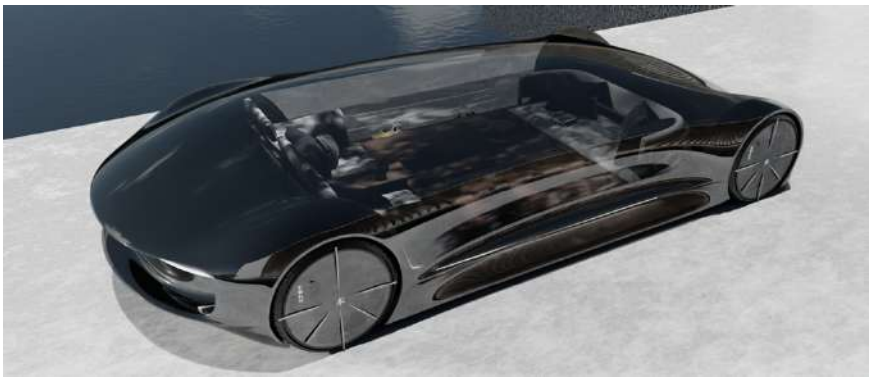
Too intense dynamism can, however, feel aggressive and provocative, which is why for one, the rim design has an even number of 6 spokes for providing a calming and harmonious sense of symmetry and balance, and secondly having the top part of the concept mirroring the organic and soft structure of a bonsai which adds a sense of fluidity and natural form to the overall design. In contrast, the lower part reflects the bonsai pot and employs a static and geometric approach by incorporating straight and angular lines to convey stability and

solidity. This geometric foundation provides a visual anchor and adds a sense of structure to the design.

The graphics are kept simple and non-obtrusive to the remaining aspects of the car, and instead are used to exert an emotional expression and to highlight the proportions and negative spaces.

Without an ICE, the bonnet is lowered significantly to allow more natural light to enter the cabin, improving visibility and openness within the interior. To maximize the intake of light even further, the side windows are extended all the

way to the floor, essentially eliminating conventional doors. This not only serves an aesthetic purpose but also contributes to the overall volume and functionality of the vehicle.



The bodywork features streamlined and flowing lines that not only have a visual purpose but also serve function. The defined and prominent shoulders enhance the visual appeal while creating a more dynamic and sculpted appearance, helping in managing airflow along the sides, reducing turbulence and drag for improved performance. The concept aims to utilize the volume properly, maximizing interior space while establishing a slim body frame expressing lightness and agility.

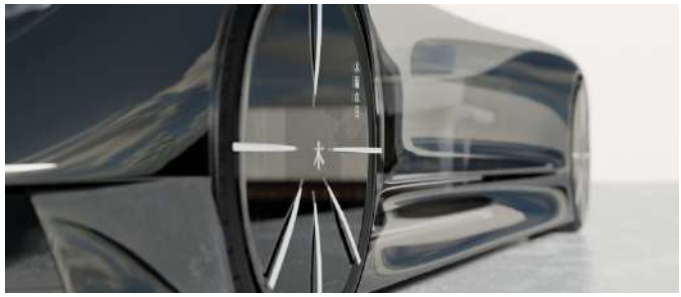
Being a continuation of Direction C, the final concept embodies the biomorphic forms and resemblance of a tree and adopts the concept of "kōyō", making a connection to the natural system of seasonal change. The concept is however, not only limited to autumn leaves but considers the changings and blooming of leaves and flowers of all four seasons. This is the part where technology is utilized with an exterior bodywork of energized glass, also known as smart glass. Energized glass is a type of glass that can dynamically adjust its properties such as transparency, reflectivity, or tint in response to an external stimulus, such as an electrical current, heat, light, or magnetic field.

This technology is combined with an advanced color changing technology, an example already being displayed and developed by BMW in their concept model BMW I Vision Dee. For further reading see (BMW, 2023).

Thereby, the concept offers a customization option that changes with seasonal differences. The vehicle recognizing and adapts its “leaf” colors to match the trees in its surroundings. Alluding to the concept of yūgen and mono no aware, it suggests the beginnings and ends of each season and the ephemeral beauty of impermanence and perishability.

The main feature of the concept that highlights its connection with nature, is the dynamic and dappled light being created by the sun and simulated tree leaves. This natural phenomenon is described by the Japanese word “*Komorebi*” which roughly translates to “sunlight that filters through the leaves of trees.” The dappled light is an instance of stochastic and unpredictable movements in nature which serves as a non-rhythmic sensory stimulus. This play between light and shadow embraces the dynamic changes in light intensity as well as the light color variations of sunlight.

Wheel design is kept simple, alluding to the kanji meaning ‘tree’. Large flat wheel rims play a major role in displaying a visually coherent proportion but are also important for vehicle dynamics. Especially relevant with the assumption that AVs are fully electric, in which these kind of wheel designs could reduce drag, ensure proper air flow which consequently results in increased range and performance.



6.1.2 **Interior**

The absence of a traditional transmission tunnel and other mechanical components associated with ICEs allows for a more spacious and versatile interior. Electric AVs enable a flat floor design, which not only increases legroom but also facilitates easier configuration of seating arrangements. Additionally, without the need for traditional instrument panels or controls, there is an opportunity to reimagine the interior layout, offering a more open and customizable space.

The 3+2 seat arrangement promotes a social environment within the vehicle with plenty of space, resembling a personal living room setup giving the occupants a large freedom for customization and transforming the interior to their own

preferences and needs. This arrangement also allows for easy communication and interaction among passengers but also enhances the visual contact with the surrounding natural environment through the openness and consideration of *ma* in the cabin.

