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In
DESIGN
by

SHAHID AHMAD
(Roll No: 2K20/PHDDES/02)

Under the Supervision of

75 **Dr. Ranganath M. Singari**
Founder Head, Department of Design,
Professor, Mechanical Engineering Department,
Delhi Technological University, Delhi.

Dr. S.L. Bhandarkar
Automotive Design Expert
107 **Controller of Examination**
Guru Gobind Singh Indraprastha University Delhi, India

4 **Department of Design**

DELHI TECHNOLOGICAL UNIVERSITY
(Formally Delhi College of Engineering)
Shahbad Daulatpur, Main Bawana Road, Delhi-110042, India.
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This research would not have been possible without the collective support of all these individuals, and for that, I extend my heartfelt gratitude.

Shahid Ahmad

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CANDIDATE'S DECLARATION

4

I, **Shahid Ahmad**, hereby certify that the work presented in this thesis, entitled "**Enhancing User Experience with Automobile Design, A Study**," submitted in partial fulfilment of the requirements for the award of the **Degree of Doctor of Philosophy** in **Design at Delhi Technological University**, is an original and authentic record of my research. This work was carried out under the supervision of **Dr. Ranganath M. Singari** and **Dr. S.L. Bhandarkar** during the period from **August 2020 to October 2025.**

3

I further declare that the content of this thesis has not been submitted for the award of any other degree at this or any other institution.

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This is to certify that the student has incorporated all the corrections suggested by the examiners in the thesis and the statement made by the candidate is correct to the best of our knowledge.

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29

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124 This is to certify that **Shahid Ahmad** (2K20/PHDDES/02) has conducted the research work presented in this thesis, entitled "**Enhancing User Experience with Automobile Design, A Study**," for the award of the **Doctor of Philosophy** from the Department of Design, Delhi Technological University, Delhi, under our supervision. The thesis embodies the results of original research, and the studies have been carried out independently by the candidate. The contents of this thesis have not been submitted as the basis for the award of any other degree to the candidate or to any other individual from this or any other University/Institution.

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Signature	Signature
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Founder Head, Department of Design	Automotive Design Expert,
Professor Mechanical Engineering,	Controller of Examination,
Delhi Technological University,	Guru Gobind Singh Indraprastha University,
Delhi, India	Delhi, India

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ABSTRACT:

The evolution of automobile design has transitioned from a purely engineering-driven approach to a user-cantered paradigm, recognizing that user experience (UX) plays a pivotal role in consumer satisfaction and market success. This research systematically integrates UX factors into the automobile design process, addressing critical parameters such as safety, functionality, ergonomics, aesthetics, sustainability, connectivity, ease of use, accessibility, responsiveness, and navigation. Despite the increasing significance of UX in automobile development, existing frameworks fail to holistically incorporate these factors into the design lifecycle.

A mixed-methods research approach was employed, combining quantitative surveys and qualitative expert interviews. The study utilized the Delphi method in two stages: first, to identify key UX parameters through expert consensus, and second, to validate the refined framework with experienced design professionals. Data was gathered from over 150 automobile designers, spanning various expertise levels and domains, ensuring a diverse and industry-relevant perspective. A comparative case study analysis was conducted on two prominent car segments—Compact SUVs and Hatchbacks—evaluating vehicles based on the proposed UX framework. Parameters were assessed using a Likert-scale evaluation, and real-user surveys were conducted to validate the framework's applicability in practical scenarios.

Findings indicate that UX factors significantly influence design preferences, with safety, ergonomics, and functionality emerging as critical determinants of user satisfaction. The study demonstrates that integrating UX considerations enhances not only usability but also brand perception and competitive positioning. The developed User Experience Driven Automobile Design (UX-DAD) framework provides a structured methodology for assessing and optimizing UX in vehicle design. This framework offers a practical tool for automobile manufacturers, designers, and UX strategists to create vehicles that align with evolving consumer expectations. The research contributes to academic discourse by establishing a structured UX assessment model while providing actionable insights for industry practitioners. Future research can expand validation across diverse vehicle segments and global markets to further refine the UX-DAD framework.

LIST OF PUBLICATIONS:

Journal Publications:

1. Shahid Ahmad, Ranganath M Singari, & S.L. Bhandarkar. (2024). Key Factors in Automobile Design: Expert Views on Enhancing User Experience during New Product Development. *Educational Administration: Theory and Practice*, *30*(5), 13145–13156. https://doi.org/10.53555/kuey.v30i5.5676.

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4. Shahid Ahmad, Monica Singh, Ranganath M Singari, & S.L. Bhandarkar. (2025). USER EXPERIENCE IN AUTOMOTIVE DESIGN: A COMPREHENSIVE LITERATURE REVIEW. *Oeconomia Copernicana*, 16(1), 147-162. https://oeconomiacopernicana.com/index.php/OECO/article/view/151

Conference Presentations:

1. Ahmad, S., Singari, R. M., & Bhandarkar, S. L. (2024, January 28). A comprehensive analysis of key factors in user experience design. Paper presented at the International Journal of Advance Research and Innovation (IJARI) Conference, Delhi State Centre, Institution of Engineers (India), New Delhi.

2. Ahmad, S., Singari, R. M., & Bhandarkar, S. L. (2024, January 28). A comprehensive analysis of key factors influencing automobile design: Insights from industry experts on user experience design in new product development. Paper presented at the International Journal of Advance Research and Innovation (IJARI) Conference, Delhi State Centre, Institution of Engineers (India), New Delhi.

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CHAPTER 1:

INTRODUCTION

These days, innovation and technology play a major role in our daily lives and have an impact on many sectors, including the automobile industry. Technological developments have had a major impact on the automobile sector, with several advances combining to build contemporary vehicles. Vehicle functions are now managed by software updates and programmable power-train control units due to the increased integration of digital technology in cars in recent years (Kiencke & Nielsen, 2005). In addition to satisfying consumer needs and being competitive, these technologies are made to lessen driver attention, improve safety, and reduce pollution.

Human-Computer Interaction (HCI) has become an essential component of the automobile industry as these advancements arose (Norman, 2013). In order to design effective and user-friendly systems, HCI focuses on how people interact with technology and computing devices. Seamless HCI is crucial in cars since they include multiple processors and applications that rely on human inputs and outputs. Since high user satisfaction happens when systems match user expectations, achieving easy-to-use HCI and optimizing user experience are essential (Gkatzidou et al., 2021). Automobile manufacturers must thus comprehend and give priority to consumer expectations.

The significance of the user experience with respect to different in-car technology has been investigated in earlier studies. In 2008, Leshed, examined the advantages and perceived security that GPS navigation provides for consumers (Leshed et al., 2008). According to a different study on eco-friendly interfaces, people approved the systems that were already in place and intended to change driving behaviour. However, Eckoldt, found that driver assistance features might have a detrimental effect on the user experience by making driving less enjoyable (Eckoldt et al., 2012). On the other hand, (Harris & Nass, 2011) discovered that characteristics intended to control emotions and lower the hazards associated with driving resulted in fewer negative feelings and better driving behaviour.

These findings suggest that further research is needed to understand user preferences. Innovations and implementations in automobile technology are only valuable if they meet customer needs. In the automobile industry, value is achieved through customer satisfaction, which can lead to increased sales and positive outcomes for companies. Therefore, easy-to-use HCI and high user experience levels are crucial for success in the automobile industry (Kramer, 2012).

The purpose of this research is to identify UX design factors that improve user preferences for existing in-car features. There is still little research on consumer preferences, despite recent advancements. In order to close this gap, a survey of the literature was done to determine the successes and contributing factors of user experience (UX) in the automobile sector. Furthermore, interviews were carried out in order to classify and identify the most crucial in-car features as well as provide support for the survey design. The methodology chapter provides a full account of the survey that was used to obtain user perspectives and gain a better knowledge of their needs. Determining true user preferences is critical to meeting client expectations and attaining high levels of user experience, both of which benefit car firms in the long run.

1.1 BACKGROUND

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The automobile industry has undergone substantial transformation, with advancements in technology, safety, and user experience shaping the market. In recent years, the significance shift towards user experience (UX) in automobile design has gained unprecedented attention, underscoring its pivotal role in shaping the future of the automobile industry. This study attempts to clarify the vital significance of incorporating user experience factors into the automobile design process through in-depth research. Historically, mechanical performance, safety features, and visual appeal have dominated car design. But as customer expectations rise, there's a rising need for cars that offer not only safety and functionality but also an intuitively pleasant and emotionally fulfilling driving experience. This study emphasizes the complex interplay between users' emotional reactions, cognitive exchanges, and sensory impressions when interacting with their cars (Norman, 2013).

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Through an exploration of the psychological foundations of user happiness, this study pin-points critical factors that substantially improve the overall driving experience, including usability, accessibility, aesthetics, responsiveness, and navigation (Schifferstein & Hekkert, 2008). By including these components into the design process, car owners may experience a shift in how they view and engage with their vehicles, which will boost customer happiness and brand loyalty (Krippendorff, 2005). Automobile designers can produce automobiles that are not only aesthetically pleasing but also incredibly functional and pleasurable to operate by using the output from this research.

1.2 MOTIVATION

The motivation for this research is deeply rooted in my personal journey of over 10 years in the automobile design industry, providing a profound understanding of its complexities. Notably, the core automobile design process has seen only two major updates since the 1920s. The first transformation occurred when General Motors (GM) sought to challenge the dominance of the Ford Model T by emphasizing style over pricing or technological innovation, leading to the creation of the original automobile design process—a structured sequence of procedures aimed at developing commercially successful vehicles that justified production resources same can be also referred in the below figure 1 (General Motors, 2023). The second significant update came between 1927 and 1950 under the leadership of Harley Earl at GM's Art and

Colour Section, where Earl introduced annual model style changes and leveraged the established archetype of cars—engine, cabin, cargo space, and four wheels—within the framework of a business model based on personal ownership and city infrastructure (Harley Earl, 2023; Munoz et al., 2022).

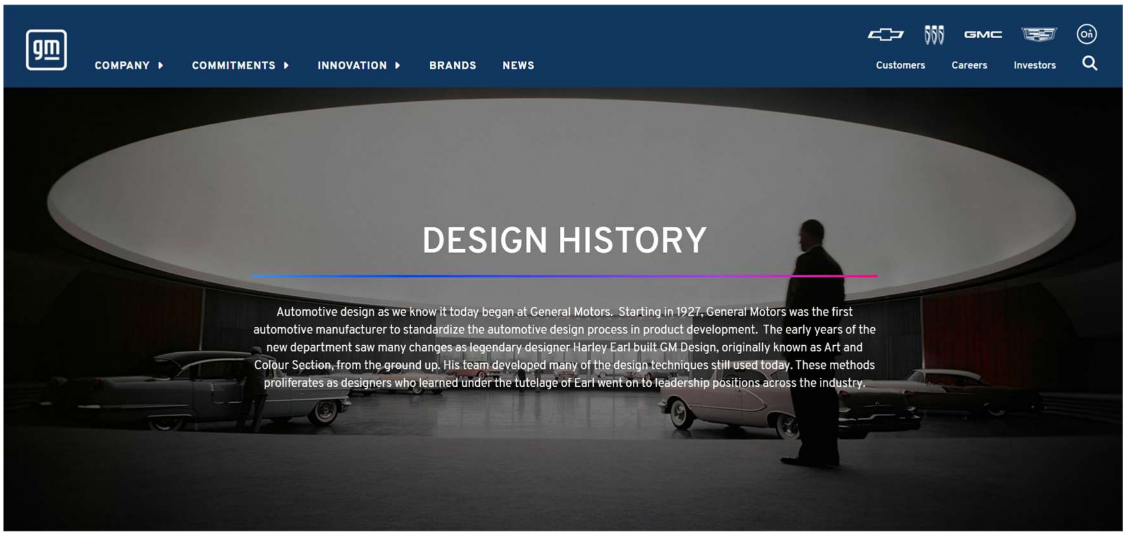

Figure 1: Shows creation of the design history at General Motors
Source: https://www.gm.com/design

1.3 PROBLEM STATEMENT AND RESEARCH GAPS

1.3.1 PROBLEM STATEMENT

Since user experience (UX) in vehicle design is receiving more attention, there is still a lack of a thorough framework that integrates many UX components. Previous research frequently looks at discrete factors, including aesthetics or technological integration, without taking a comprehensive approach. Research on automobile comfort, for instance, ignores emotional and cognitive interactions in favour of seating and control usability. Similar to this, research on ADAS and infotainment systems places a strong emphasis on functionality but ignores their contribution to brand loyalty and emotional fulfilment. This disjointed method emphasizes the necessity of a systematic framework to direct designers in striking a balance between all UX aspects and guaranteeing that cars offer a smooth and satisfying user experience.

1.3.2 RESEARCH GAPS:

The research gaps identified in the literature highlight below:

1.3.2.1 Lack of Focus on Core UX Factors in Automobile Design:

- User experience (UX) is a crucial factor influencing industrial growth globally, especially post-COVID-19.

- While many studies explore digital UX in apps and websites, research on UX in automobile settings, particularly in driving, seating, and long journeys, remains limited.
- A comprehensive study is needed to identify UX factors that enhance mental relaxation and comfort for drivers and passengers.

1.3.2.2 Limited Research on UX Beyond Colour & Psychology:

- Existing studies emphasize colour psychology and human interaction in product design but do not comprehensively address key UX factors in vehicles.
- There is a need for a structured framework that helps designers consider usability, accessibility, and mental fatigue reduction when developing automobile systems (Jurgen et al., 2020).
- Identifying UX factors that enhance user satisfaction can bridge this gap.
- Current research overlooks cognitive and functional dimensions - how users process information, interact with systems, and adapt to changing driving conditions.
- Few studies integrate cognitive workload analysis, usability testing, or behavioural interaction studies in the vehicle environment.

1.3.2.3 Need for UX Integration in Automobile Design:

- Industries have successfully enhanced products using UX methodologies, leading to improved sales and customer engagement.
- Applying similar UX principles in automobile design could transform transportation, improving vehicle usability and overall user experience (Krippendorff, 2005).

1.3.2.4 Broader UX Factors Beyond Emotion & Aesthetics:

- True UX in vehicles must go past aesthetics and emotion to include safety, functionality, ergonomics, responsiveness, and ease of use.
- Long-term user satisfaction depends on intuitive interaction, cognitive simplicity, and physical comfort, not just first impressions of design.
- With AI-assisted systems and connected interfaces, new UX variables arise - trust, system transparency, and predictability.
- UX research should focus on interaction between driver and intelligent systems, ensuring safety, comfort, and engagement in dynamic conditions.

1.4 RESEARCH OBJECTIVES

This research aims to develop a user experience driven automobile design that integrates essential UX factors throughout the design process. The specific objectives include:

To identify the factors which are responsible to enhance user experience in automobile car design industry:

The increased focus on user experience (UX) in the auto sector emphasizes the importance of identifying the factors associated with a well-designed and user-friendly automobile. Conventional automobile design has largely been centered around performance, safety, and beauty, ignoring the wider range of UX factors that determine the satisfaction of drivers and passengers. This study identifies critical UX considerations—e.g., safety, functionality, ergonomics, aesthetics, sustainability, connectivity, ease of use, accessibility, responsiveness, and navigation—that influence user engagements with cars. Through the synthesis of existing research, expert interviews, and applying structured methods like the Delphi technique, this research seeks to develop an integrative understanding of UX considerations for car design. The discovery of these factors forms the basis for incorporating user-centered principles into contemporary automobile design to provide a more intuitive, efficient, and enjoyable driving experience.

To develop a framework for automobile design using user experience design factors:

A systematic method of incorporating UX considerations into the car design process is necessary to develop cars that address both functional and emotional user requirements. Although current automobile design practices include aspects of safety, efficiency, and technology, a standardized framework that clearly integrates UX principles across the design life cycle is underdeveloped. This study attempts to fill this gap by developing a User Experience Driven Automobile Design (UX-DAD) model, which incorporates UX parameters systematically into automobile design, prototyping, and validation phases of car development. Employing the Delphi method based on expert consensus among industry experts, this model sets up a systematic guideline for automobile designers to evaluate, quantify, and optimize UX factors optimally. The framework proposed seeks to improve design processes so that cars are not just technologically sophisticated but also easy to use, comfortable, and responsive to the needs of users.

To analyze the framework with different segments of cars:

To validate the effectiveness of the **User Experience Driven Automobile Design (UX-DAD) framework**, it is crucial to analyse its applicability across different car segments. The automobile market comprises various vehicle categories, each with distinct user expectations, driving conditions, and design priorities. This study employs a comparative case study approach, evaluating compact SUVs and hatchbacks to assess the framework's adaptability in diverse market segments. Using a combination of Likert-scale evaluations and real-user experience surveys, the research examines how different vehicles align with UX parameters such as safety, ergonomics, and connectivity. By systematically analysing UX performance across these segments, this study not only validates the framework but also provides insights into how UX factors influence consumer preferences, usability, and brand perception in the automobile industry.

1.5 TERRITORY OF THE STUDY

The scope of this study extends to both academic research and industry applications. It contributes to academic literature by offering a structured UX framework for automobile design, enriching existing knowledge in the fields of design methodology, human factors, and consumer behaviour (Garrett, 2010; Cooper et al., 2014). For the automobile industry, this research provides practical guidelines for integrating UX factors into vehicle design, ensuring a balance between user-centric design and manufacturing feasibility (Ulrich & Eppinger, 2020).

The research is centered mainly on the Delhi NCR region because of its heterogeneous consumer base and fast-growing automobile market. The sample population consists of automobile designers, UX experts, and end-users with different levels of experience and familiarity with various geographical locations. Surveys, expert interviews, and case studies will be used to validate the findings to ensure strength and practicality.

The framework is structured with a future-oriented approach, enabling the effortless integration of additional UXD parameters as new technologies emerge and user expectations shift. This adaptability ensures the framework’s continued relevance and scalability, supporting its application in both future academic research and evolving industry practices.

Through filling the gaps in UX-centered car design, this study will provide an in-depth, flexible framework that can improve vehicle usability, user satisfaction, and competitiveness in the market.

1.6 INTEGRATION OF ARTIFICIAL INTELLIGENCE (AI) FOR VISUAL REPRESENTATION

In recent years, Artificial Intelligence (AI) has emerged as a valuable tool for conceptual visualization and design validation. As part of this research, AI was used to visually represent the outcomes derived from the proposed UX-DAD (User Experience–Driven Automobile Design) framework. The intent was not to generate new designs but to translate framework-driven insights into visual form to demonstrate how UX factors influence the aesthetic and ergonomic expression of different automobile segments. These AI-generated visualizations, presented in the later chapters, serve as illustrative evidence of how the UX-DAD framework can inform concept design directions across various car categories such as compact SUVs, hatchbacks, and luxury sedans.

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CHAPTER 2:

LITERATURE REVIEW

This chapter provides a thorough analysis of the pertinent literature and underlying ideas that underpin this argument. The first part of the article looks at UXD and how it affects car design (Garrett, 2010; Norman, 2013). After that, it examines car design and current constraints, emphasizing important factors like usability, accessibility, and aesthetics in the early stages of car development (Krippendorff, 2006; Hassenzahl, 2010). The chapter emphasizes changing user needs and human-centered design approaches (Cooper et al., 2014; Ebert et al., 2012). It also evaluates existing in-car technologies, such as infotainment and driver-assistance systems (Henfridsson et al., 2014; Pfleging et al., 2012), and points out research gaps that need to be filled (Pettersson, 2016; Norman, 1998).

6

2.1 OVERVIEW OF USER EXPERIENCE (UX) DESIGN

User Experience Design (UXD) is an interdisciplinary practice that improves the interaction between users and products in both digital and physical spaces. It is a user-centered design process that makes products functional, easy to use, and enjoyable (Garrett, 2010; Norman, 2013). The most important principles of UXD are usability, accessibility, consistency, feedback, and aesthetic integrity. Usability makes products easy to use, accessibility makes them inclusive, and consistency makes them predictable. Feedback assists users in navigating interactions, while aesthetic integrity enhances engagement and satisfaction (Hassenzahl, 2010).

Don Norman coined the term "User Experience" in the 1990s to highlight the integrated nature of UX, going beyond usability to encompass design, interaction, and user perception (Norman, 2013). The UXD process is composed of research, design, testing, implementation, and evaluation. Research is fed into design by user insights, followed by prototyping, usability testing, and iterative refinement (Cooper et al., 2014).

In the car manufacturing sector, UXD is crucial because of changing customer expectations and technology growth. Research indicates that UX has a direct impact on user satisfaction, safety, and productivity (Korber, 2013; Roto et al., 2009). As AI, VR, AR, and green design grow, UXD keeps pace by providing individualized, engaging, and eco-friendly user experiences (Bayly et al., 2009; Walker, 2001).

2.1.1. What is User Experience?

Although numerous experts have defined the term "user experience," UX pioneer Peter Morville has provided one significant definition. As stated by Morville (2004).

"A user's experience with a system encompasses their feelings, perceptions, and attitudes as a result of their interactions with it."

By addressing not only usability but also users' emotional and cognitive reactions while interacting with products or services, UXD seeks to enhance the total experience. Design, usability, accessibility, and user pleasure are all included in this comprehensive definition of user experience (Morville, 2004).

2.1.2 UX Theories and Models

User Experience (UX) theories examine how the user experiences the product both on a cognitive and emotional level, influencing their general satisfaction and engagement.

2.1.2.1 Product pleasures

According to Jordan (2000), good human factors (for example, ergonomics and usability) are no longer sufficient to achieve good design solutions. Good human factors no longer signal added value; their absence results in condemnation. Jordan makes his case using a hierarchical model of consumer requirements inspired by
25 Maslow's hierarchy of needs. According to this hierarchy (Figure 2), the bottom layer of the pyramid represents functionality, implying that a successful design should provide suitable functionality. The second level of the pyramid is usefulness. Once the functional requirements are met, people begin to look for a design that is simple to use. Pleasure is located at the top of the pyramid.

Jordan contends that individuals are continually looking for more value in their decisions. Thus, as usability problems are addressed, emotional benefits begin to influence decision-making (Jordan, 2000). Figure 2 depicts Jordan's hierarchical user needs model.

76 Jordan offers four distinct product pleasures: psycho-pleasure, physio-pleasure, ideo-pleasure, and socio-pleasure. Psycho-pleasure is defined as features such as usability and functionality, whereas physio-pleasure refers to factors associated to the human senses. Both of these joys are deemed significant for this project.

According to Jordan (2000):

"If the driver cannot reach the climate control functions easily, he/she will experience difficulties that might have consequences ranging from discomfort (e.g. if the driver is unable to set the climate) to danger (e.g. if the driver gets distracted from the road and result in an accident)."

The remark exemplifies psycho-pleasure and physio-pleasure, both of which play essential roles in user happiness when engaging with and utilizing products. In other words, discomfort in a driving setting might lead to unsafe situations; therefore, any problems in completing activities will result in discontent and a negative user experience.

Ideo-pleasure and socio-pleasure refer to the personal beliefs and social influences that shape a user's interaction with products and services. Ideo-pleasure arises from an individual's values and ideals reflected in a product, while socio-pleasure stems from social connections and cultural context surrounding its use. Together, these dimensions help explain how users emotionally relate to a design, beyond just its functionality or aesthetics. Understanding these aspects allows designers to create more meaningful experiences that resonate with users on both personal and social levels, offering a deeper insight into emotional engagement with products and enhancing overall user satisfaction.

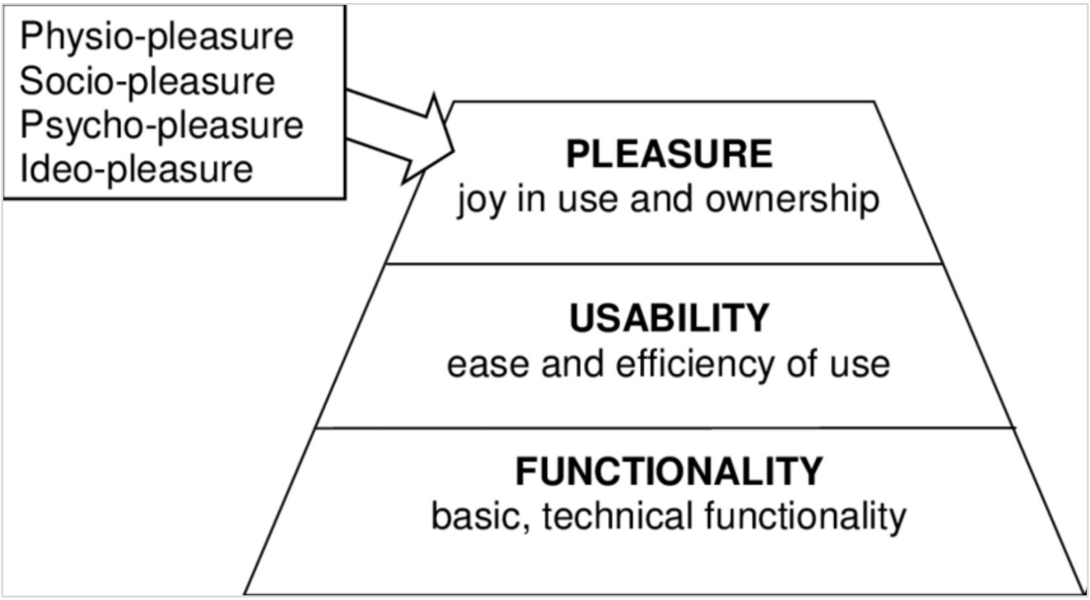

Figure 2: Jordan's hierarchical user needs model, (Source: Jordan, 2000).

2.1.2.2 Product emotions

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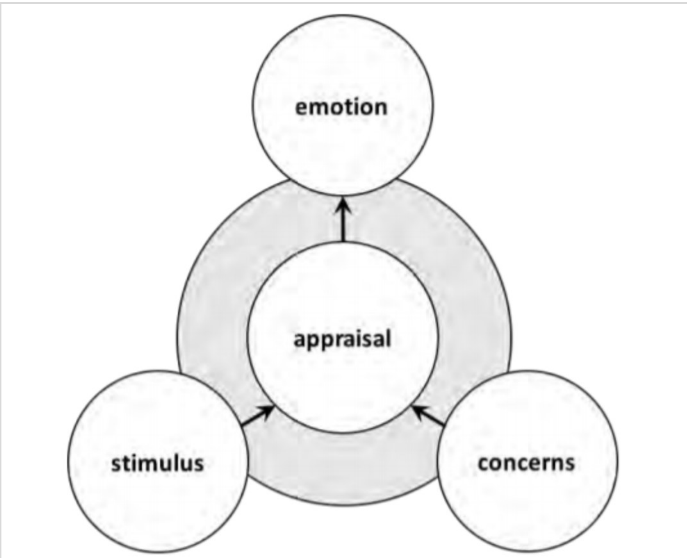
Desmet and Hekkert proposed the 'fundamental model of product emotions,' which highlights the importance of elicited emotions in user-product interactions. This model identifies four major components of the emotional process: the product as a stimulus, the user's worry, the appraisal process, and the resulting emotion as a response. Desmet went on to say that emotions arise from a person's interaction with a certain object; for example, one may feel fearful of something or proud of something. Shown in Figure 3. In this approach, terminology like object, product, and artifact all refer to the stimulus. Notably, the stimulus that causes an emotion is not always the immediate target of that emotion. In this study, various areas of the In-Vehicle Infotainment (IVI) system.

Concern reveals the hidden components of all emotions. For example, in the current study, if the car interface meets our concerns (e.g., safety, learnability, ease of use), it is rated as useful; if it does not, it is rated as negative. Concerns related to the issue addressed here include the motivation for utilizing the infotainment system, the need to be entertained in the car, the goals to be achieved through the use of automobile features, and safety. However, safety is defined as a broader concern that is not context dependent. The product is the object that is constantly present in the relationship between the individual and the experience (Desmet, 2003). In this investigation, the product serves as the IVI.

12 12 **Appraisal** refers to the fact that an emotion is always accompanied with an assessment or appraisal of a product's harmfulness or benefits. This appraisal is a subconscious, automatic evaluation of the stimuli for one's personal well-being. As a result, if the stimulus is a product, an evaluation can yield one of three outcomes: the product is useful, detrimental, or irrelevant to human well-being. These three results provide 12 either a pleasant emotion, an unpleasant emotion, or an absence of emotion.

Emotion is the human response to and outcome of the process. According to Desmet (2013), emotions are also known as mood. However, there are two major differences. For starters, mood is a long-term occurrence, whereas emotion is a transient one. Second, emotions are intentional (i.e., they are responses to various aspects of the product), whereas moods are fundamentally unintentional. As a result, mood is not incorporated in Desmet's model (2013) or the research reported here, as the users being examined are assumed to be in a neutral mood/affect at the time of the study.



42 *Figure 4: Desmet's basic model of product emotions,* (Source: Desmet & Hekkert, 2002)

102 Desmet further categorizes product emotions into five categories: instrumental, aesthetic, social, surprise, and interest emotions (Figure 4).

Although Desmet says that the five categories of product emotions do not cover all possible emotional responses toward a product, this model is nevertheless applicable for the current study because it includes the majority of the features that are under investigation here.

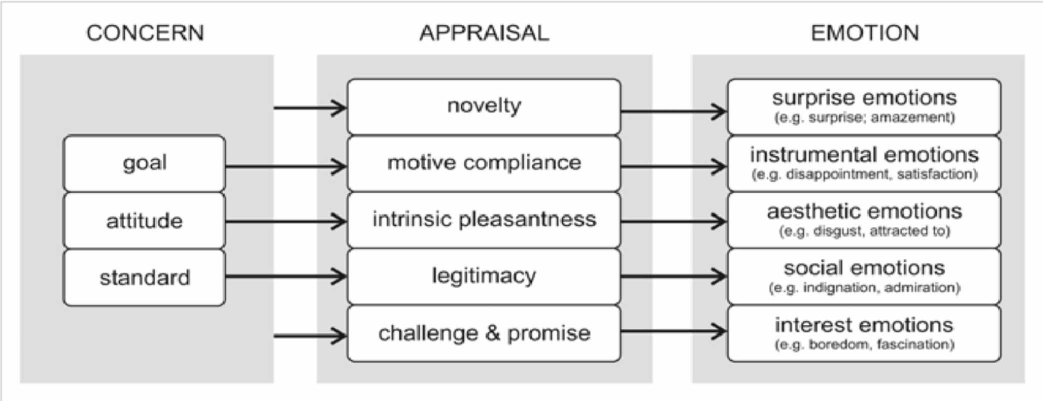


Figure 5: Classification of product emotions (Source: Desmet, 2013).

2.1.3. Importance of UX

8 User Experience Design (UXD) has emerged as a vital component in modern automobile design, ensuring that automobiles are straightforward, efficient, and fun to operate. As automobile technology evolves, UXD is critical for increasing consumer pleasure, promoting brand loyalty, and providing manufacturers with a competitive advantage. According to research, customers are more likely to engage with products that offer seamless contact, assuring both functionality and emotional involvement (Garrett 2010). UXD in the automobile sector includes several characteristics such as usability, safety, comfort, and efficiency, all of which lead to a better driving experience (Hassenzahl, 2010; Norman, 2013).

2.1.3.1 Enhancing Customer Satisfaction and Brand Loyalty

A well-executed UXD strategy improves automobile usability and functionality, hence
49 increasing customer happiness. UX design is more than just aesthetics; it is also about making a product intuitive and efficient, resulting in positive interactions (Garrett, 2010). According to Hassenzahl (2010), user experience design builds emotional ties between people and products, which has a substantial impact on long-term brand loyalty. Tesla, for example, uses a minimalist interior design and a highly responsive infotainment system to provide consumers with a seamless and efficient interaction, hence increasing customer trust and retention.

25 Norman (2013) emphasizes that ease of use plays a critical role in shaping customer loyalty. When a product, such as an automobile, requires minimal cognitive effort to
125 operate, users are more inclined to remain loyal to the brand. This principle is

increasingly reflected in modern automobile design, where manufacturers are prioritizing intuitive user experiences. To enhance usability and reduce the mental load on drivers, carmakers are incorporating advanced technologies such as voice-activated assistants, intelligent navigation systems, and haptic feedback mechanisms. These features are designed to streamline interactions, allowing drivers to focus more on the road and less on operating complex controls. By making the driving experience more user-friendly and engaging, manufacturers not only improve user satisfaction but also encourage long-term brand attachment. As vehicles become more connected and feature-rich, ensuring simplicity and ease of interaction remains central to building positive user experiences and fostering sustained customer relationships in the automobile sector.

2.1.3.2 Competitive Advantage in the Market

In an increasingly competitive automobile market, UXD is a critical differentiation. According to Korber (2013), today's consumers value user-friendly technology over mechanical performance. Vehicles that provide a better user experience through interactive dashboards, speech recognition, and driver assistance systems typically outperform competitors in terms of consumer satisfaction.

BMW and Mercedes-Benz, for example, have incorporated UXD principles into their electric vehicle (EV) designs, simplifying the charging process and improving range management through user-friendly digital displays. The incorporation of such features guarantees that consumers are comfortable shifting to newer automobile technologies, which strengthens brand trust and market leadership (Walker, 2001).

2.1.4 Integrating Sustainability, Technology, and User Needs in Automobile UX Design

The convergence of sustainability, technological advancement, and evolving user needs has become a defining paradigm in contemporary automobile User Experience (UX) design. A comprehensive, user-centered approach to automobile design is based on these three dimensions, which are no longer separate factors but rather are becoming more interconnected, according to recent studies (Norman, 2013; Krippendorff, 2006). By striking a balance between technical innovation, ecological responsibility, and user delight, UX serves as a unifying discipline inside this crossroads.

2.1.4.1 Sustainability and UX Design

Sustainability has evolved from being an engineering or environmental goal to becoming a fundamental dimension of the user experience. Modern consumers evaluate automobiles not only on performance and aesthetics but also on their environmental footprint and material sustainability. Research highlights that sustainable practices - such as the use of recyclable materials, energy-efficient systems, and low-emission technologies contribute to positive user perception and long-term emotional attachment (Weber, 2025; Walker, 2001).