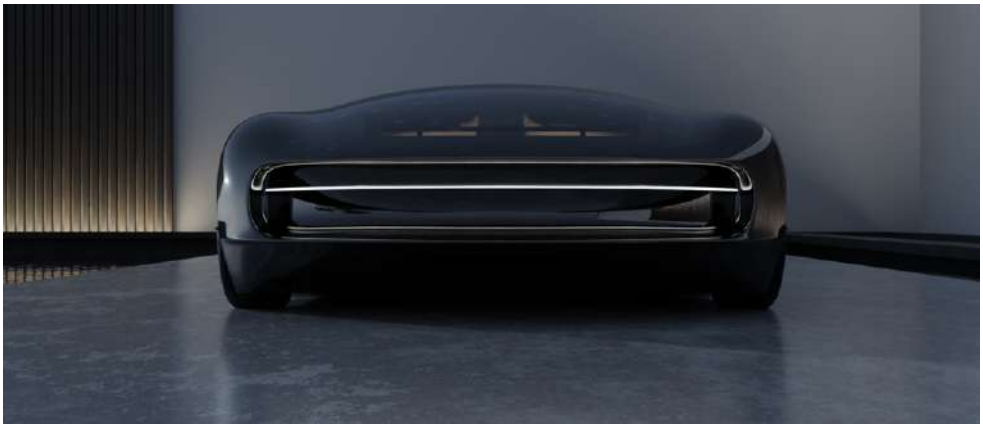
The concept features a form of *zaisu* seating, or floor chairs. Zaisu seats bring the user closer to the ground which could represent a way of getting closer to the earth and nature. At the same time, the low seating arrangement enhances the spaciousness within interiors by indirectly heightening the ceiling. Within the context of the concept, this improves the overall visibility and creates a wider unobstructed view of the sky and the natural surroundings, further enhancing the connection to nature. The low design considerations also help enhance the perceived feeling of sitting under a tall tree and the dappling shade of its canopy.

The wood-frame of the backseat displays a biomorphic element, symbolizing the steadfastness and strength of a tree trunk. Within the woodframe, an integrated tray provides a practical solution for passengers to conveniently place their belongings or utilize it as a supportive armrest.

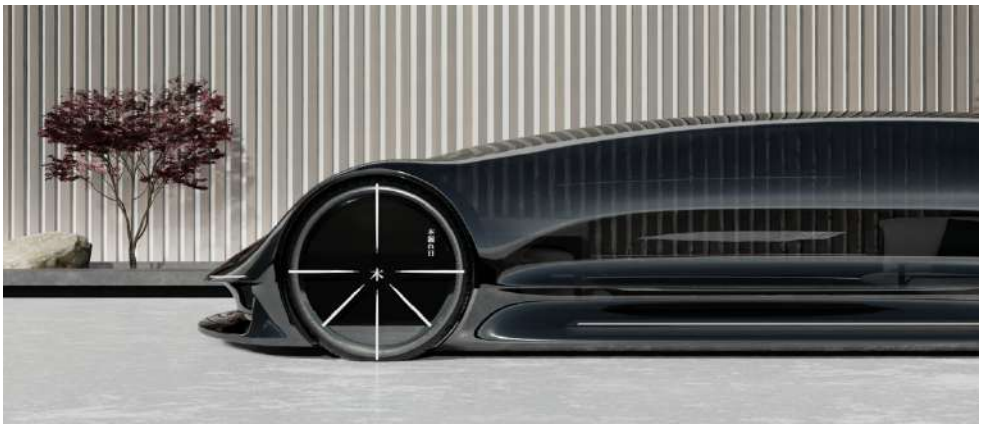
Wood is not only utilized for its aesthetic appeal but also alludes to a material connection with nature and creates a sense of warmth within a space. The experience is further enhanced by the choice of neutral colors and a diverse range of textile patterns and textures. These colors have the ability to visually expand the space, making it feel more open and inviting. The diversity of patterns found in natural wood grains and textile designs adds depth and visual interest to the interior.

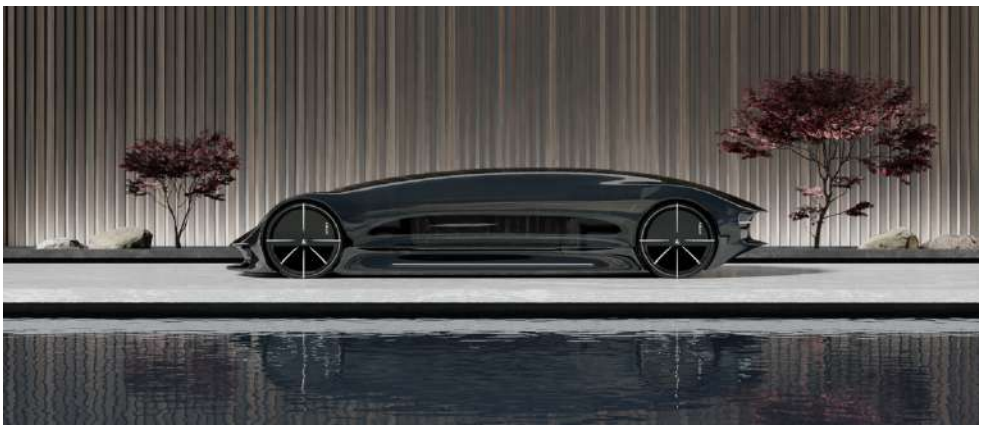
Drawing inspiration from the concept of a genkan, a Japanese entranceway, the inclusion of a separate platform on the sides serves as a transitional space for entering and leaving the vehicle. It is a reference to the cultural tradition of removing shoes before entering someone's home, common in Japanese and Scandinavian homes. This act further enhances the connection to the concept of the vehicle as a welcoming space. Removing shoes before entering also reinforces the connection to nature by providing a tactile experience and allowing direct contact with the wooden flooring.