Moreover, the notion of *emotional sustainability* has emerged as a critical UX element, emphasizing products that maintain relevance, desirability, and usability throughout their lifecycle (Hassenzahl, 2010). This shift extends the scope of UX beyond initial usability toward enduring satisfaction and ethical responsibility. For instance, the integration of renewable materials in vehicle interiors or the design of modular components that allow for easy replacement not only enhance usability but also reinforce user trust and brand credibility (Lu et al., 2024). As sustainability becomes a determinant of purchase intent, UX designers must consider how environmental consciousness aligns with sensory, cognitive, and emotional engagement in automotive contexts.

2.1.4.2 Technology as an Enabler of User Experience

Technological innovation remains a primary driver of transformation in the automobile industry. However, within the UX context, technology is perceived not as an end in itself but as a means to facilitate intuitive, adaptive, and human-centered interaction. Advanced technologies such as Artificial Intelligence (AI), Augmented Reality (AR), Internet of Things (IoT), and biometric interfaces are redefining how users experience automobiles (Park et al., 2024; Al-Fuqaha et al., 2020).

AI-powered personalization systems adapt to driver preferences by automatically adjusting seat positions, climate control, and infotainment settings. AR-based Head-Up Displays (HUDs) project contextual information directly onto the windshield, reducing cognitive distraction and enhancing situational awareness. Similarly, connected infotainment ecosystems synchronize seamlessly with users' digital lifestyles, promoting continuity between the automobile and their broader technological ecosystem (Strayer et al., 2022).

However, technological proliferation also presents challenges. Over-automation and interface complexity can increase cognitive load, potentially diminishing the sense of control and trust (Körber et al., 2013). Hence, UX design plays a vital mediating role by ensuring that technological advancements remain transparent, reliable, and aligned with human capabilities. The ultimate objective is to design meaningful interaction, where technology amplifies rather than replaces the human experience.

2.1.4.3 Evolving User Needs and Experience Expectations

Automobile users today seek products that combine convenience, emotional connection, environmental responsibility, and digital integration. Traditional parameters such as safety, comfort, and functionality remain essential, but emerging priorities like sustainability, personalization, and mental well-being are increasingly influencing user expectations (Gomaa, 2022).

User-Centered Design (UCD) and Kansei Engineering approaches have proven particularly effective in addressing these evolving expectations. UCD ensures that vehicles are designed around real-world user requirements through iterative testing and participatory design (Cooper et al., 2014). Kansei Engineering, conversely, translates emotional responses, such as perceptions of luxury, sportiness, or comfort into tangible design elements, bridging psychological and physical experience (Lu et al., 2024). Together, these methodologies enable designers to anticipate not only functional but also emotional and ethical user needs, thereby enriching the UX value proposition.

2.1.4.4 Integrated Perspective

Integrating sustainability, technology, and user needs under the UX framework establishes a comprehensive foundation for future-oriented automobile design. This triadic relationship is critical for developing vehicles that are simultaneously innovative, responsible, and human-centric. The proposed User Experience-Driven Automobile Design (UX-DAD) model embodies this integration by positioning UX as the mediator between technological capability and user desirability within sustainable boundaries.

From an academic standpoint, this synthesis contributes to the theoretical advancement of UX research by connecting environmental consciousness, human psychology, and technological mediation into a unified design discourse. From an industrial perspective, it equips automobile designers and manufacturers with actionable insights to create vehicles that not only meet regulatory and market demands but also foster long-term user trust, emotional engagement, and brand differentiation.

2.2. OVERVIEW OF AUTOMOBILE DESIGN

Automobile design is a complex, multidisciplinary field that combines creativity, engineering, technology, and user experience to develop vehicles that are aesthetically pleasing, functional, safe, and sustainable (Heimann, 2012). The process of design has grown more complex as the automobile industry changes due to quick technical breakthroughs and changing consumer demands. This need for knowledge of a number of topics, including material science, ergonomics, digital interfaces, and aerodynamics (Phaidon, 2023). The core goal of automobile design is to blend art and science, ensuring that vehicles not only resonate emotionally with users but also meet stringent safety standards, functional requirements, and regulatory compliance. Digitalization and user interface innovation further influence modern automobile design, enhancing user interaction and overall driving experience.

2.2.1. What is Automobile Design

Automobile design refers to the process of developing a vehicle's appearance, functionality, and performance. It involves creating a vehicle's shape, structure, and layout, along with the integration of safety features, ergonomics, and advanced technologies (Lewin, 2010). Designers work to balance aesthetics with practicality, ensuring that the vehicle meets consumer needs while also adhering to environmental and safety regulations (Norton, 2009). As the automobile industry evolves, automobile design continues to integrate new technologies, materials, and user experience principles (Koester, 2017). The field is ever-evolving, with advancements in sustainability, aerodynamics, and smart mobility solutions shaping the future of automobile design (Bakker, 2020).

2.2.2. History of Automobile Design

2.2.2.1 Early Automobiles (1880s–1930s)

Early automobiles were primarily designed for mechanical reliability and efficiency, with little emphasis on user comfort or convenience. These rudimentary horseless carriages had open-top structures, exposing passengers to external conditions, and seating was often rigid and uncomfortable. Their mechanical controls demanded considerable physical effort, requiring drivers to manually crank engines, navigate non-assisted steering, and operate primitive braking systems. Dashboards lacked essential indicators like speedometers and fuel gauges, making vehicle operation reliant on experience rather than real-time feedback (Norton, 2009). Due to complex controls, only trained individuals could operate them, limiting accessibility to the public.

Figure 6: Design of Early Automobiles during 1880s–1930s (Source: Flynn, 2020).

2.2.2.2 Mid-20th Century (1940s–1970s)

By the 1940s, automobile design had started shifting towards user comfort and accessibility as shown below in figure 6. With industrial advancements, manufacturers began incorporating ergonomically designed seats, enclosed cabins, and improved steering mechanisms. This period saw the introduction of power steering, which significantly reduced the effort required to manoeuvre vehicles, enhancing driver control and minimizing fatigue during long-distance travel.

Automatic transmissions emerged as a revolutionary innovation, eliminating the need for manual gear shifting and making driving more accessible to a broader range of users. This development drastically improved the driving experience, particularly in urban environments with frequent stop-and-go traffic. Additionally, climate control systems, such as air conditioning and heating, were introduced, allowing drivers and passengers to maintain a comfortable interior environment regardless of external weather conditions.

Figure 7: Design of Automobiles during 1940s–1970s
*(*Source: 1940s Cars: Classic Cars, Sports Cars & Luxury Cars, *n.d.).*

Safety also became a growing concern during this period. The 1950s and 1960s saw the incorporation of seat belts as a standard feature, significantly reducing fatalities in the event of collisions. Automakers began experimenting with crash-absorbing structures, padded dashboards, and reinforced frames to enhance passenger protection. Towards the late 1960s, the development of early airbag prototypes began, signalling the industry's commitment to safety-centric UX improvements. This era marked a pivotal transition from purely mechanical design to user-focused enhancements, setting the foundation for future UX advancements in automobile design.

2.2.2.3 Late 20th Century (1980s–2000s)

The 1980s and 1990s marked an era of rapid technological advancements in automobile UX, driven by the rise of electronic integration and digital innovations. Vehicles during this period began incorporating electronic dashboards, providing drivers with real-time feedback on speed, fuel levels, and engine performance. This shift towards digitization improved usability and enhanced decision-making by presenting critical information in an accessible format.

Cruise control systems became increasingly common, allowing drivers to maintain a consistent speed on highways without constant pedal engagement. This feature significantly reduced driver fatigue during long journeys and improved fuel efficiency. The late 1990s also witnessed the advent of advanced suspension systems, which improved ride quality by automatically adjusting to road conditions, enhancing both comfort and handling.

Human-Machine Interface (HMI) factors started becoming more refined, with the introduction of touchscreen infotainment systems in the early 2000s. These systems provided intuitive access to navigation, entertainment, and vehicle settings, marking the beginning of interactive UX in automobiles. The integration of GPS-based navigation aids revolutionized the driving experience by eliminating reliance on physical maps and providing real-time traffic updates.

Driver assistance technologies also gained traction during this period. Features such as anti-lock braking systems (ABS), traction control, and electronic stability programs (ESP) were introduced, significantly enhancing vehicle safety and driving confidence. The growing emphasis on connectivity led to the inclusion of Bluetooth-enabled hands-free calling systems, reducing distractions and improving in-car communication.

*Figure 8: Design of Automobiles during 1980s–2000s (*Source: A History of Cars From 1980-2002*, n.d.).*

The late 20th century laid the groundwork for modern UX trends by prioritizing driver convenience, electronic assistance, and interactive interfaces, shaping the future direction of automobile design.

2.2.2.4 21st Century (2000s–Present)

The 21st century has seen remarkable advancements in automobile user experience (UX), driven by artificial intelligence (AI), automation, and personalized interfaces. Automakers now prioritize adaptive Human-Machine Interface (HMI) solutions that integrate voice recognition, gesture-based controls, and biometric authentication to create intuitive and distraction-free interactions, enhancing both safety and user engagement (Körber et al., 2013; Park et al., 2024).

AI-powered voice assistants, such as Apple's Siri, Amazon's Alexa, and Google Assistant, have become integral to modern vehicles. They allow drivers to control navigation, climate settings, and infotainment systems hands-free, reducing cognitive load. Studies have shown that the performance and visual appearance of in-vehicle voice assistants significantly influence user satisfaction, with cultural differences also playing a role (Yusoff et al., 2025).

Gesture-based controls have emerged as a valuable addition to vehicle interfaces. Research has demonstrated their potential to enhance user experience, particularly for individuals with physical challenges, by enabling hands-free interaction with core functions (Yao et al., 2020).

Augmented Reality (AR) displays represent another leap forward. Head-Up Displays (HUDs) now project real-time driving data, such as speed, navigation, and alerts onto the windshield, allowing users to access critical information without taking their eyes off the road. Recent reviews have explored how AR HUDs improve safety and usability in dynamic driving environments (Smith & Gupta, 2024).

The emergence of Advanced Driver Assistance Systems (ADAS) has also reshaped the UX landscape. Features such as lane-keeping assistance, adaptive cruise control, and automated emergency braking now define modern driving experiences. Trust in these systems, as recent research notes, hinges on transparency and user education (Lin et al., 2023).

Personalization is another defining feature of modern automobile UX. AI-driven systems tailor various aspects of the vehicle—such as seat position, climate control, and infotainment based on user behaviour. Biometric authentication methods, like fingerprint and facial recognition, enhance security while offering a seamless, user-specific interface (Kumar & Sharma, 2019).

Connectivity continues to be central to user satisfaction. Smart infotainment ecosystems now sync effortlessly with smartphones and wearables. Over-the-Air (OTA) software updates ensure that vehicle systems remain current, bringing the user experience closer to that of consumer electronics (Al-Fuqaha et al., 2020).

In conclusion, automobile UX has evolved dramatically, from mechanical simplicity to digitally sophisticated systems focused on personalization, automation, and seamless interaction. The ongoing integration of AI, AR, and autonomous technologies promises to further elevate user satisfaction and redefine future mobility.

2.3 KEY UX FACTORS IN AUTOMOBILE DESIGN

2.3.1 Comfort and Ergonomics

Ergonomics is a critical factor in automobile UX, directly affecting driver comfort, fatigue levels, and overall satisfaction. Proper ergonomic design ensures that vehicle seats, controls, and interfaces are optimally positioned for ease of use and accessibility as shown in Figure 8.

- **Seat Adjustability and Support:** Modern vehicles incorporate multiple seat adjustment features, including height, lumbar support, and recline options. Studies have shown that individual characteristics, such as standing lumbar lordosis, significantly influence seated lumbar flexion and seatback pressure, underscoring the importance of personalized seat adjustments to enhance comfort and reduce strain during long drives (Burgess et al., 2023). Additionally, advancements in seat technology, such as dynamic cushioning that adapts to driving conditions, have been developed to further improve driver comfort (Lucintel, 2023).
- **Steering Wheel Design:** Adjustable steering wheels with tilt and telescopic functions contribute to improved driving posture and ease of handling. Innovations in steering wheel design have focused on enhancing driver comfort and control, with features like heated steering wheels and grip-enhancing materials becoming more prevalent (Sweeney et al., 2023).
- **Pedal and Control Positioning:** The placement of pedals and controls significantly affects driving fatigue. An ergonomic study identified that the

combination of operation methods and in-vehicle locations for electronic gearshifts impacts driver performance and comfort, highlighting the need for intuitively located controls to reduce physical strain and enhance usability (Kim et al., 2023).

- **Climate Control and Ventilation:** Advanced climate control systems, including multi-zone air conditioning and ventilated seats, contribute to an improved in-cabin experience by ensuring thermal comfort for all occupants. The integration of seat ventilation systems has been recognized as a valuable feature in modern cars, enhancing comfort by circulating air through the seat's upholstery (Acdcecfan, 2023). Furthermore, the automobile seat climate system market is projected to grow, reflecting increasing consumer demand for enhanced in-car comfort features (Market Research Future, 2023).

Incorporating these ergonomic considerations into vehicle design is essential for enhancing driver comfort, reducing fatigue, and improving overall user satisfaction.

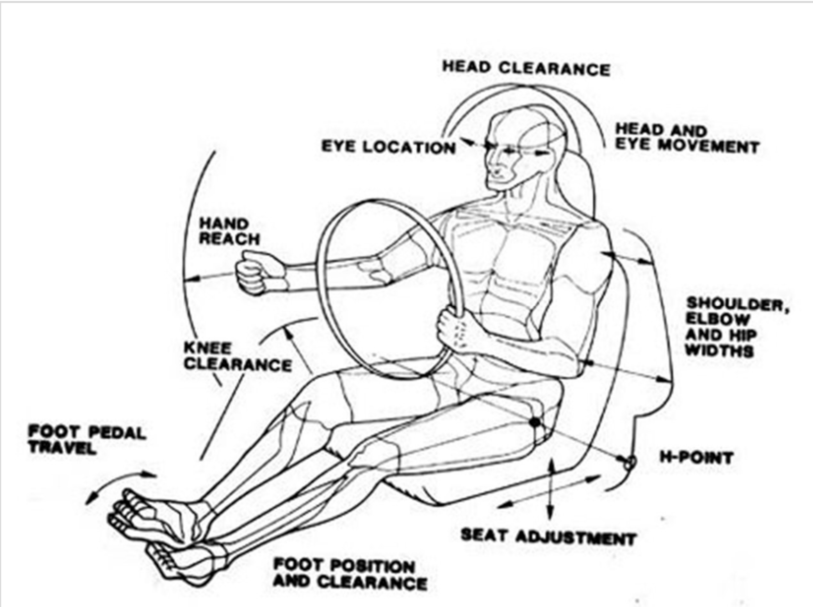


Figure 9: Functional task-oriented measurements
(Source: Peacock and Karwowski, 1993).

2.3.2 Human-Machine Interaction (HMI)

HMI plays a crucial role in modern automobile UX, bridging the interaction between the driver, passengers, and the vehicle's technological features.

- **Touchscreen Infotainment Systems:** The integration of large, high-resolution touchscreens offers intuitive access to navigation, entertainment, and vehicle settings. However, studies have shown that task complexity in touchscreen-based in-vehicle information systems (IVIS) can significantly impact driving behaviour and increase mental workload (Zhang et al., 2024). This underscores the need for designs that minimize driver distraction.

- **Voice-Controlled Assistants:** AI-driven voice assistants, such as Apple CarPlay and Android Auto, enable hands-free operation of key vehicle functions, thereby reducing driver distraction and enhancing safety. Research indicates that while these systems offer convenience, they can also increase cognitive workload, particularly when drivers engage in complex tasks like sending text messages via speech-based assistants (Strayer et al., 2022).
- **Head-Up Displays (HUDs):** Augmented reality HUDs project real-time data, including navigation directions, speed, and safety warnings, onto the windshield, allowing drivers to access information without diverting attention from the road. Recent reviews highlight the effectiveness of AR HUDs in enhancing driving safety and user experience (Winkler & Soleimani, 2024).
- **Haptic Feedback and Adaptive Controls:** Incorporating haptic feedback in steering wheels, touchpads, and buttons provides tangible confirmation of user inputs, improving interaction efficiency and response accuracy. Studies have demonstrated that haptic feedback can significantly enhance driving control and reduce mental load (Gao et al., 2023).

2.3.3 Aesthetics and Emotional Appeal

A vehicle's visual appeal significantly influences consumer perception and emotional connection to the brand.

- **Exterior Styling:** Sleek body designs, aerodynamic contours, and distinctive lighting factors significantly enhance a vehicle's attractiveness. Unique features such as signature grille designs and emblem positioning contribute to brand recognition and consumer preference. Recent studies have shown that the brightness of light reflections on a car's exterior can influence consumer purchase intentions, particularly in compact cars (Chen et al., 2022).
- **Interior Material Selection:** The use of high-quality materials like soft-touch plastics, genuine leather, brushed metal accents, and ambient lighting creates a premium and inviting cabin environment. Automakers are increasingly adopting sustainable materials to meet environmental standards and consumer demand for eco-friendly interiors (Weber, 2025).
- **Dashboard and Instrument Cluster Design:** Digital instrument clusters with customizable display options allow drivers to personalize their visual interface, enhancing readability and engagement. The market for digital instrument clusters is projected to grow significantly, reflecting their increasing integration into modern vehicles (Verified Market Research, 2024).
- **Personalization and Customization:** Modern vehicles offer a range of personalization options, including configurable ambient lighting, digital themes, and tailored seat stitching, enabling users to create a more personalized driving space. Studies have demonstrated that ambient lighting in vehicle interiors positively influences driver perception and comfort (Caberletti et al., 2023).

2.3.4 Safety and Assistive Technologies

Safety is a cornerstone of UX in automobile design, with modern vehicles incorporating advanced systems that enhance driver confidence and reduce accident risks.

- **Advanced Driver Assistance Systems (ADAS):** Features such as lane departure warnings, adaptive cruise control, and automatic emergency braking actively assist drivers in navigating complex road conditions. Recent studies have demonstrated that ADAS can significantly reduce crash rates and enhance road safety (Kuehn et al., 2023).
- **Collision Avoidance Systems:** Utilizing radar and LiDAR technologies, these systems detect potential obstacles and can autonomously apply brakes or steer the vehicle to prevent accidents. A comprehensive survey of collision avoidance algorithms highlights their critical role in autonomous vehicle safety (Zhao et al., 2023).
- **Driver Monitoring Systems:** AI-driven monitoring systems track eye movements, facial expressions, and head positioning to detect drowsiness or inattentiveness, issuing alerts when necessary. Innovative approaches combining deep learning techniques have shown promise in real-time drowsiness detection (Li et al., 2023).
- **Autonomous Driving Capabilities:** As self-driving technology advances, semi-autonomous and fully autonomous vehicles are emerging, necessitating redefined UX principles to ensure passenger trust, interaction, and comfort during autonomous operation. Research indicates that multimodal explainable artificial intelligence interfaces can enhance passenger experience during unexpected autonomous vehicle behaviours (Smith et al., 2024).
- **Passive Safety Enhancements:** Improved crash structures, energy-absorbing materials, and enhanced airbag deployments contribute to minimizing injuries in the event of a collision. Studies analysing airbag structures have provided insights into reducing driver injury during frontal impacts (Jones et al., 2023).

2.4. FRAMEWORKS AND THEORIES ON UX IN AUTOMOBILES

2.4.1 Norman’s Three Levels of Design

Three stages of user experience are distinguished by Donald Norman's emotional design model: visceral, behavioural, and reflective. Understanding these levels allows designers to create products that not only function well but also resonate emotionally with users (Norman, 2004).

- **Visceral Design:** This stage concerns the initial, instinctive reaction to the appearance of a vehicle. Colour, shape, lighting, and general appearance affect a user's initial impression. An elegant, high-tech design may generate enthusiasm, whereas a more conservative design might give a sense of trustworthiness.

- **Behavioural Design:** This stage considers the usability and functionality of a car. It encompasses features like ease of driving, dashboard organization, infotainment system control, comfort in seating, and overall drivability. An ergonomic interface that is well-designed increases usability, lessening driver fatigue and cognitive load.
- **Reflective Design:** This is the level that involves the deeper emotional relationship a user develops with the car. Brand reputation, perceived status, efforts towards sustainability, and long-term emotional bonding with a car are all included in this category. The capacity of a car to mirror the user's identity and lifestyle makes it more attractive.

2.4.2 Kansei Engineering

Kansei Engineering is a process of mapping users' feelings and mental reactions into concrete design characteristics. First used in Japan, it has become popularly applied across automobile UX to match design characteristics with customer sentiments.

- **Data Collection:** Emotions of users are collected using surveys, interviews, and analysis of biometric data.
- **Factor Identification:** Emotions are categorized into attributes such as sportiness, luxury, aggressiveness, or comfort.
- **Implementation:** They are then applied to concrete design factors, such as the shape of a dashboard, the comfort of seats, or the noise of an engine.

Recent studies have demonstrated that vehicles designed using Kansei Engineering foster stronger emotional bonds between users and cars, enhancing satisfaction and loyalty (Lu et al., 2024).

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2.4.3 User-Centred Design (UCD)

The User-Centred Design (UCD) iterative design process is focused on the user's requirements and preferences, and usability testing. It ensures that vehicle functions are designed for actual user conditions and not exclusively on the basis of engineering considerations. Implementing UCD in automobile design ensures that vehicles are tailored to meet user expectations, leading to enhanced satisfaction and safety (Gomaa, 2022).

- **Phase 1: User Research:** Understanding target demographics, their driving behaviour, and expectations through focus groups and surveys.
- **Phase 2: Ideation & Prototyping:** Developing early prototypes of dashboard interfaces, seating configurations, and infotainment systems based on collected data.
- **Phase 3: Testing & Refinement:** Conducting usability tests, eye-tracking studies, and driving simulations to assess the effectiveness of design factors.
- **Phase 4: Implementation:** Incorporating feedback-driven refinements into final production models.

2.5 AUTOMOBILE SEGMENTS

Segmentation groups prospective customers into specific groups based on demographics, lifestyle, and buying behaviour. This enables designers to modify their ideas to meet the specific needs of different market segments, whether targeting families, young professionals, or eco-conscious consumers.

In 2002, Society of Indian Automobile Manufacturers (SIAM) classifies passenger cars in India into six categories based on length shown in table 1.

Table 1: Indian Car Segment as per SIAM

Segment	Length Range	Examples	Ref Images
Mini	Up to 3,400 mm	Maruti Suzuki Alto, Datsun Redi-Go	
Compact	3,401–4,000 mm	Maruti Suzuki Swift, Hyundai Grand i10, Tata Tiago, Tata Nexon, Maruti Brezza	
Mid-size	4,001–4,500 mm	Honda City, Hyundai Creta, Vento, Rapid	
Executive	4,501–4,700 mm	Toyota Camry, Skoda Superb	
Premium	4,701–5,000 mm	Mercedes-Benz E-Class, BMW 5 series Camry, Skoda Superb	
Luxury	5,001 mm and above	Mercedes-Benz S-Class, Audi A8, BMW 7 series, Jaguar XJ	

As we are in transition phase of development we have seen multiple new segment from other countries are entering in Indian automobile market because of that we are seeing new segment as well. Below table 2 shows other segments used in automobile industry.

Table 2: Shows Automobile segments available in industry

Segment	Car Examples	Characteristics	Reference Images
A-Segment (Mini Hatchbacks)	Renault Kwid, Maruti Suzuki S-Presso, Datsun Go	- Length: <4 meters - Small, Efficient petrol engines - Basic features to keep costs low	
B-Segment (Small Hatchbacks)	Honda Jazz, Tata Altroz, Maruti Suzuki Swift, Maruti Suzuki Baleno	- Length: <4 meters - Wider and taller than A-Segment - Premium features and interiors	
C-Segment (Small Sedans)	**Sub-Compact Sedans:** Maruti Suzuki Dzire, Hyundai Aura, Honda Amaze	**Sub-Compact Sedans:** - Length: <4 meters - Shared platform with B-Segment - Similar powertrain	
	Small Sedans: Hyundai Verna, Honda City, Toyota Yaris, Maruti Suzuki Ciaz	**Small Sedans:** - Length: >4 meters - Bigger engines: 1.5L to 1.6L - Petrol and diesel options	
D-Segment (Mid-Sized Family Cars)	Honda Civic, Skoda Laura, Hyundai Elantra, BMW 3-Series	- Larger than C-Segment - Focus on luxury and interior features - Owners often use back seat - Engines are powerful but secondary to luxury	
E-Segment (Executive Luxury Cars)	Audi A6, BMW 5-Series, BMW 7-Series, Skoda Superb	- Very long and wide - Focus on maximum luxury - Spacious interiors for business class - Powerful engines-Difficult for city driving	
M-Segment (Multipurpose Cars)	**Small MPVs:** Maruti Suzuki Ertiga, Renault Triber	**Small MPVs:** - Length: ~4 meters - 6-7 seats	

	Medium MPVs: Toyota Innova, Mahindra Marazzo	**Medium MPVs:** - Moderate size - Adequate power and features	
	Large MPVs: Toyota Vellfire, Kia Carnival	**Large MPVs:** - Can seat 8+ comfortably - Luxurious features - Not city-friendly	
J-Segment (SUVs)	**Sub-Compact SUVs:** Maruti Suzuki Vitara Brezza, Ford Ecosport, Tata Nexon, Kia Sonet, Hyundai Venue	**Sub-Compact SUVs:** - Length: <4 meters - Decent engine and features - Petrol and diesel options	
	Compact SUVs: Hyundai Creta, Kia Seltos, Nissan Kicks, Renault Duster	**Compact SUVs:** - Larger than sub-compact - Powerful engines - Latest tech and features	
	Mid-Size SUVs: Tata Harrier, Mahindra XUV500, MG Hector Plus	**Mid-Size SUVs:** - Seats 5-8 - Latest tech and safety features - Some offer 4X4 drivetrain	
	Large SUVs: Toyota Fortuner, Ford Endeavour, Toyota Land Cruiser, BMW X5	**Large SUVs:** - Very large - Advanced tech - Powerful engines - Usually automatic transmission	
Crossovers	Maruti Suzuki S-Cross, Honda W-RV	- Hatchbacks on stilts - Easy city manoeuvrings and parking - Similar power figures to compact SUVs - Feature-loaded	

The Indian automobile market has experienced significant growth in the compact SUV segment over the past decade (2012–2023), with passenger vehicle sales rising steadily year-on-year. According to data from the Society of Indian Automobile Manufacturers (SIAM), total passenger vehicle sales increased from 27.74 lakh units in FY 2019-20 to 42.19 lakh units in FY 2023-24. A slight dip was observed in FY 2020-21, with sales declining to 27.11 lakh units due to pandemic-related disruptions, but the market rebounded strongly in subsequent years. FY 2021-22 recorded sales of 30.70 lakh units, followed by a significant jump to 38.90 lakh units in FY 2022-23, and an all-time high of 42.19 lakh units in FY 2023-24. This steady rise in passenger vehicle sales reflects the growing popularity of compact SUVs, driven by their affordability, advanced features, and suitability for Indian road conditions. Compact SUVs have become a key growth driver in India's automobile landscape, with manufacturers consistently introducing innovative and competitive models. The figure below illustrates this growth trend, highlighting the significant increase in passenger vehicle sales over the years (SIAM, 2024).

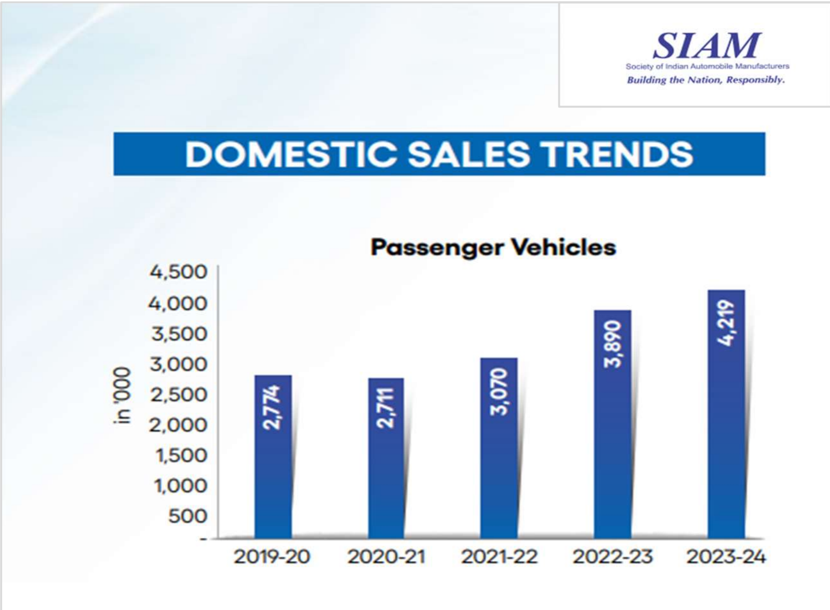

Figure 10: Shows the sales figure form passenger vehicle from 2019-20 to 2023-24

As per Team-BHP, a leading automobile forum in India known for its in-depth reviews, industry analysis, and high-quality content, SUVs and Hatchbacks sales are increasing continuous, particularly compact SUVs, have been the primary growth drivers in this segment. The forum highlights the steep rise in SUV sales, which grew from just 9,354 units in 2011 to a staggering 1,67,555 units by 2024. This dramatic increase underscores the growing demand for SUVs, driven by their versatility, blending of style, utility, and affordability. Compact SUVs, in particular, stand out due to their ability to cater to urban and semi-urban buyers while meeting the practical needs of Indian road conditions. Figure shows the SUVs car sales from 2011- 2024 (Team BHP, 2024).

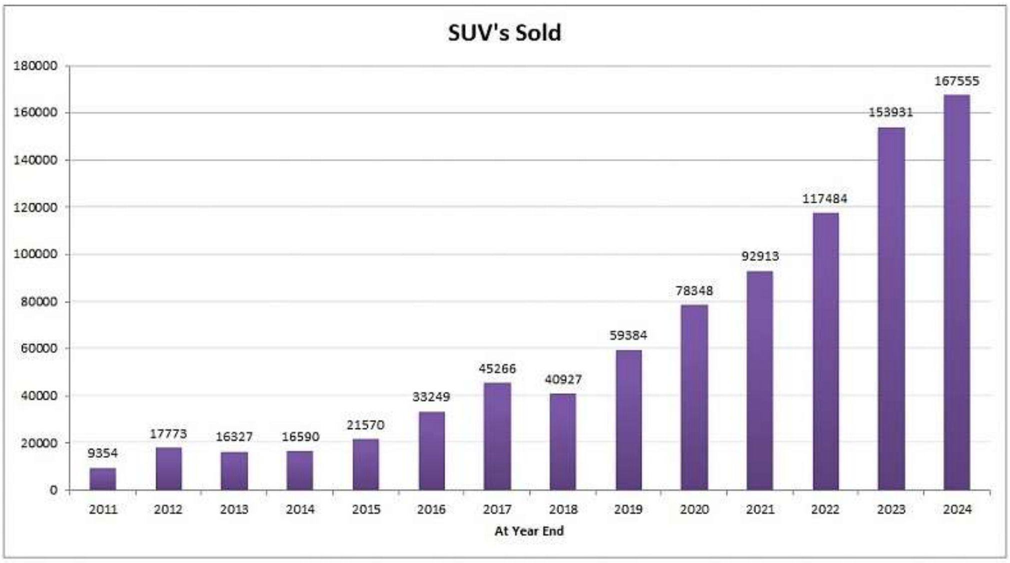

Figure 11: SUVs car sales from 2011- 2024. (Source: Jdmboi, 2025)

Manufacturers have capitalized on this trend by introducing cutting-edge, feature-packed models at competitive prices, further fuelling demand. With compact SUVs playing a pivotal role, the segment has transformed India's automobile landscape, setting the foundation for sustained growth in the future. The figure below provides a clear visual representation of this growth trend in SUV sales, showcasing the exponential rise over the years.

2.6 UX APPROACHES IN AUTOMOBILE DESIGN PROCESS

This section explores how User Experience (UX) methodologies and the automobile design process works together. Modern automotive development has evolved beyond aesthetics and mechanical performance to include emotional, cognitive, and experiential dimensions that influence user satisfaction and brand perception. Despite variations across manufacturers, most follow six foundational process—Research**,** Concept Generation**,** 3D Modelling**,** Clay Modelling**,** Color–Material–Finish (CMF)**,** and Visualization—each contributing uniquely to the overall user experience. These stages form the basis of integration within the proposed *User Experience–Driven Automobile Design (UX-DAD) Framework*, which aligns user-centered methods with traditional vehicle design workflows.

The automobile design process is a comprehensive, iterative journey that transforms initial concepts into fully realistic vehicles prototype. It begins with establishing a design brief, outlining objectives, target markets, and functional requirements. This is followed by concept generation, where designers create sketches and digital models. The process involves various departments in the current industry setups, including Research and Design Brief, Concept Generation (Sketching and Rendering including exterior, interior and accessories design), 3D Modelling, Clay Modelling and

Prototype Development, CMF (Colour Material and finish), Visualization. The process also incorporates advanced materials and technologies and innovative manufacturing methods, ensuring that the final design is both efficient and manufacturable.

In the late 1920s, General Motors (GM) opted for style over pricing and technological innovation to compete with the dominant Ford Model T. Hence, they have come up with the design process with 4 Stage Technical Package, Sketching, Orthographic sketches and clay modelling was led by Harley Earl with timespan from 1927-1950.

In the 1960s, the automobile design process began to be impacted by the digital revolution. The automobile design process was largely remained unchanged as the business were majorly personally owned. The only change we can see that of introduction of 3D in Technical package and introduction 3D Modelling in the following years. Along with that we had seen introduction of technology in in multiple areas like Clay millings, AR/VR, etc. Also, various departments also get added during this development years colour & Trims, Accessories, visualisation etc. Similarly, Toyota Research Institute has unveiled new generative AI techniques that incorporate precise engineering constraints into the design process, facilitating the creation of innovative vehicle designs (Toyota Research Institute, 2023).

Furthermore, the application of AR and VR technologies has transformed vehicle design by enabling real-time virtual modelling and adjustments. Designers can build virtual prototypes, significantly reducing costs and enhancing safety. This approach allows for rapid adjustments before committing to physical production, streamlining the design process (Plutomen, 2025).