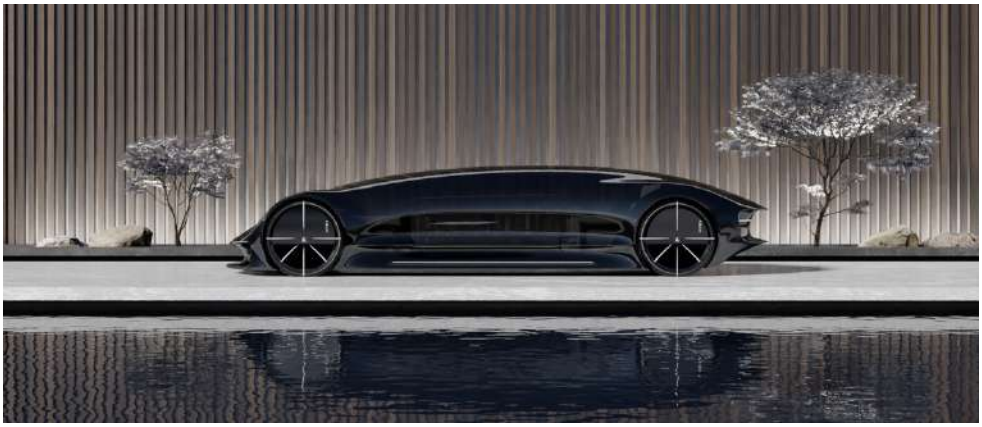
Ambient warm lights were positioned behind the seats to provide diffuse lighting. The lights are specifically chosen for their warm and gentle glow, creating a cozy and relaxing ambiance within the interior, particularly for travels during nighttime. Furthermore, the warm lighting complements the overall ambiance created by the wood and textile elements to help establish an inviting space that promotes well-being and a sense of calmness.