The automobile design process is a multidisciplinary approach that combines creativity, engineering, and technology to develop vehicles that are functional, aesthetically appealing, and aligned with market demands (Doyle, 2018). This process transforms conceptual ideas into fully realized products, integrating user experience, safety standards, and sustainability (Chakrabarti, 2013). It is a systematic journey that ensures the final design is both innovative and feasible for production. The industry typically follows six key stages to achieve this: Research and Design Brief, Concept Generation (Sketching and Rendering), 3D Modelling, Clay Modelling and Prototype Development, Colour, Material, and Finish (CMF), and Visualization. Each stage plays a crucial role in refining the design, addressing technical challenges, and ensuring the vehicle meets consumer expectations and regulatory requirements (Ulrich & Eppinger, 2020). Together, these stages represent a dynamic interplay of art and science, driving the evolution of automobile design in a competitive and rapidly advancing industry. Key Stages of the Automobile Design process are briefly described bin following report. Below Figure 11, Shows the automobile design process currently used in industry.

- **Research and Design Brief:** The research and design brief stage lay the foundation for the entire automobile design process. It begins with extensive market research, consumer behaviour analysis, and technological trend studies to identify user needs, market demands, and industry gaps. This research informs the creation of a design brief, a strategic document outlining the project's objectives, target audience, functional requirements, and desired aesthetic appeal. The brief acts as a guiding framework, ensuring that all stakeholders are aligned. By defining parameters such as cost, safety regulations, and environmental considerations, this stage ensures that the design process is both focused and innovative.
- **Concept Generation (Sketching and Rendering):** Concept generation is where creativity flourishes as designers translate ideas into visual representations. This stage involves brainstorming, sketching, and rendering initial concepts to explore a wide range of possibilities. Designers experiment with proportions, shapes, and innovative features, often producing multiple iterations to refine the aesthetic and functional aspects of the vehicle. Advanced tools such as digital sketching tablets and rendering software enable designers to create high-quality, detailed images that help visualize how the vehicle will look and function. This phase is critical for establishing the design's overall direction, allowing stakeholders to evaluate and select the most promising concepts.

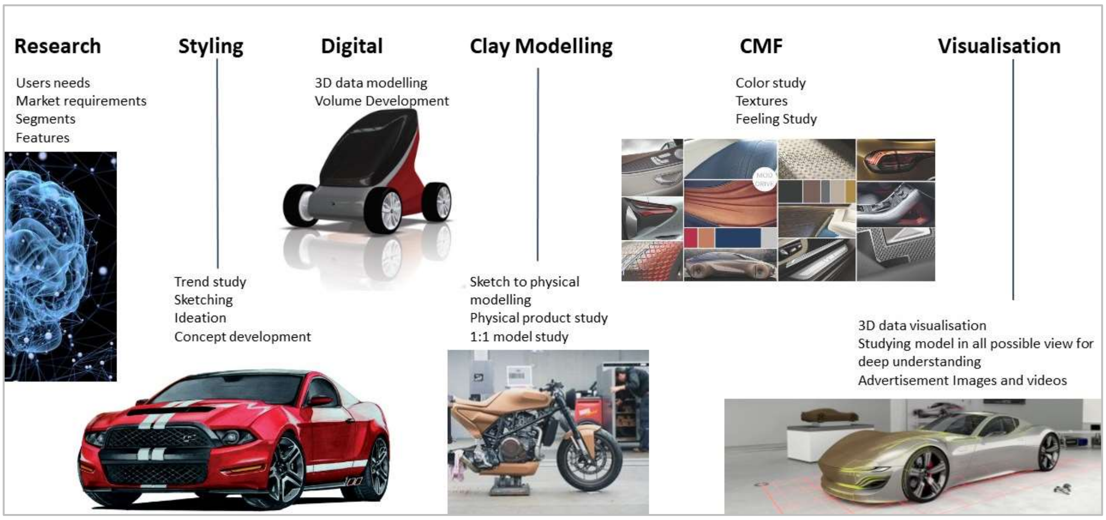

Figure 12: Shows the automobile design department in industry.

- **Digital/3D Modelling:** 3D modelling transforms 2D sketches and renderings into detailed three-dimensional digital representations of the vehicle. Using advanced computer-aided design (CAD) software, designers create virtual models that simulate the vehicle's dimensions, ergonomics, and structural integrity. This step allows for precise evaluation of the design, ensuring feasibility and functionality while maintaining aesthetic appeal. Designers can manipulate and refine every aspect of the model, from surface details to interior layouts. 3D modelling also facilitates collaboration across teams, enabling engineers and designers to assess manufacturability and address potential challenges early in the development process.

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- **Clay Modelling and Prototype Development: Clay** modelling bridges the gap between virtual designs and physical reality. A life-sized clay model is crafted to bring the digital design to life, allowing designers to assess its proportions, contours, and surface details tangibly. Clay models are instrumental in visualizing how light interacts with the vehicle's form and refining aesthetics. Following this, prototypes are developed to test functionality, safety, and performance. Prototypes include working models equipped with functional components, enabling rigorous evaluations. Feedback from these tests informs further refinements, ensuring the design is ready for production. This stage is pivotal for balancing creativity and practicality.

- **CMF (Colour, Material, and Finish):** The CMF phase focuses on selecting the colours, materials, and finishes that define the vehicle's personality and appeal. Designers consider trends, user preferences, and brand identity to create a cohesive and emotionally engaging look. This process involves extensive experimentation with textures, hues, and finishes, such as metallic paints, leather upholstery, or sustainable materials. CMF decisions impact not only the vehicle's aesthetics but also its durability, sustainability, and tactile experience. This phase ensures that the design resonates with the target audience, aligning with market expectations and enhancing the overall perception of quality and innovation.

- **Visualization:** Visualization is the final step in bringing the automobile design to life before production. Advanced visualization tools, including virtual reality (VR) and high-definition rendering software, create realistic simulations of the vehicle in various environments and lighting conditions. Designers use these tools to present the finalized design to stakeholders, ensuring clarity and alignment. Visualization also aids in marketing efforts, enabling the creation of promotional materials that showcase the vehicle's features and design highlights. By providing an immersive and detailed representation, visualization ensures that the design is optimized and ready to capture consumer interest effectively.

UX approaches have progressively transformed the automobile design process from a linear, engineering-driven model into a cyclical and user-centered ecosystem. Each process—from early research to final visualization—now incorporates user insights, emotional mapping, and iterative feedback loops that ensure alignment between functional performance and human experience. The convergence of UX practices with digital prototyping tools, virtual reality simulations, and data-driven evaluation methods has further accelerated the shift toward *experience-led innovation* in the automotive industry.

Table 3: Show UX integration during each automobile design process

Stage	UX Integration Focus	Example Methods or Tools
1. Research	Understanding user needs, driving context, and emotional expectations.	Ethnography, interviews, empathy mapping, contextual inquiry.
2. Concept Generation	Translating insights into design opportunities and experience goals.	Journey mapping, persona creation, ideation workshops, storyboards.
3. 3D Modelling	Evaluating spatial comfort, ergonomics, and visibility.	CAD simulations, digital ergonomics studies, eye-tracking tools.
4. Clay Modelling	Validating usability and feedback mechanisms.	AR/VR simulation, usability testing, heuristic evaluation.
5. CMF (Colour–Material–Finish)	Linking sensory perception to emotional and brand experience.	Kansei engineering, mood boards, material perception analysis.
6. Visualization	Communicating final experience to stakeholders and users.	Interactive renders, experience videos, digital twins.

Recent research and design practice indicate that AI tools are increasingly integrated into early-stage conceptual design for simulation, visualization, and predictive modelling. In the context of automobile UX, such tools provide a visual platform to translate abstract design factors into perceivable forms. The integration of AI visualization in this research is thus consistent with evolving industry practices, where computational design methods augment human-centered frameworks to create faster, data-driven concept validation.

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CHAPTER 3:

METHODOLOGY

3.1 OVERVIEW OF RESEARCH DESIGN

With a mixed-methods approach, this research integrates qualitative and quantitative methods to examine user experience (UX) in car design depicted in figure. Through online surveys, observations, and interviews, this method provides a thorough assessment of both subjective user opinions and objective performance measures (Wan et al., 2024).

Figure 13: Show the Mixed method research approach

The Delphi method has been used for UXD factor selection and parameter identification, ensuring expert validation. Additionally, Likert scales were applied in case studies to assess UX factors impact on user satisfaction and vehicle performance. Insights from 150 automobile designers (2–20 years of experience) highlight UX challenges and overlooked factors in current practices. The qualitative data uncovers these gaps, while quantitative analysis validates their significance. By integrating these methodologies, the study delivers practical recommendations for embedding UX into automobile design, ensuring vehicles align with both functional and emotional user needs, ultimately enhancing industry innovation (Dalkey & Helmer, 2023; Liu et al., 2023).

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3.2 METHODOLOGY APPROACH

The research methodology for this study follows a structured approach to identifying, developing, and evaluating user experience design (UXD) factors relevant to automobile design. Figure below shows the details methodology approach in graphical format. The methodology consists of several key phases shown in figure 13.

- **Research Area and Literature Review**: The study begins by defining the research area and conducting a comprehensive literature survey to understand existing knowledge, theories, and research on UXD factors in automobile design. This phase helps in identifying the research gap, which forms the basis for defining the research objective.

- **Defining the Research Objective and Methodology**: Based on the identified gap, the research objective is formulated, focusing on enhancing user experience in automobile design. The research methodology is outlined, which includes a multi-stage approach involving literature analysis, expert consultation, and empirical validation.

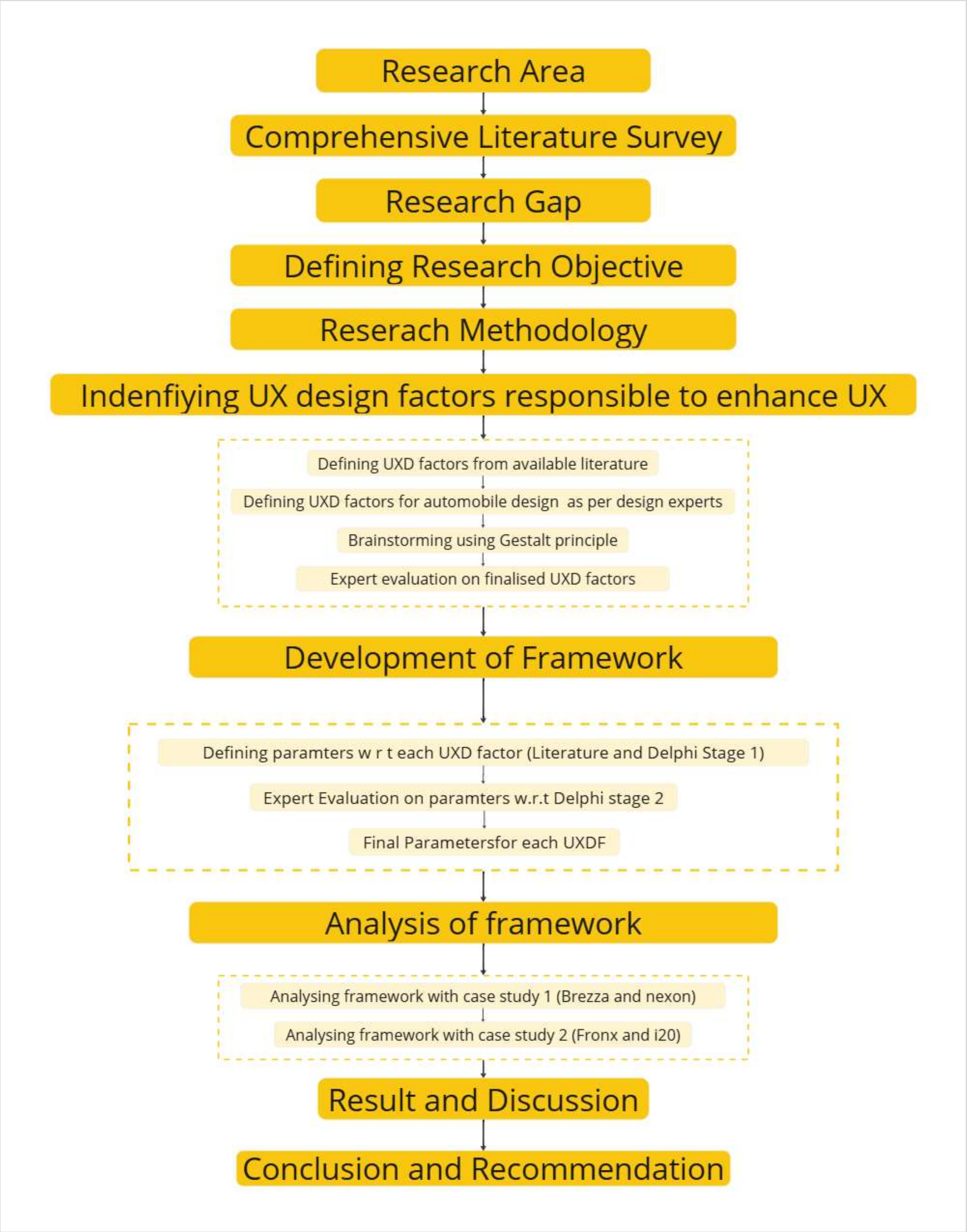

Figure 14: Research Methodology

- **Identifying UXD Factors Responsible for Enhancing UX**: This phase aims to define key UXD factors that influence user experience in automobile design. The process includes:
  - Extracting UXD factors from available literature.
  - Consulting design experts to refine and validate the identified factors.
  - Using Gestalt principles for brainstorming and structuring the UXD factors.
  - Conducting expert evaluations to finalize the UXD factors.

- **Development of Framework**: Once the UXD factors are identified, a framework is developed to systematically assess and measure their impact. This involves:
  - Defining parameters corresponding to each UXD factor based on literature and Delphi Stage 1.
  - Conducting expert evaluations in Delphi Stage 2 to validate these parameters.
  - Finalizing the parameters for each UXD factor, forming the foundation of the framework.

- **Analysis of the Framework**: The developed framework is analysed through empirical validation using case studies. Two case studies are considered:
  - **Case Study 1: Evaluating the framework with Brezza and Nexon models.**
  - **Case Study 2: Evaluating the framework with Fronx and i20 models.**

  These case studies help in understanding how well the framework applies to real-world automobile designs and its effectiveness in enhancing user experience.

- **Result and Discussion**: The findings from the framework analysis are discussed, highlighting insights into UXD factors, their impact on automobile design, and potential improvements.

- **Conclusion and Recommendation**: The study concludes with a summary of key findings, contributions to the field of automobile UXD, and recommendations for future research and design improvements.

This methodological approach ensures a comprehensive investigation of UXD factors, leveraging both literature and expert insights while validating the findings through real-world case studies. The use of the Delphi method enhances the reliability and credibility of the framework, making it a robust tool for evaluating and improving user experience in automobile design.

3.3 SURVEY AND DATA COLLECTION ANALYSIS METHODS

3.3.1 Survey Design and Purpose

The survey was meant to capture factors of user experience (UX) which have an impact on automobile design. It sought to collect information from two major sources:

- **Design practitioners and experts** with hands-on experience in diverse phases of automobile design, including Research, Styling, 3D Modelling, Clay

Modelling, CMF (Colour, Materials, and Finish), and Visualization. Their insights helped refine the UXD factors in line with industry best practices (Huang et al., 2023).

- The structured survey evaluated UXD factors such as safety, functionality, ergonomics, aesthetics, sustainability, connectivity, ease of use, accessibility, responsiveness, and navigation (Wan et al., 2024).

3.3.2 Expert Consultation

After reviewing the literature, the study focused on gathering insights from design experts and practitioners they possess a wealth of knowledge in the Automobile sector. These professionals provided in-depth knowledge of UXD principles, factors, and attributes based on real-world applications (Liu et al., 2023).

Expert consultation in this research played a pivotal role in bridging theoretical knowledge with practical industry insights. It validated the selection of UX factors, guided the refinement of the UX framework, and ensured that the proposed solutions are both user-centered and implementable across diverse automobile segments. The method strengthened the credibility, reliability, and practical relevance of the research outcomes.

3.3.3 Delphi Method

The Delphi method was employed to identify key UXD factors and define parameters for each factor. This iterative process involved multiple rounds of expert evaluations, ensuring a consensus on the most critical UXD parameters. The process involved the following steps (Dalkey & Helmer, 2023; Salmeron & Lopez, 2022):

- **Selection of Experts** – Selected design experts and practitioners in the domain of UX and automobile design with experience ranging from 2-20 years.
- **Round 1: Initial Questionnaire** – Experts respond to open-ended or structured questions related to the research topic.
- **Analysis and Feedback** – Responses are analysed, and a summary is shared for second round expert survey.
- **Round 2 Validation:** – Experts refine their responses based on their experience and expertise.
- **Final Aggregation** – By compiling the final results, all outcomes above 80% were deemed final and utilized for framework development or decision-making.

3.3.4 Gestalt Principles

The Gestalt Principles were applied in this research to support the logical grouping and classification of the User Experience (UX) factors identified during the literature review and expert consultations. While Gestalt theory originated from the field of visual perception, explaining how humans naturally organize elements into coherent wholes, this study extends its application into the textual and conceptual domain of UX factor organization.

The essence of Gestalt lies in its ability to segregate, relate, and organize, humans perceive individual stimuli as structured, meaningful patterns rather than isolated parts (Wertheimer, 1923; Koffka, 1935). In this research, that same perceptual logic was adopted to group text-based UX elements that represent experiential or perceptual constructs rather than visual forms.

During the questionnaire-design stage, several UX factors, such as Safety, Ergonomics, Functionality, and Aesthetics showed conceptual overlaps when expressed as textual items. To achieve clarity and remove redundancy, Gestalt's Law of Similarity and Law of Proximity were extended to textual segregation, grouping related UX attributes by their cognitive and experiential relationships.

Examples include:

- Seat adjustability, driver posture, and visibility were grouped under Ergonomics, as they represent comfort and human–vehicle interface quality.
- Dashboard layout, interface responsiveness, and ease of control were clustered under Functionality, emphasizing usability and feedback quality.

This process of conceptual grouping using Gestalt logic enabled a more coherent, cognitively natural structure for the UX factors before expert validation through the Delphi method. It ensured non-redundant, clearly defined categories aligned with user cognition.

This study thus proposes a novel extension of the Gestalt principle, from its traditional role as a visual segregation model to a textual and experiential segregation framework suitable for modern UX and digital-design research. As industries have evolved from physical products to digital ecosystems, the need to structure information, labels, and text-based constructs according to perceptual logic has become increasingly vital. Recent studies confirm that Gestalt grouping effectively organizes hierarchical and semantic information in digital interfaces (Ma, 2025) and influences both interface clarity and cognitive load reduction in UX design (Aliyev, 2025; UXmatters, 2024).

77 By adopting this expanded interpretation, the research preserves the Gestalt philosophy that "the whole is greater than the sum of its parts" (Koffka, 1935) while enabling its use in non-visual contexts such as questionnaire design, UX factor clustering, and experiential mapping. This extension provided better conceptual precision, cognitive alignment, and methodological rigor during the Delphi validation and subsequent UX-DAD framework development.

The Gestalt-based grouping process served as a cognitive and structural foundation for refining UX factors, ensuring they were organized, comprehensible, and experientially aligned for both experts and respondents. This methodological adaptation not only enhances the rigor of the present study but also contributes a contemporary extension of Gestalt theory into the field of UX strategy and automobile design.

3.3.5 Likert Scale for Analysis

In the framework validation and user experience survey, responses by participants were measured through the Likert scale. This was a systematic approach to quantifying the user opinions and validating the UX DAD framework developed (Finstad et al., 2022). The scale provides a structured method to capture subjective opinions in a form that can be statistically analysed to validate the proposed UX framework.

Purpose in the Research

The Likert scale will be used to:

- Assess user perception of interface usability, visual hierarchy, and control layout. Evaluate emotional responses and satisfaction levels to in-car interactions, such as infotainment, navigation, and dashboard clarity. Compare UX performance across different car segments to identify patterns and segment-specific preferences.
- A 5-point Likert scale was adopted, ranging from **1 – Strongly Disagree** to **5 – Strongly Agree**, allowing participants to indicate the degree of agreement with statements related to UX factors.

The Likert scale serves as a critical instrument in this research to quantify user perceptions, validate the proposed UX approaches in automobile design, and provide actionable insights for designing user-centered, intuitive, and safe automotive interfaces.

3.4.6 Use of AI Tools for Visual Representation

In addition to traditional analytical tools such as Miro, and Figma, AI-based visualization tools were employed to create conceptual representations of automobile segments designed under the UX-DAD framework. The purpose of this AI integration was to visually validate how each UX factor cluster (Safety, Functionality, Ergonomics, Aesthetics, etc.) could influence the design language and proportion of different automobile types. Prompts were systematically derived from the validated UX-DAD framework parameters to ensure conceptual fidelity. The AI-generated visuals were not treated as final design outputs but as evidence of experiential translation, assisting in communicating the framework's applicability to real-world automotive design.

CHAPTER 4:

IDENTIFYING FACTORS ENHANCING USER EXPERIENCE IN AUTOMOBILE DESIGN

This chapter explores the factors that influence and enrich user experience (UX) in design to create a understand experience that enables designers to surpass user expectations. The discussion focuses on navigating the research journey, starting with defining UXD, then exploring UX factors from the literature such as usability, accessibility, emotional resonance, and aesthetic harmony (Norman, 2013; Rosenfeld et al., 2015). These factors establish the importance of aligning design with user needs and behaviours, showcasing how thoughtful design can create seamless and satisfying interactions. It proceeds to identify automobile-specific UX factors based on prior industry experience and interactions with industry experts. To refine these factors, brainstorming sessions were conducted with design experts from various fields, followed by questionnaires to finalize the UX factors (Wan et al., 2024).

4.1 USER EXPERIENCE DESIGN FACTORS

Peter Morville, a renowned UX expert and author who consults with numerous Fortune 500 companies, highlights seven key factors below figure 14 (Raemy, 2017), as the best framework for understanding user experience.

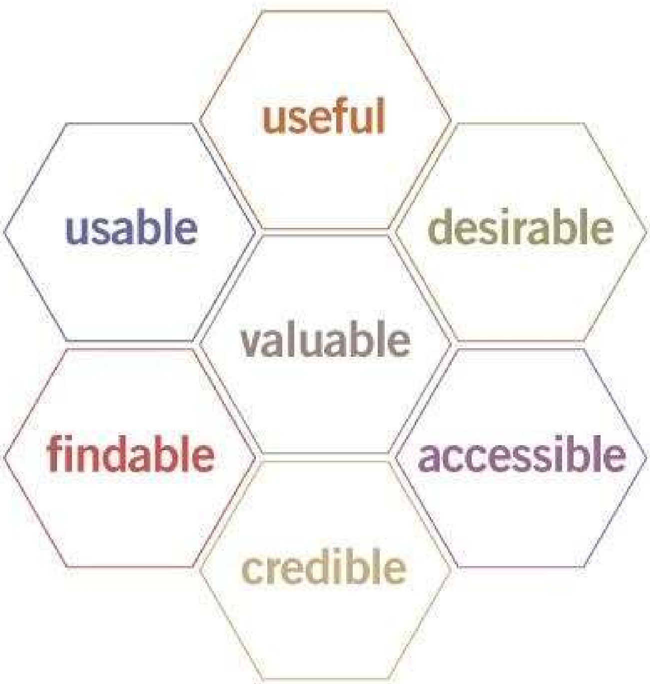

Figure 15: Morville's User Experience Honeycomb (Source: Raemy, 2017)

User Experience Design (UXD) is a multidisciplinary approach that enhances user interactions with both digital and physical products. At its core, UXD prioritizes usability, accessibility, efficiency, and engagement to create seamless experiences. Norman emphasizes that usability plays a crucial role in effective design, highlighting factors such as error prevention, user control, learnability, and cognitive load management, which reduce frustration and enhance efficiency. Similarly, the organization of information and navigation structures significantly impact user experience (Norman, 2013). Rosenfeld in 2015 assert that well-structured data visualization, content prioritization (Rosenfeld et al., 2015), and intuitive navigation are essential for effective UX, while Cooper in 2014 stresses the importance of user goal alignment and interaction design in creating predictable and satisfying interactions (Cooper et al., 2014).

In addition to functionality, aesthetics plays a vital role in user engagement. Norman in 2004 describes the significance of emotional design in shaping user perceptions, explaining that brand alignment, visual appeal, and emotional engagement contribute to long-term satisfaction. Supporting this, Lidwell emphasize the importance of typography, colour schemes, visual hierarchy, and gestalt principles in ensuring clarity and reducing cognitive strain (Lidwell et al., 2010). Personalization and context awareness further enhance UXD by adapting to user needs dynamically. Gothelf and Seiden highlight progressive enhancement, personalization, and user feedback as integral factors that ensure adaptive and intelligent design (Gothelf et al., 2016. The shift toward mobile-first design has also influenced UXD principles, with Wan in 2024 advocating for considerations such as touch target sizes, device compatibility, and mobile-friendliness to create accessible and responsive interfaces (Wan et al., 2024).

Beyond usability and aesthetics, interactive factors foster deeper user engagement. Anderson introduces concepts such as progress indicators, micro interactions, gamification, and hover states, which enhance engagement and encourage user interaction. These factors create a more immersive experience, making digital and physical products not only functional but also enjoyable. As UXD continues to evolve, the integration of these principles across different domains remains essential in delivering user-centered design solutions. By leveraging usability, information architecture, emotional design, and interactive factors, designers can create experiences that prioritize user needs, ensuring intuitive, engaging, and high-quality product interactions.

Additionally, as per literature referred we have found around 97 user experience design factors for digital and physical product, which relates to user experience. Shown in table no 4.

Table 4: User Experience Design factors

User Experience Design factors		
Usability	Progressive enhancement	Onboarding process
Typography	Intuitive interface	Error validation in forms
Data visualization	User goal alignment	Contextual assistance
Colour scheme	Engagement	Affordance
User-cantered design	Indeterminate loading states	Contextual navigation
Speed and performance	Clear labelling	Gestalt principles
Progress indicators	Voice UI design	Minimalism
Error prevention	Interaction design	Help and support
Context awareness	Predictive text input	Offline functionality
Scan ability	Learnability	Visual feedback on actions
Call-to-action buttons	Feedback	Customizable user preferences
Accessibility	Animation and transitions	Visual consistency
Touch target size	Social proof	User flow
Information architecture	Clarity	Visual consistency
Animations for emphasis	Content prioritization	Information overload avoidance
User control	Cognitive load	Modals and pop-ups
Aesthetics	Ease of Use	Touch gestures
Data security and privacy	User task analysis	Form design
Navigation structure	User testing	Dropdowns and menus
Error recovery	Product performance	Heatmaps and analytics
Tooltips	Accessibility for disabilities	User motivation
Personalization	Cross-platform compatibility	Hover effects
Responsiveness	Social integration	Content readability
Hover states	Micro interactions	Localization
Progressive enhancement	Error messages	Contextual menus
Trust signals	Simplicity	Design for trustworthiness
Consistency	Persona development	Notifications
Task completion rate	Usability testing	Exit intent triggers
Compatibility with devices	Consistency in design	Gamification
Visual hierarchy	Emotional design	Sticky factors
User feedback collection	Search functionality	Design for different exp. levels
Brand alignment	Mobile-friendliness	

4.2 USER EXPERIENCE (UX) DESIGN IN THE AUTOMOBILE INDUSTRY

The goal of user experience (UX) design in the automobile industry is to make user-vehicle interactions smooth, simple, and interesting. To improve functionality, appearance, and the overall driving experience, it entails comprehending user requirements, preferences, and expectations. Before designing a new product, automobile designers must consider key factors identified through a comprehensive literature review and expert discussions. As part of Delphi Stage 1, industry experts identified these factors, ensuring their relevance. Key factors shaping Automobile UX design included are shown below in table 3.

A total of 23 automobile design experts were interviewed in person using a structured questionnaire about their experiences in vehicle design. These discussions provided valuable insights into key user experience (UX) factors influencing automobile design. Alongside a thorough literature review, this process helped identify 47 UX design factors that play a crucial role in shaping vehicle usability, aesthetics, functionality, and overall user satisfaction. The findings, summarized in Table 5, highlight the essential factors that designers must consider to create user-friendly and well-designed automobiles. This research ensures a comprehensive understanding of UX in car design, improving future vehicle development. Below figure shows the personal interaction forms.

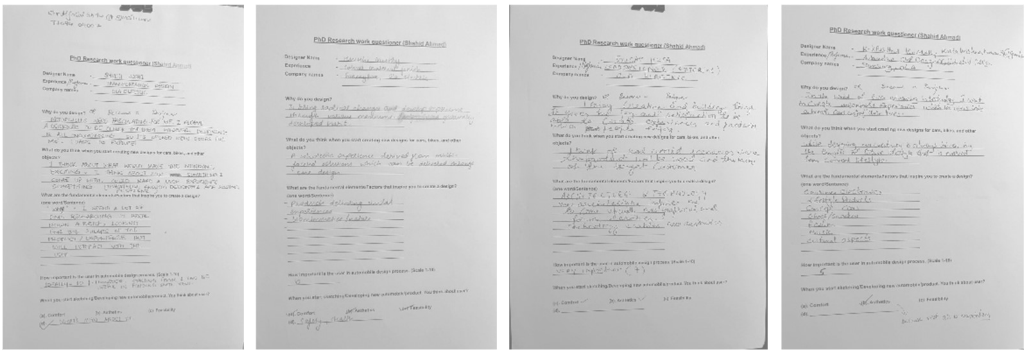

Figure 16: Expert Persona Interview Forms

Table 5: Automobile User experience design factors

UX Design Factors in Automobile Design		
Ease of Use	Performance signals	Sustainability
Safety	Quiet operation	Eco-friendly materials
Self-driving interface	Ergonomics	Reliability & Trust
Hands-free control	Comfortable seating	Aesthetics
Easy servicing	Efficient cabin design	Visual appeal
Accessibility	Interior Layout	Adaptive lighting
Inclusive design	Space Optimization	Safety
Intuitive Controls	User Customization	Protection features

Easy interaction	Personalized settings	Brand Identity
System alerts	Feasibility	Durability & Quality
Responsiveness	Connectivity	Functionality
Quick system reaction	Simplicity	Practical usability
Minimal lag	Driving insights	Navigation
Responsiveness	Clear directions	Cost
Emotion	Usability	Comfort
Uniqueness	Desirability	

4.3 SEGREGATION OF USER EXPERIENCE DESIGN FACTORS

Gestalt principle is used for segregation of factors from which was defined from literature review and design expert's interactions. These factors are segregated as per their proximity, similar family of scope and reference is also taken from automobile design experts segregated automobile UXD factors. This segregation was done through a brainstorming session setup reference shown in below figure 15 with design experts and practitioners from different domains. Product Design, User experience design and Digital strategy domain working in industry with an average of 10+ years.

The design expert team systematically categorized Automobile User Experience (UX) Design Factors by integrating UX design principles from both digital and physical products with automobile-specific UX considerations. This structured approach was guided by the Gestalt principles of proximity and similarity, ensuring that closely related UX factors were grouped based on their functional, visual, and experiential similarities. The categorization aimed to enhance usability, accessibility, and engagement in automobile design, aligning with user expectations and improving the overall driving experience.

The first category, Functionality, ensures practical usability by focusing on form design, error validation, content prioritization, and real-time monitoring. Accessibility enhances inclusivity with features such as system alerts, contextual assistance, and voice UI design to support a diverse range of users. Aesthetics influences the visual appeal and emotional response, incorporating adaptive lighting, typography, color schemes, and animations to enhance user engagement. Responsiveness focuses on minimal lag, quick system reaction, and performance signals, ensuring seamless interactions. Ease of Use plays a crucial role in making vehicle operations intuitive, hands-free, and efficient, with a focus on learnability, simplicity, and task completion rate.

With increasing technological advancements, Connectivity enhances user experience by enabling seamless integration with smart devices, social platforms, real-time data analytics, and over-the-air (OTA) updates. Ergonomics ensures user comfort through efficient cabin design, seating optimization, and intuitive interior layouts, while Safety emphasizes accident prevention with features such as error prevention, trust signals, data security, and driving feedback. User Customization enhances personalization by allowing multimedia integration, personalized settings, and user control over driving preferences. Sustainability has emerged as a key UX factor in automobile design, integrating eco-friendly materials, energy efficiency, reliability, and noise control to meet modern environmental standards. Finally, Navigation focuses on wayfinding and directional clarity, ensuring a structured and user-friendly interface with clear directions, user flow, contextual navigation, and search functionality.

The application of Gestalt principles allowed the expert team to categorize UX factors logically. Proximity was used to group functionally related factors together, ensuring that users perceive connected UX attributes as a unit. Meanwhile, similarity ensured that factors with shared design intent were categorized into corresponding groups, such as Aesthetics and Ergonomics for visual and spatial experience, or Connectivity and Navigation for digital integration and user guidance. By integrating digital UXD principles with automobile-specific user experience considerations, this framework ensures a user-centric approach to vehicle design, addressing the evolving needs of modern drivers and passengers.

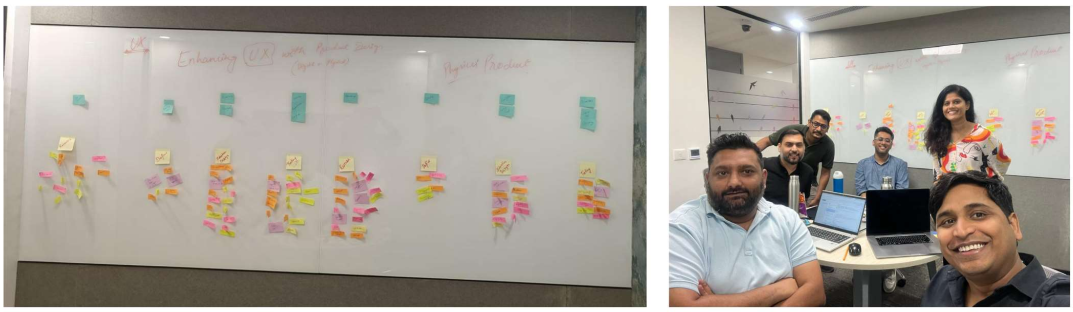

Figure 17: Brainstorming session conducted with design expert

Figure 16, Shows the segregated UXD factors, The Automobile User Experience (UX) Design Factors encompass multiple critical factors that support a smooth, effective, and enjoyable driving experience. These factors are categorized into various dimensions, each addressing specific design principles and user needs.