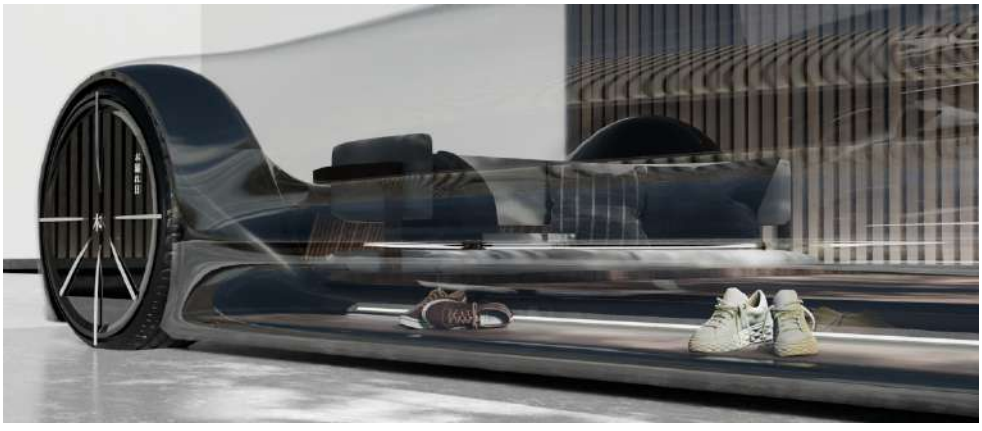


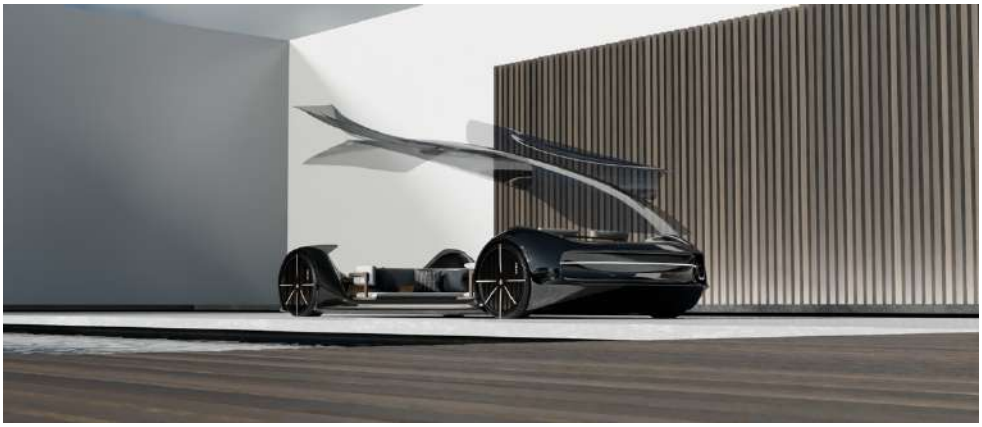
6.1.3 **Renderings**

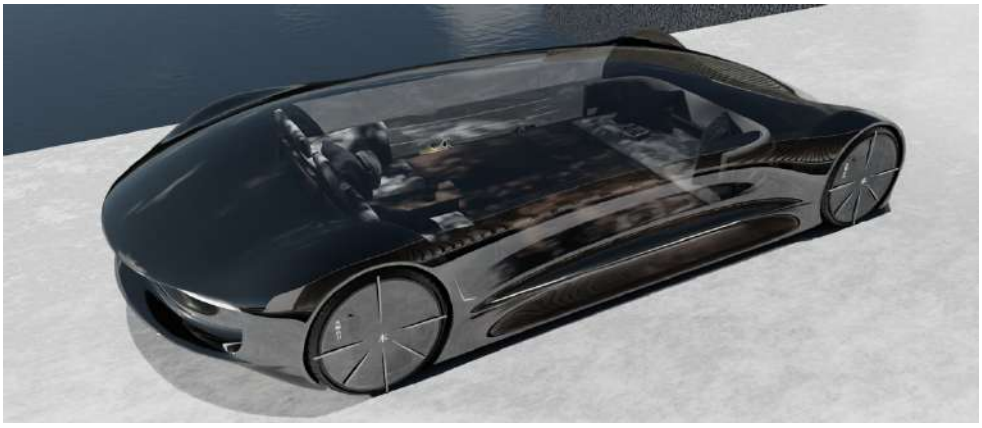


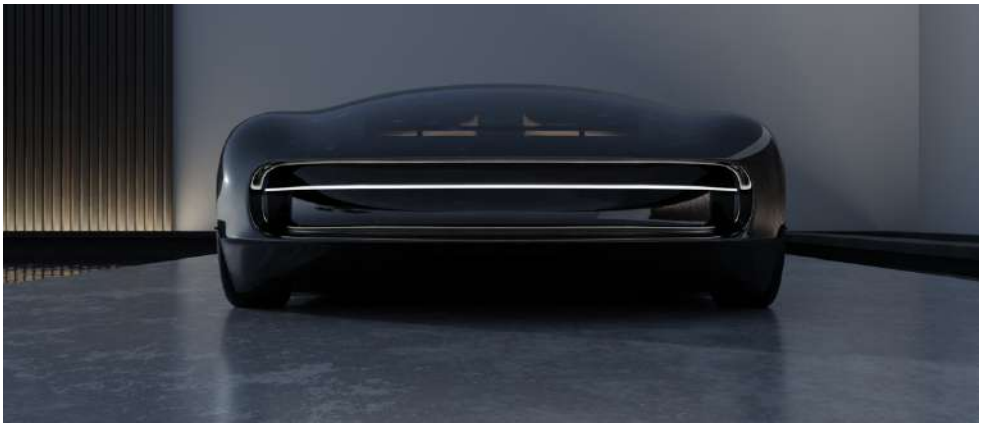


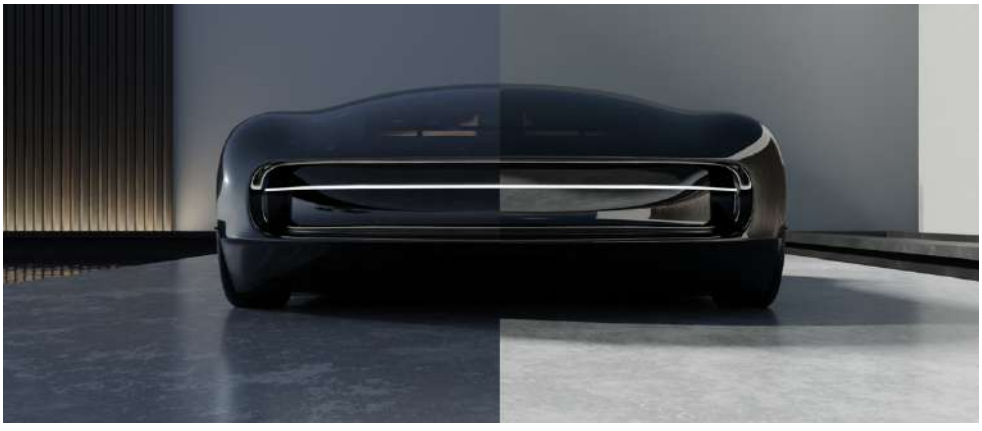












6.2 Final Concept Test

The evaluation of the final concept is done through an online questionnaire measuring UX, as well as meeting with representatives from multiple automotive brands who were willing to give feedback on the concept.

The questionnaire draws inspiration from the Attrak Diff and UX Questionnaire (UEQ) templates and incorporates additional nature-oriented questions. It follows a similar structure to the UEQ, consisting of pairs of contrasting UX attributes relevant to the concept. These attributes are represented by seven circles indicating gradations between the opposites. Usability aspects are excluded in this test since there is no physical concept to measure. The questionnaire is enclosed in appendix D.

The pairs of contrasting attributes are categorized into three main UX aspects: Attractiveness, Stimulation, and Novelty. For consistency, the words favoring each aspect is placed on the right-hand side. A summary of the categorization is presented in figure 6.1. below.

Attractiveness	Stimulation	Novelty
Technology focused/Nature focused	Technical/Human	Unimaginative/Creative
Impersonal/Personal	Stressful/Calming	Conservative/Innovative
Complicated/Simple	Impractical/Practical	
Ornate/Elegant	Unconscious/Reflecting	
Not Secure/Secure	Isolating/Connective	
Confusing/Clear	Mindless/Mindful	
Cluttered/Minimalistic		
Unattractive/Attractive		
Geometric/Organic		
Cheap/Premium		
Artificial/Living		
Rejecting/Inviting		

Table 6.1. Categorization for UX evaluation.

More attributes are included under Stimulation and Attractiveness as they hold greater importance. Multiple words with similar meanings are included to help enhance data reliability and minimize the risk of input errors and mistakes.

To ensure a smooth answering process for participants, the questionnaire contains a reasonable length of 20 pairs of contrasting attributes. Participants are encouraged to provide spontaneous responses to convey their original impressions.

In the final question, participants are asked to select five words that best describe the concept. These words are then used to generate a word cloud, where the size of each word corresponds to its frequency. The purpose of a word cloud is to get a clear and general overview of how respondents perceive the concept as a whole and to see which words the concept is most associated with. The words are then used to evaluate the concept against the established criteria in the design challenge and whether the concept exhibits the chosen requirements. Figure 6.3 displays the resulting word cloud.

Figure 6.1. Word Cloud based on questionnaire respondent input.

The brand representatives are presented with the same set of images and questions that is used in the questionnaire. The purpose of this session, however, is to gather more in-depth feedback and insights based on their direct observation of the images. The participants will be able to make comments and give feedback while looking at the pictures and explain their thought process when evaluating the concept.

6.3 Final Concept Evaluation

The questionnaire was distributed relatively late, resulting in the collection of only 32 responses before the survey was closed for evaluation. The results should therefore be reviewed with caution as the limited data sample introduces some uncertainty. Despite this limitation, the scale scores were compared to the three UX aspects: Attractiveness, Stimulation, and Novelty.

The findings reveal a general inclination towards the right side of the scoring scale for both Attractiveness and Novelty, indicating an overall visually appealing concept with originality. Words that evoke positive emotional and sensory responses, such as attractive, inviting, and calming, predominantly yielded right-sided answers. The Stimulation category, however, yielded more mixed opinions among the respondents.

Attractiveness

However, there are some noteworthy remarks for certain pairs of contrasting attributes within the Attractiveness category, namely Complicated/Simple, Not Secure/Secure, and Artificial/Living.

The Complicated/Simple pair shows a few answers on the far left-hand side, indicating that some participants were perplexed after seeing the concept. This observation aligns with the findings from other fractal patterns researched during the project, where complex and reflective designs could occasionally overload with sensory information and in turn yield negative user experiences. The application of a highly reflective glass material for the exterior of the final concept may have contributed to this perceptual challenge.

The Artificial/Living attributes exhibit a spread of responses across the scoring scale. During the feedback sessions, representatives also expressed ambiguity, seeking clarification, or opting for the middle score. These attributes were intended to assess how natural the concept felt in relation to its surroundings. However, since the concept does not incorporate any explicit "living" functionalities, it is reasonable for the results to show this variation. Substituting the attribute of Living with Natural could improve the clarity.

The Not Secure/Secure pair yielded the most distinguishable difference in responses, which is consistent with observations made during the physical meetings. In hindsight, these words were found to be ambiguous, primarily interpreted by most respondents in terms of mechanical and physical safety

rather than the intended emotional sense of feeling secure. Another more suitable pairing of attributes could have been Unprotected/Protected.

Stimulation

Some notable remarks were made regarding the attributes in the Stimulation category, specifically Impractical/Practical and Isolating/Connective.

In terms of the Impractical/Practical attribute, the concept's practicality generated mixed opinions among the respondents. The practical aspects of the concepts can be seen as providing occupants with a relaxing and spacious environment to perform various activities, or through the functional properties of either: exhibiting streamlined forms and surfaces for enhanced exterior performance, alternatively providing practical connectiveness to the natural environment.

On the other hand, some respondents may have evaluated practicality based on more traditional criteria, such as how the concept would function in current real-world applications, its compatibility with other vehicles on the road, or the perceived fragility of the glass bodywork. This discrepancy in understanding and evaluation criteria may contribute to the range of opinions expressed regarding the practical aspects of the concept.

The pairing of Isolating/Connective was expected to elicit varied responses, as the concept was intentionally designed for a balance between being connective with the surroundings and creating a welcoming environment for its occupants while also providing a certain degree of isolation and privacy. In the questionnaire, most exterior shots showcased the concept with tinted windows, which may have influenced respondents' perceptions of isolation. It is worth considering that if images of fully transparent glass were included instead, the survey results might have shown different outcomes.

Word Cloud

"Futuristic" and "innovative" were the most frequently used by the respondents to describe the concept. This aligns with the aim of the concept, which is to express novelty and mirror the future possibilities of autonomous driving.

An interesting observation is that respondents regarded the concept as premium and luxurious, a category that had not been considered previously. This perception may arise from the association of glass with fragility, which is seen as a delicate and expensive aspect. Drawing connection to architecture, wide glass windows and open spaces are often considered high-end features typically

found in expansive floor plans associated with luxury. The inclusion of nature in buildings is often seen as a luxury, and this perception likely extends to the design concept as well.

Furthermore, words such as "elegant," "relaxing," "relaxed," and "comfortable" were frequently mentioned by respondents, framing the stimulative aspects of the concept. These describe the concept's ability to provide a serene and comfortable experience for the users correlating with the aim of evoking positive emotional responses. While a few respondents described the concept as technical or technologically focused, these mentions were not as prevalent as the words associated with the nature-inspired aspects of the concept, such as "calming," "organic," and "flowing."

Additionally, many respondents described the concept as "minimalistic." This interpretation suggests that respondents perceive simplicity in the design, which aligns with the principles of Japanese and Scandinavian aesthetics.

7 Discussion

In this section, the project is reflected upon. The final concept is discussed along with future developments.

7.1 Methodology

The design process methodology used in this project was based on *The Double Diamond*, with a particular focus on UX. It entailed a comprehensive focus on the discovery phase, which involved conducting extensive literature research about future autonomy, nature-oriented design, and its resulting impacts, as well as user research to gain insights into the current customer needs and trends within the automotive industry.

Benchmarking of nature-based concept cars was conducted to investigate how biophilic design patterns have been and could been implemented into vehicle concepts. This was partly to gain inspiration, and partly to diverge from existing ideas and find novelty.

Furthermore, the project also placed significance on the concept generation and modeling aspects of the development and delivery phases. This involved studying three distinct directions of ideation, whereafter one was selected through Ulrich and Eppinger's scoring matrix for further development. The chosen concept was then visualized through a 3D-model and digital renderings to effectively communicate the conceptual ideas and ensure they were suitable for a final evaluation. The process involved employing divergent methods at different stages, which allowed for multiple evaluations.

In line with an approach focusing on visceral design, the visual aspect and initial impressions played a significant role. Consequently, images were extensively utilized throughout the project to effectively convey the intended design.

7.2 User Research

Interviews were conducted at car dealerships of selected brands considered relevant to the scope of the thesis. Visits were made to Mercedes, Toyota, and Volvo, aiming to cover areas such as comfort, Japanese design, and Scandinavian design.

The interviews were conducted with salespeople who have regular interactions with customers, providing them with firsthand experience of customer needs and preferences. Their perspective offered valuable insights into the current demands and expectations of car buyers. It is however important to note that salespeople are representing the car companies and therefore complete objectivity is difficult to achieve. To minimize the influence of bias, questions were asked less about what they could provide in comparison to other brands, and more so regarding actual implementations and elements seen within the vehicles as well as actual experiences with customers.