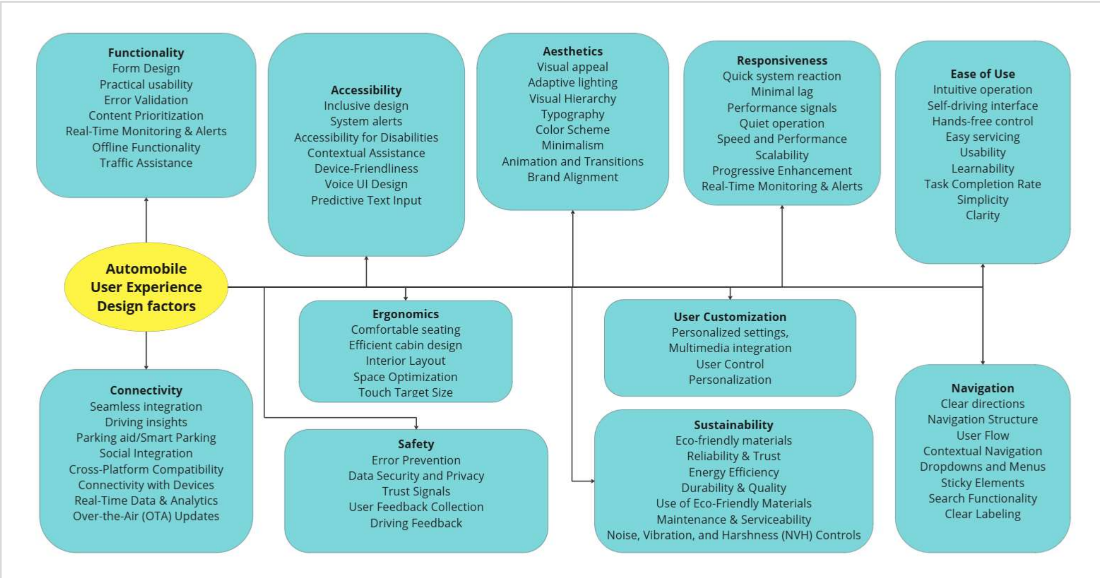

Figure 18: Segregated UXD factors post Gestalts law

Each of these UX design factors collectively enhances the overall automobile experience, ensuring that vehicles are not only functionally efficient but also user-centric, safe, aesthetically pleasing, and technologically advanced.

4.4 FACTORS ENHANCING USER EXPERIENCE IN AUTOMOBILE DESIGN

To finalize these User Experience Design (UXD) factors, the Delphi method was employed, involving 10 design experts who participated in expert survey through google form. Through interactions, the experts provided insights on automobile design user experience factors, ultimately reaching a consensus on the most critical factors. This structured approach ensured that the selected UXD factors were validated based on expert opinions. Additionally, we are attaching screenshots figure 17, from the expert survey, showcasing the validation process and the rigorous assessment conducted to confirm the relevance of these UXD factors in automobile design.

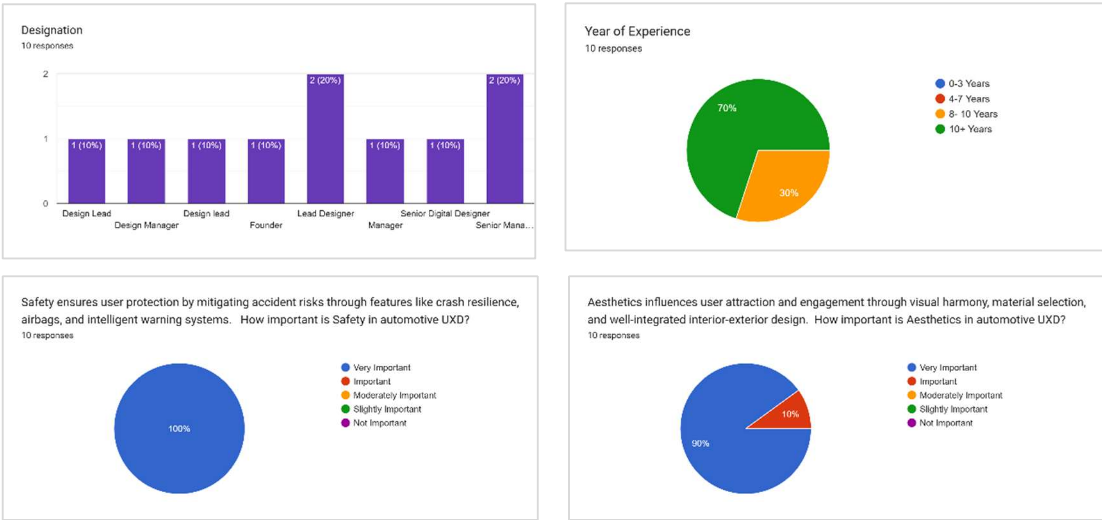

Figure 19: Expert survey responses screenshot

The Delphi Stage 2 outcome for User Experience Design (UXD) factors presents the final validation results based on expert consensus. The evaluation highlights Safety, Functionality, Ease of Use, and Accessibility as the most critical UXD factors, each receiving a 100% agreement score from the panel of design experts. Ergonomics, Aesthetics, Connectivity, and Responsiveness were also highly rated, with 90% consensus, indicating their significant role in shaping user experience in automobile design. Sustainability and Navigation received 80% agreement, reflecting their growing importance in modern vehicle development but indicating slight variability in expert opinions. User Customization, while still relevant, was rated the lowest at 70%, suggesting that while it enhances user experience, it is not as universally prioritized as other factors. These results shown in figure18 reinforce the structured selection of UXD factors, ensuring a data-driven approach to optimizing automobile design.

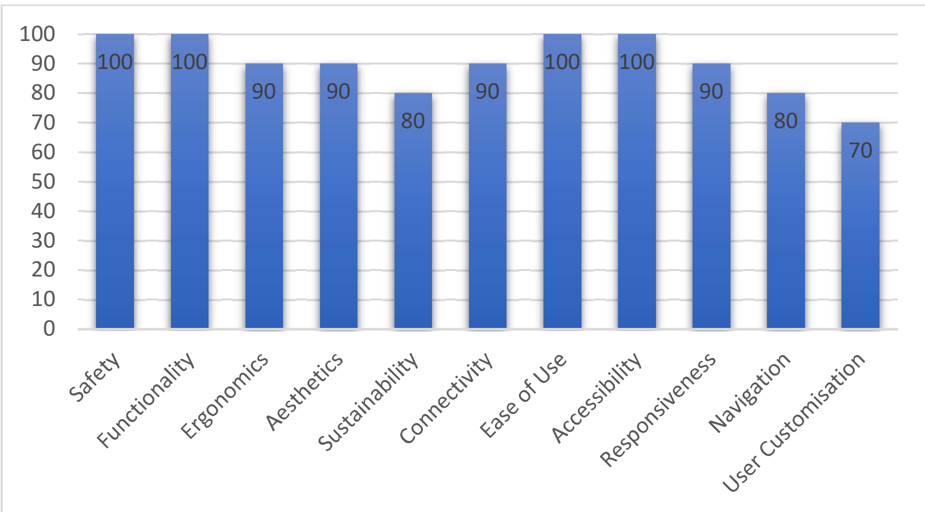

Figure 20: Delphi Stage 2 outcome user experience design factors

Table 4 presents the finalized User Experience Design (UXD) factors that impact automobile design, derived from a comprehensive survey, literature review, and expert validation using the Delphi method. Through iterative discussions with design experts, a consensus threshold of 80% or higher was established for selecting the most critical UXD factors. Factors that met or exceeded this threshold were considered essential for enhancing usability, functionality, and overall user experience in vehicle design. This structured approach ensured that only highly relevant and widely accepted UXD factors were included, reinforcing the framework's accuracy and industry applicability.

Table 6: Final Automobile User Experience Design factors

Sr No.	UX Design Factor
1	Safety
2	Functionality
3	Ergonomics
4	Aesthetics
5	Sustainability
6	Connectivity
7	Ease of Use
8	Accessibility
9	Responsiveness
10	Navigation

CHAPTER 5:

DEVELOPING A FRAMEWORK FOR AUTOMOBILE DESIGN USING UX FACTORS

This chapter is dedicated to the development of a comprehensive framework for automobile design that integrates the various user experience (UX) factors identified in the preceding chapter. The goal of this framework is to provide approach that design industry can follow to ensure that every aspect of a vehicle's design contributes to an exceptional user experience. In the rapidly evolving automobile industry, where technological advancements and shifting consumer expectations are constantly reshaping the landscape, the importance of a cohesive design framework that prioritizes UX cannot be overstated. By drawing on the insights gained from extensive research and analysis, this framework seeks to bridge the gap between isolated UX considerations and a holistic design approach.

Cars are more than just machines; they are extensions of human ambition, tools of convenience, and symbols of personal identity. The experience of a car is multifaceted, encompassing the act of driving, the responsibilities of ownership, the joys of travel, and the comfort of sitting. Each aspect contributes uniquely to how individuals perceive and value their vehicles. This research focuses primarily on intuitive experience; which includes the intellectual, sensorial, and emotional dimensions of experience. The car experience transcends the simple utility of transportation. It is a blend of dynamic and static interactions that cater to individual preferences and needs. By understanding these diverse user experience design factors, Design industries can innovate and design vehicles that resonate deeply with users, creating enduring relationships between people and their cars.

This framework aims to work as a tool for automobile design during product design and development process by applying that we can easily say that the automobile design output vehicle has good user experience. It spans from the physical design of the vehicle to the creation of digital interfaces and the overall brand experience. By offering a structured approach, the framework seeks to ensure that user-centered considerations are integrated at every stage of development, fostering a seamless and cohesive experience across all touchpoints.

5.1 CONCEPTUAL FRAMEWORK- USER EXPERIENCE DRIVEN AUTOMOBILE DESIGN (UX-DAD)

As safety, functionality, ergonomics, aesthetics, sustainability, connectivity, ease of use, accessibility, responsiveness, and navigation are identified as essential factors of user experience design, the overall acceptance and success of a product can significantly improve when these ten factors are effectively addressed. Safety ensures that users feel secure while interacting with the product, while functionality guarantees that the product performs its intended tasks efficiently. Ergonomics enhances comfort and ease during use, whereas aesthetics contributes to the product's visual and emotional appeal. Sustainability ensures environmentally responsible practices, while connectivity allows seamless integration with other systems and devices. Ease of use simplifies interactions, making the product accessible to a broader audience, while accessibility ensures inclusivity for users with diverse needs. Responsiveness improves system feedback and performance, while navigation supports intuitive and efficient interaction. When these ten UXD factors are harmoniously integrated into the design process, the likelihood of the product being perceived positively and delivering an enhanced user experience increases significantly. Consequently, products designed with these factors in mind are more likely to meet user expectations, foster product attachment, and achieve long-term success in the market through the principles of user experience design.

1 When a product undergoes assessment within a structured User Experience (UX) framework, it is evaluated based on predefined UX factors and their corresponding parameters. Each factor—such as safety, functionality, ergonomics, aesthetics, sustainability, connectivity, ease of use, accessibility, responsiveness, and navigation—is assigned a quantitative score reflecting its effectiveness in meeting user expectations.

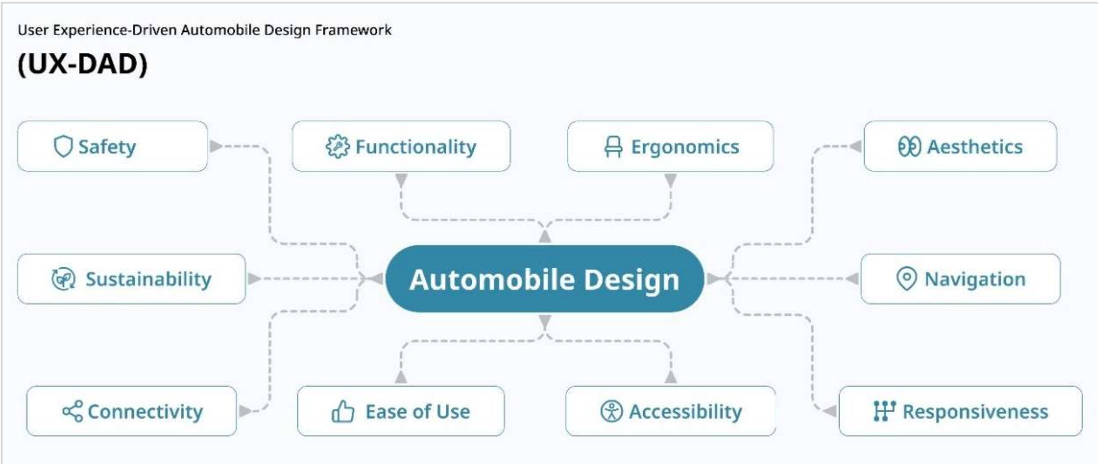

Figure 21: Conceptual UX-DAD Framework

If the evaluated score for any factor falls below the acceptable threshold, it indicates areas that require refinement and optimization to enhance the overall user experience. This process follows an iterative approach, wherein the design and development teams repeatedly refine the product, implementing necessary adjustments to address identified shortcomings. The evaluation cycle is repeated multiple times in a bidirectional manner until the product attains a satisfactory UX score across all key factors.

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By employing this continuous improvement methodology, teams ensure that the final product aligns with user needs, industry standards, and market expectations. This iterative refinement process mitigates usability flaws, enhances user satisfaction, and strengthens product-market fit, ultimately contributing to the long-term success of the product.

5.2 USER EXPERIENCE DESIGN FACTORS AND THEIR PARAMETERS

This chapter focuses on the parameters associated with User Experience Design (UXD) factors, which serve as the foundation for deriving ratings for each parameter. The chapter begins by defining the core UXD factors and identifying the critical parameters that contribute to the evaluation process. To achieve this, an extensive literature review was conducted, drawing insights from previous research studies, industry standards, and academic publications. This review helped in identifying potential parameters relevant to various UXD factors. Following the literature review, the Delphi Method was employed to finalize these parameters through a structured, iterative process. In Stage 1 of the Delphi Method, a panel of experts from various domains within automobile design, including research, styling, 3D modelling, clay modelling, CMF, and visualization, participated in identifying key parameters based on user experience perceptions. The panel consisted of experienced professionals, each possessing five to twenty years of industry experience, ensuring a diverse and informed perspective. Subsequently, in Stage 2 of the Delphi Method, the initially selected parameters underwent a validation process. This stage involved iterative rounds of feedback, where experts re-evaluated and refined the parameters until consensus was reached. The goal was to establish a robust set of parameters that accurately reflect user experience perceptions. Through this systematic approach, the chapter provides a clear methodology for deriving parameter ratings based on UXD factors. The combination of literature review, expert validation, and structured evaluation ensures that the parameters are both relevant and reliable, laying a strong foundation for further analysis and application in automobile design.

5.2.1 SAFETY

Ensuring user safety is paramount in automobile user experience design. From conceptualizing a vehicle to its actual use, safety remains a critical focus. Evaluating a car's safety involves assessing multiple parameters, including crash tests and ground clearance. For instance, drivers often feel more secure operating vehicles with higher ground clearance.

Safety is a fundamental consideration in automobile user experience design, necessitating the evaluation of various critical parameters to ensure comprehensive occupant protection. Crashworthiness assesses a vehicle's ability to protect passengers during collisions by examining structural deformation and injury prevention. Structural Integrity evaluates the vehicle's frame resilience, ensuring it can withstand external forces and maintain cabin safety during crashes (National Highway Traffic Safety Administration [NHTSA], 2023). The integration of Advanced Driver Assistance Systems (ADAS), such as adaptive cruise control and lane-keeping assistance, enhances accident prevention by improving situational awareness and vehicle control. Emergency Response Time measures the speed at which a vehicle's systems detect and respond to potential hazards, directly influencing accident mitigation efforts. Additionally, Visibility and Illumination parameters ensure adequate lighting for optimal driving conditions, reducing night-time and low-visibility accident risks. Airbag Deployment Time is crucial in determining the speed at which airbags inflate upon impact, safeguarding passengers from severe injuries. Braking Distance calculates the distance required for a vehicle to come to a complete stop from a given speed, which is essential for collision avoidance. Furthermore, Global and Bharat NCAP Ratings offer standardized safety performance assessments based on crash tests under varied scenarios as per Ministry of Road Transport and Highways. Lastly, the Number of Airbags installed is assessed to evaluate the distribution and protective effectiveness of airbags in the event of a collision. These parameters collectively contribute to developing safer vehicles, enhancing user confidence across diverse driving environments.

These parameters are integral to comprehensive vehicle safety assessments. For example, the Bharat New Car Assessment Program (Bharat NCAP, 2023) evaluates vehicles based on Adult Occupant Protection, Child Occupant Protection, and Safety Assist Technologies, assigning star ratings to inform consumers about safety performance.