For more in-depth information regarding brand identity and internal visions for development process of future car models, it would have been ideal to reach out to individuals working directly in the design and development departments of the car companies. However, reaching such individuals proved challenging as many of them are located internationally and beyond the reachable network available for this project. Moreover, due to the increasing competition in the automotive industry and the importance of maintaining secrecy around novel innovations for future car models, OEMs may be reluctant to share information.

Efforts were made to contact the developing teams of several brands to gather additional insights, but unfortunately, the requests were either declined or did not yield successful outcomes. This limited the ability to access further information directly from the design and development teams.

The user research also included an interview with a backpacker to gain insights and perspectives of people regularly spending time in nature and their experiences and motivations in natural environments.

The customer needs identified through the entire research phase were based on current identifiable needs and future predictions. These interpreted needs were derived from contemporary expected needs within the market. However, it is important to acknowledge that the market is constantly evolving, making it difficult to determine whether these needs will remain the same in the future.

Therefore, there is a level of uncertainty regarding the long-term consistency of these needs as the industry continues to evolve and new trends emerge.

7.3 Design Process

Throughout the design process, a significant emphasis was placed on utilizing and interpreting a great number of images. These images served both as a source of inspiration and in conveying ideas and associated feelings related to the various design concepts. They were evaluated through tests to ensure that the intended messages were accurately portrayed and to gather valuable responses and thoughts from the test participants.

The modeling phase of the project took a substantial amount of time and effort. However, several challenges arose, particularly towards the end of the process. One of the major issues encountered was related to visualizing the intended tree symbolism from the exterior of the final concept. Addressing this concern became a primary focus, and significant time and effort were dedicated to finding a solution. However, despite a lot of efforts, the desired outcome was not fully achieved in the renderings. This limitation unavoidably has an impact on the final evaluation of the concept to some extent.

7.4 Final Concept

The objective of this thesis was to develop a holistic concept that integrates the design disciplines of exterior, interior, and user experience. The concept attempts to establish a connectiveness to nature from both the inside and outside, with transitional spaces being seamlessly incorporated to blur the boundaries between the interior and exterior. Privacy considerations were considered by utilizing layered transparency in the glass, allowing for adjustable opacity to emphasize either a sense of prospect or refuge. Customizability was a key aspect of the concept, allowing users to personalize their experience which was both a current but also anticipated need for the future.

Although the concept generation process took a holistic approach and considered all the following aspects, there was a specific order in which the concepts were

developed, starting with form development, and then moving on to exterior and interior design.

While following an existing design language could have facilitated the process, there were advantages to not being bound by preexisting models and forms. This allowed for the exploration of ideas without being limited by specific design guidelines. The starting point for the development of a new car model is typically the predecessor or a competitor car (Münster et al., 2016). However, with the introduction of new technologies, it becomes challenging to use previous models as they were developed under different conditions. On the other hand, this provides opportunities for new degrees of freedom and unconventional solutions.

This freedom is further emphasized with the established delimitations, including not being limited by current knowledge, technologies, economic considerations, manufacturing restrictions, or legal regulations. The assumption of electric AVs instead of ICEs also creates new and broader design opportunities.

7.5 Concept Evaluation

Due to time constraints and limitations, it was not feasible to conduct long-term tests or assess the long-term impacts of the concepts on UX and cognitive abilities. As a result, initial impressions and immediate feelings played a crucial role in evaluating the concepts. However, during concept evaluations it was observed that individuals found it challenging to express their thoughts and find descriptive words on the spot.

To overcome this challenge, a questionnaire was employed for the final evaluation. The aim was to provide respondents with a more relaxed and personal space for answering, creating an environment that would encourage natural impressions and reaction while giving the needed time to come up with answers that best describe their initial thoughts.

Although the short-term evaluation method through questionnaires had its limitations, it provided valuable insights into the immediate responses and impressions of the respondents. While long-term assessments would have provided a more comprehensive understanding of the concept's effects on UX and cognitive abilities over time, the use of questionnaires aimed to capture the

initial and authentic reactions of the participants in a comfortable and relaxed manner.

7.6 Further Developments

During the last month of the project, several challenges arose regarding the modeling phase. As a result, the modeling problem had to be set aside to ensure the completion of the final evaluation and report. However, this means that there is still room for further development in terms of visualizing the intended direction of the concept.

To enhance the robustness of the project, more thorough tests and evaluations can be conducted, involving a larger and more diverse population sample. This will allow for a deeper understanding of how the concept, along with the employed biophilic patterns, influences and evokes positive responses in users.

Additionally, there is potential for further development by exploring other biophilic patterns and taking the project in a different direction. This could involve focusing on different combinations of patterns and exploring alternative interpretations of biophilic design. The project's concept generation phase already explored two different directions, demonstrating that there are numerous ways to incorporate biophilic principles and evoke a connection with nature in various ways.

An alternative approach to the concept generation in this project could involve starting from a different perspective. Traditionally, the design of vehicles has been driven by regulatory requirements. However, AVs are beginning to be defined starting from the interior instead (Tzivanopoulos et al., 2015). Because the concept would be of holistic nature, the project could set the starting point in either of the design disciplines being incorporated, i.e., exterior, interior or UX. The choice of having nature as an origin was thought to create a more natural and authentic development process and in bridging the nature-based design with UX. Working on the form development, exterior, and interior in that order, was a decision found most suitable for the chosen concept as inspiration was taken from the visual structures of a “shakan” style bonsai.

The aim of this project is to explore future visions for autonomous car concepts, free from limitations imposed by current knowledge, technologies, economic considerations, manufacturing restrictions, or legal regulations. By establishing

these delimitations, the development of the concept was granted the freedom to explore the full potential of integrating nature into vehicle design, enabling a design process that was driven by limitless imagination. However, while pushing the boundaries of creativity, it remained essential to anchor these visions in reality, ensuring that the concepts maintained a practical foundation and retained a recognizable aesthetics of a car. This approach allowed for the exploration of new proportions and volumes that seamlessly blended nature-inspired elements with functional and realistic design principles.

The project assumes a level 5 degree of autonomy, where no driver is required, allowing for a complete transformation of the interior space. It is worth mentioning that biophilic design patterns can be implemented even in lower levels of autonomy, although the considerations for driving aspects and the presence of a driver and driver seat need to be appropriately incorporated. By choosing to design for the highest level of autonomy, the project sought to explore the full range of possibilities and serve as inspiration, showcasing what could be achieved in the future.

More emphasis can also be put into the digital fatigue aspect of the project to further emphasize the potential consequences of constant digital connectivity and the ever-increasing trend of larger and wider digital screens in car interiors. This would allow for an even bigger emphasis on the importance of reconnecting to nature and allowing moments of relaxation and rejuvenation of cognitive abilities.

8 Conclusion

This chapter presents the conclusion of the thesis.

In this thesis, an overview of predicted trends in autonomous cars is presented along with the potential risks of prolonged exposure to digital connectivity. The aim is to explore new possibilities of enhancing UX and relaxation in fully autonomous vehicles by incorporating biophilic design. Numerous biophilic design patterns are introduced and combined in various ways to develop concept ideas that provide a restorative and rejuvenating environment with reconnection to nature.

The result is a holistic concept, presented through renderings of a digital 3D-model, that combines the design disciplines exterior, interior and user experience. The concept incorporates principles from the Japanese and Scandinavian design philosophies as inspirational sources to give depth to the design and to achieve a harmonious integration of nature and man-made environments.

The design process adopts the Double Diamond Methodology with a focus on UX. An extensive literature research is conducted to investigate the benefits of biophilic implementations on human cognitive performance and well-being. Concept ideas are generated with basis on the biophilic patterns and evaluated throughout the process to consider current and future predictions of customer needs. Throughout the project emphasis lies in the visceral aspects and the initial impressions as no long-term assessments of the biophilic impacts could be conducted due to time constraints and limitations.

Main takeaways from this project are presented below.

Given that the project involved developing a concept in a relatively unexplored field where "real" user needs has not yet been clearly defined, certain aspects of the concept were based on contemporary needs and anticipated needs derived from current and predicted trends. However, it is important to acknowledge that the market is constantly evolving, making it difficult to determine whether these

needs will remain the same in the future. Therefore, there is a level of uncertainty regarding the long-term consistency of these needs as the industry continues to evolve and new trends emerge.

The perception of complex geometries and patterns, such as fractals, is highly subjective and can vary greatly among individuals. While some may find them intriguing and visually stimulating, others may find them overwhelming or confusing, leading to a negative effect that increases stress levels.

Although UX is most readily discernible within the interior of a vehicle, the exterior design also plays a vital role in establishing a good initial impression. Subtle and subconscious responses to the vehicle's exterior aesthetics can influence the overall user perception and satisfaction. Therefore, a holistic approach that considers both the interior and exterior design is essential to create a harmonious and cohesive user experience.

Biophilic design is more prevalent in the field of architecture compared to the automotive industry. While biophilic design concepts have been explored in the automotive realm, they are still mostly in the conceptual phase, and their integration into production vehicles is not yet as widespread. This difference in priorities between the architecture and automotive industries highlights the unique challenges and considerations involved in implementing biophilic design principles within the automotive context.

However, as AVs continue to evolve rapidly, OEMs are starting to shift their focus to the transformative potential of autonomous vehicle interiors. With increased attention on creating comfortable and immersive interior environments for occupants, there is an opportunity to explore and integrate biophilic design elements that contribute to relaxation, well-being, and an enhanced user experience.

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Appendix A Time plan

A.1 Gantt Chart

For the initial stages of the project, the project plan aligned with the actual execution of tasks. However, as the project progressed and entered the later phases of concept development, there was a shift in focus away from report writing. This was primarily due to diverting the focus to concept development where issues were encountered during the modeling phase, as elaborated in chapter 7. These challenges impacted the timeline and caused some delays.

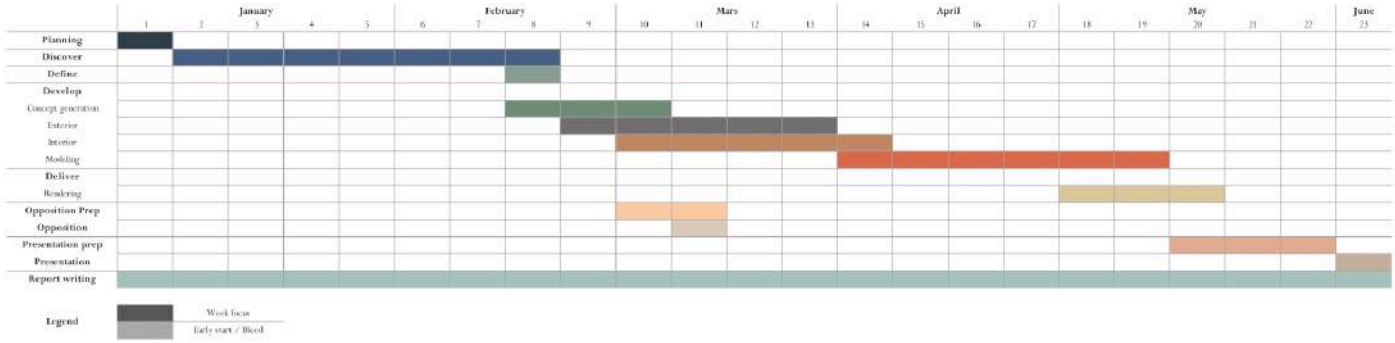

Figure A.1 Planned project plan.

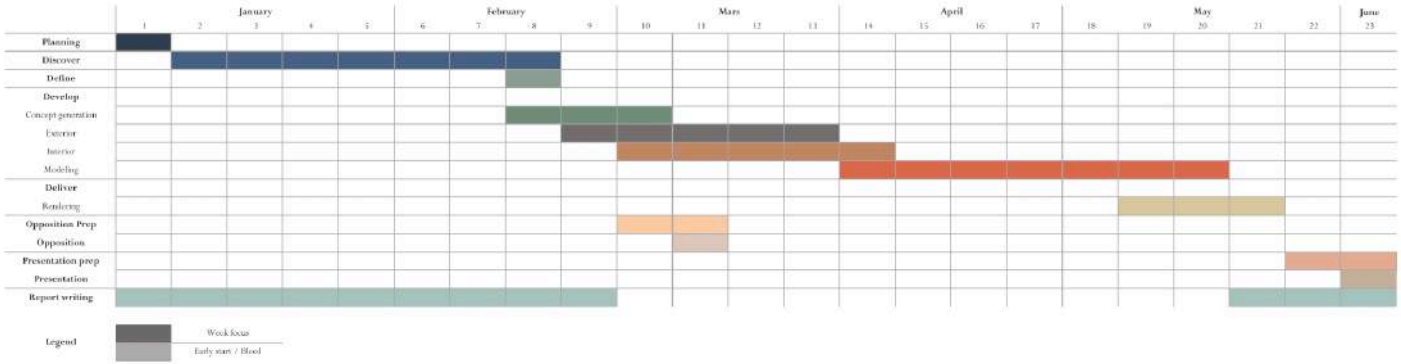

Figure A.2 Actual project plan.

Appendix B Interviews with car dealerships

1. How does the brand take user experience into account? Are there any specific measures or initiatives to enhance the user experience for customers?
2. How important is comfort for your brand? Could you provide information about the comfort features available in the vehicles? What specific elements or technologies contribute to a comfortable driving and passenger experience?
3. How does the brand support customer customization? Are there options for customers to personalize their vehicles according to their preferences and needs? If so, what kind of customization options are available?
4. Are there any connections to nature or any nature-oriented features present in the vehicles?
5. What is the brand's stance on autonomous driving technologies? Are there any autonomous driving features or technologies available in the vehicles? What are your predictions for the future of autonomous cars?

Appendix C Interview with backpacker

1. What got you into backpacking?
2. When you go backpacking, which destinations do you usually choose and what attracts you to those places?
3. Are there any places you haven't visited yet but would like to go? If so, what is the reason behind your desire to visit those places?
4. What emotions or sensations do you experience when you are immersed in nature during your backpacking trips?
5. What is your preferred mode of transportation when backpacking? Are there any specific advantages or disadvantages associated with certain modes of transportation?
6. In terms of experience, does backpacking during the day differ from backpacking at night?
7. Does traveling during different seasons impact your backpacking experience?
8. In your opinion, what is the most rewarding aspect of going backpacking?
9. How do you typically feel after returning home from a backpacking trip?
10. Is there anything else you would like to share about your backpacking experiences or any other related topics?

Appendix D Questionnaire

Nature-based concept for enhanced UX

With an ever-increasing demand for constant digital connectivity, reconnecting with nature will be crucial for reducing cognitive stress and promoting healing and well-being.

This novel concept aims to enhance user experience in fully autonomous cars by incorporating biophilic, nature-oriented design patterns.

Please look through the images of the concept and fill out the questionnaire at the end!

Please decide spontaneously. Don't think too long about your decision to make sure that you convey your original impression.

Thank you!

E-post *

Giltig e-postadress

Det här formuläret samlar in e-postadresser. Ändra inställningar

1 *

	1	2	3	4	5	6	7	
Technology Focused	○	○	○	○	○	○	○	Nature Focused

2 *

	1	2	3	4	5	6	7	
Technical	○	○	○	○	○	○	○	Human

3 *

	1	2	3	4	5	6	7	
Unimaginative	○	○	○	○	○	○	○	Creative

4 *

	1	2	3	4	5	6	7	
Stressful	○	○	○	○	○	○	○	Calming

5 *

	1	2	3	4	5	6	7	
Impersonal	○	○	○	○	○	○	○	Personal

6 *

	1	2	3	4	5	6	7	
Complicated	○	○	○	○	○	○	○	Simple

7 *

	1	2	3	4	5	6	7	
Ornate	○	○	○	○	○	○	○	Elegant

8 *

	1	2	3	4	5	6	7	
Not Secure	○	○	○	○	○	○	○	Secure

9 *

	1	2	3	4	5	6	7	
Confusing	○	○	○	○	○	○	○	Clear

10 *

	1	2	3	4	5	6	7	
Impractical	○	○	○	○	○	○	○	Practical

11 *

	1	2	3	4	5	6	7	
Cluttered	○	○	○	○	○	○	○	Minimalistic

12 *

	1	2	3	4	5	6	7	
Unattractive	○	○	○	○	○	○	○	Attractive

13 *

	1	2	3	4	5	6	7	
Geometric	○	○	○	○	○	○	○	Organic

14 *

	1	2	3	4	5	6	7	
Conservative	○	○	○	○	○	○	○	Innovative

15 *

	1	2	3	4	5	6	7	
Unconscious	○	○	○	○	○	○	○	Reflective

16 *

	1	2	3	4	5	6	7	
Isolating	○	○	○	○	○	○	○	Connective

17 *

	1	2	3	4	5	6	7	
Mindless	○	○	○	○	○	○	○	Mindful

18 *

	1	2	3	4	5	6	7	
Cheap	○	○	○	○	○	○	○	Premium

19 *

	1	2	3	4	5	6	7	
Artificial	○	○	○	○	○	○	○	Living

20 *

	1	2	3	4	5	6	7	
Rejecting	○	○	○	○	○	○	○	Inviting

Please write 5 words that you believe best describe the concept: *

Lång svarstext