5.2.2 FUNCTIONALITY

Functionality is a fundamental aspect of automobile user experience design, encompassing various parameters that contribute to vehicle performance and user convenience. Storage Efficiency refers to the optimal utilization of available spaces, ensuring that compartments and cargo areas provide maximum practicality without compromising passenger comfort. Climate Control Performance evaluates the efficiency of a vehicle's heating, ventilation, and air conditioning (HVAC) systems in maintaining cabin temperatures across varying external conditions. This assessment includes AC Cooling Time, which measures the time taken to cool the cabin to a comfortable level. Trunk Space Utilization focuses on the accessibility and arrangement of trunk space to accommodate diverse storage needs efficiently (Human Factors and Ergonomics Society. Feature Usability examines the intuitiveness and accessibility of essential features like infotainment, navigation, and driver-assistance controls (Society of Automobile Engineers [SAE], 2023). The presence of Multi-modal Controls, such as touchscreens, voice commands, and physical buttons, enhances operational flexibility and ensures ease of interaction. Cargo Volume, typically measured in litres or cubic feet, quantifies the total storage capacity, a crucial consideration for users needing substantial luggage space Powertrain Efficiency assesses how effectively a vehicle's engine and transmission convert fuel or electrical energy into motion, influencing both performance and emissions . The design and feedback of Button & Knob Usability are critical, ensuring drivers can adjust without distraction. Seating Capacity evaluates the number of passengers a vehicle can accommodate safely and comfortably, impacting design decisions for space allocation. Steering Effort pertains to the force required to turn the steering wheel, with innovations like Dynamic Steering Response (DSR) enhancing manoeuvrability and reducing driver fatigue Finally, the Maintenance Interval reflects the duration or mileage between service appointments, serving as an indicator of the vehicle's reliability and the durability of its components. Together, these parameters provide a holistic perspective on vehicle functionality, ensuring an optimal balance between performance, usability, and comfort.

List of Functionality parameters shown in table below:

- Storage Efficiency
- Climate Control Performance
- Trunk Space Utilization
- AC Cooling Time
- Feature Usability
- Multi-modal Controls
- Cargo volume
- Powertrain Efficiency
- Button & Knob Usability
- Seating capacity
- Steering Effort
- Maintenance interval

5.2.3 ERGONOMICS

Ergonomics in automobile design is a foundational factor in ensuring driver comfort, safety, and overall usability. One of the most important ergonomic factors is seat adjustability, which allows drivers to modify their seat position to suit varying body sizes and preferences. This minimizes discomfort during long drives and helps maintain healthy posture, reducing fatigue (Murata et al., 2023).

Driver fatigue is directly linked to seating ergonomics. Seats with adequate lumbar support and pressure-relieving cushioning reduce strain on the lower back and thighs—areas often prone to discomfort during prolonged travel. Seat cushion pressure distribution is also critical; even weight distribution prevents localized pressure points and promotes healthy circulation, improving long-term comfort (Hobbs & Robinson, 1985).

Reachability of controls significantly influences driver distraction and workload. Controls that are within short arm reach and require minimal hand movement improve safety by helping the driver maintain focus on the road Similarly, armrest adjustability and forearm support reduce muscle fatigue in the shoulders and neck during extended driving (Grandjean, 1987).

Ingress and egress—the ease with which a person enters or exits the vehicle—affects user satisfaction, particularly for the elderly and individuals with limited mobility. Wider door openings and properly positioned seats are key to minimizing physical strain during entry and exit (Lee et al., 2023).

Adequate legroom and thigh support are crucial for long-distance comfort. Rear passengers also benefit from enhanced legroom clearance, which helps alleviate cramping and boosts satisfaction, particularly on extended trips. Steering wheel design, including grip comfort, contour, and texture, plays a key role in long-term usability by reducing hand fatigue and improving handling (Grandjean, 1987; Hsu et al., 2022).

Collectively, these ergonomic parameters ensure a comfortable and safe driving environment. By applying modern ergonomic design principles, automobile manufacturers can enhance user experience, accommodate a broader user base, and improve long-term health and satisfaction for vehicle occupants.

5.2.4 AESTHETICS

In automobile design, aesthetics plays a critical role in shaping consumer perception, emotional connection, and overall satisfaction with a vehicle. One fundamental parameter is **visual harmony**, which refers to the cohesive integration of design factors—such as proportions, lines, and forms—to create a unified, appealing appearance. Achieving visual harmony ensures that all vehicle components complement each other seamlessly, significantly enhancing perceived value and desirability (Ponn & Lindemann, 2023).

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Customer satisfaction scores often reflect the success of a vehicle's aesthetic design. Research has shown a strong correlation between perceived design quality and consumer satisfaction, which in turn influences purchasing decisions and long-term brand loyalty Vehicles that demonstrate superior attention to detail in styling factors tend to generate more positive emotional responses from users.

Panel gap consistency is another vital aesthetic and quality indicator. Uniform gaps between body panels suggest precision in manufacturing and improve perceptions of reliability and craftsmanship. In contrast, inconsistent gaps may raise concerns about quality control and detract from the vehicle's overall visual appeal (Hsu et al., 2023).

Exterior appeal, including the vehicle's shape, styling cues, and finishes, plays a central role in attracting prospective buyers. Features such as distinctive grilles, lighting signatures, and body contours help define a vehicle's brand identity and visual character. These factors communicate core values of the brand, such as innovation, performance, or elegance.

Brand language in design includes repeated motifs, signature factors, material palettes, and visual styling that create a consistent aesthetic across a manufacturer's line-up. Cohesive brand language improves brand recall and builds loyalty by reinforcing a recognizable design DNA (Chitturi et al., 2022).

Interior aesthetics are equally significant, particularly in relation to material finishes. High-quality textures, precise stitching, and refined surface treatments convey luxury and sophistication, enhancing tactile and visual experiences. These factors strongly impact perceived quality and comfort during everyday use.

Dashboard readability is crucial for driver safety and usability. Legible fonts, high contrast, and logical layout all contribute to reducing driver distraction and improving task performance. Research confirms that dashboards designed with cognitive load in mind promote safer driving experiences (Park et al., 2023).

Cabin ambiance, shaped by ambient lighting and colour coordination, contributes to emotional well-being and comfort. Effective use of lighting schemes and harmonious colour palettes fosters a welcoming interior environment that aligns with occupant preferences.

Design awards serve as external validation of aesthetic excellence. Recognition from respected institutions enhances brand prestige and communicates innovation, creativity, and user-centric design.

Providing a wide range of colour options for consumers supports personalization and meets cultural or regional preferences. Offering diverse palettes enhances buyer satisfaction and positions the brand as responsive to evolving market demands.

5.2.5 SUSTAINABILITY

Sustainability has become a fundamental pillar in modern automobile design, reflecting the industry's commitment to environmental responsibility and resource conservation. A core parameter is material composition, which emphasizes the use of recycled plastics, bio-based materials, and natural fibres to reduce reliance on non-renewable resources (Karsan, 2023). Manufacturers are increasingly incorporating sustainable options like hemp fibers, cork, and recycled PET bottles to lower the ecological footprint of interiors.

The carbon footprint of vehicles is another critical concern. Mitigating greenhouse gas emissions throughout the vehicle lifecycle, from raw material extraction to end-of-life is essential to meet global climate goals. Deloitte reports that automakers must reduce

CO_2 emissions by 90% by 2050 to align with international targets. In response, manufacturers are embracing renewable energy, hydrogen-based steelmaking, and electric arc furnaces for low-emission steel production (IndustryWeek, 2022).

End-of-life recycling and circular design are becoming strategic priorities. Designing vehicles for disassembly and material recovery. especially for aluminium, steel, and lithium-ion batteries helps reduce energy use and environmental impact (iPoint-systems, 2022). Closed-loop recycling systems support this shift by repurposing components and avoiding landfill waste.

Sustainable manufacturing processes also contribute to reduced environmental impact. Practices such as water recycling, energy-efficient production lines, and lean manufacturing are now common among sustainability-forward automakers (Volvo Cars, 2022). BMW, for example, uses renewable-powered electric arc furnaces to reduce emissions in steelmaking (IndustryWeek, 2022).

123 **Recyclable material percentage** refers to how much of a vehicle can be recycled at end-of-life. Automakers are raising this by using biodegradable and recyclable materials like coconut fibers, soy-based foams, and plant-based plastics, promoting circularity (Microban, 2022).

Fuel efficiency remains a key performance indicator for sustainability. Lightweight materials- such as carbon fibre-reinforced polymers reduce vehicle mass, enhancing fuel economy and decreasing energy consumption (Microban, 2022). Eco mode driving technologies, which optimize powertrain parameters for efficiency, further reduce emissions during vehicle operation.

Air purification and cabin filtration systems also contribute to sustainable design by improving in-cabin air quality. These systems remove particulates, allergens, and airborne pollutants, supporting user health and aligning with broader ecological goals (Automobile Technology, 2022).

Finally, the integration of biodegradable materials like natural composites aids in reducing environmental impact at the product's end-of-life phase. These materials decompose naturally, reducing waste and supporting circular economy principles (Microban, 2022).

5.2.6 CONNECTIVITY

Connectivity has become a cornerstone of modern automobile design, directly enhancing both driver experience and vehicle functionality. A primary parameter is infotainment latency, which refers to the delay between user input and system response. Low latency improves driver interaction by enabling faster access to entertainment, navigation, and vehicle settings, reducing distraction and improving road safety (Broy et al., 2013).

The **number of connected services** within a vehicle is also essential to overall satisfaction. Integration with Advanced Driver Assistance Systems (ADAS), telematics, smartphones, and environmental sensors contributes to a seamless and informed driving experience (Shladover, 2015). For example, integration with Apple CarPlay and Android Auto allows users to access apps, music, and navigation with ease provided device pairing and compatibility are efficient and reliable.

Over-the-Air (OTA) updates have revolutionized automobile software management by allowing manufacturers to deploy firmware upgrades remotely. These updates improve performance, fix bugs, and enhance cybersecurity without requiring service center visits, thereby extending the vehicle's technological longevity.

Advanced Vehicle-to-Everything (V2X) communication connects cars to infrastructure, other vehicles, and pedestrians in real time, offering benefits like collision avoidance, dynamic route adjustment, and better traffic flow (Lee et al., 2023). These real-time interactions provide predictive navigation and context-aware driving support.

Another critical parameter is Bluetooth pairing time—the speed with which external devices like smartphones connect to the infotainment system. Rapid, reliable Bluetooth pairing facilitates hands-free communication and streaming, enhancing convenience and safety.

Infotainment boot-up speed impacts the time it takes for drivers to access key features like media or maps immediately after starting the vehicle. Shorter boot-up times reduce waiting and support a smoother user experience (Rhee & Choi, 2021). Similarly, navigation update speed reflects the system's ability to rapidly recalculate routes or incorporate real-time traffic conditions, ensuring timely navigation.

Touchscreen gesture recognition- including the system's responsiveness to swipes, taps, and pinches - enhances user interaction by making infotainment systems feel more intuitive and smartphone-like (Lin et al., 2023). This reduces cognitive load and keeps drivers focused on the road.

Finally, OTA update frequency measures how often new software versions, features, or patches are delivered. Regular updates are key to system security and customer satisfaction in an increasingly digital automobile ecosystem (Mahajan et al., 2022).

Together, these connectivity parameters ensure a smart, secure, and user-friendly driving experience, reflecting the convergence of automobile innovation with user-centric design.

5.2.7 EASE OF USE

In automobile design, ease of use is a critical factor ensuring that drivers interact with vehicle systems both efficiently and safely. A key parameter is task completion time, which measures how quickly users can perform essential tasks, such as adjusting climate controls or inputting navigation commands. Reduced task completion time minimizes distractions and enhances user satisfaction.

Dashboard icon recognition plays a vital role in facilitating accurate and rapid identification of vehicle functions. Intuitive iconography that aligns with standardized automobile symbols significantly improves response time while reducing cognitive load (MakoLab, 2023). Voice command accuracy also impacts ease of use. Accurate voice recognition enables drivers to perform tasks hands-free, such as making calls or changing settings, contributing to safer and more seamless interactions (UserTesting, 2022). In tandem, touchscreen lag negatively affects usability. Infotainment systems with responsive, low-latency interfaces provide immediate feedback and reduce driver frustration (LogRocket, 2023).

The number and placement of steering-mounted controls influence usability by allowing drivers to access essential features without taking their hands off the wheel, thus enhancing safety and convenience. A simple and intuitive user interface (UI) supports ease of navigation and reduces learning time. Minimalist designs with clear labelling and consistent layouts help users adapt quickly, especially in new or complex systems (Dans, 2023).

Onboarding and learning curves can be a challenge, but well-designed tutorials and logically placed controls reduce user confusion and enhance the onboarding experience (MakoLab, 2023). In addition, quick access features—such as shortcut buttons for climate control—streamline common tasks and improve usability (UXPin, n.d.). Dashboard readability is also crucial. High-contrast screens, clear typography, and organized layouts help drivers interpret information at a glance, improving safety (LogRocket, 2023).

Reducing driver distraction through simplified layouts and voice-activated features is essential to ensuring focused and safer driving experiences (Dans, 2023). Modern cars also enhance ease of use through quick-start features, including keyless entry and push-button ignition systems, which reduce the time to start the vehicle (MakoLab, 2023). A control familiarity test evaluates how recognizable and intuitively placed the vehicle's controls are. Familiar designs aligned with industry conventions help reduce the need for trial and error and support smoother user interactions.

Together, these parameters form a holistic framework for designing user-friendly automobile interfaces that prioritize safety, efficiency, and convenience.

5.2.8 ACCESSIBILITY

In automobile design, accessibility is essential to creating inclusive vehicles that accommodate individuals with varying physical abilities. One fundamental parameter is door opening width, which directly influences ease of entry and exit. Accessibility standards recommend a minimum clear opening of 32 inches (81.5 cm) to accommodate wheelchair users and those with limited mobility (U.S. Access Board, 2021).

Door handle accessibility is equally critical. Handles should be placed at ergonomic heights and be operable without requiring tight grasping, pinching, or twisting design principles outlined in the ISO 16201:2016 standards for accessible controls (ISO, 2016). Such considerations enhance usability for individuals with reduced dexterity. The seat adjustment force parameter measures the physical effort required to adjust seating positions. According to SAE J4002, the force should not exceed 22.2 Newtons (5 pounds) to accommodate users with limited strength. Electrically adjustable seats further enhance accessibility by simplifying seat repositioning.

Wheelchair loading tests evaluate how easily wheelchairs can be transported and secured in the vehicle. Accessibility-enhancing features like powered ramps and lifts support independent access and comply with inclusive mobility. Voice command success rate is another crucial parameter. High recognition accuracy enables safe, hands-free operation of systems like infotainment and navigation especially beneficial for individuals with limited upper-body mobility (Liu et al., 2021).

High-contrast display usability ensures visibility of dashboard information across lighting conditions. Interfaces with adjustable brightness and high contrast help drivers with visual impairments access information with ease (Ware, 2012). The universal design approach integrates accessibility throughout the vehicle. This includes adjustable pedals, seats, and steering wheels, which allow personalization for individuals of different body types and physical needs. These features are critical for enabling a safe and comfortable driving position.

Handicap-friendly controls such as large, tactile buttons and simplified interfaces ensure that individuals with motor impairments can interact with vehicle systems efficiently (ISO, 2016). Likewise, door and trunk accessibility through power-operated liftgates and hands-free entry systems, minimizes physical effort during loading and unloading, benefiting users with mobility constraints (MakoLab, 2023). Dashboard and display contrast are important for reducing visual strain. The use of large fonts, clear symbols, and adjustable brightness supports drivers with visual limitations.

5.2.9 RESPONSIVENESS

In automobile design, responsiveness is a critical factor that influences performance, safety, and user satisfaction. It reflects how quickly and accurately a vehicle reacts to driver inputs, ensuring a seamless and controlled driving experience.

A primary metric is 0-100 km/h acceleration time, which measures how swiftly a vehicle accelerates from a standstill. High-performance models like the Porsche Taycan Turbo S achieve this in just 2.8 seconds, illustrating cutting-edge responsiveness in electric vehicles (Porsche AG, 2022). This metric is particularly significant in performance-focused segments where acceleration dynamics influence consumer perception. Transmission shift time, often measured in milliseconds, reflects how quickly gear changes occur. Technologies like the Mercedes-AMG SPEEDSHIFT MCT deliver near-instantaneous shifts, enhancing both performance and comfort (Mercedes-Benz, 2021). Smooth transitions support acceleration and fuel efficiency.

Screen touch delay and input lag in infotainment systems directly affect the user experience. Laggy interfaces can frustrate users and increase cognitive load, negatively impacting safety (NHTSA, 2020). Steering input delay is another key parameter. A prompt response to steering inputs enhances vehicle control, particularly in emergency manoeuvres or high-speed driving (Chalmers University of Technology, 2019). Climate control adjustment speed measures how quickly the HVAC system responds to user inputs, which contributes to both comfort and safety by allowing the driver to remain focused on the road (NHTSA, 2020).

Brake response time quantifies the delay between pedal engagement and actual brake activation. Technologies like electronic brake force distribution (EBD) reduce this delay, ensuring swift deceleration in critical situations Gear shift reaction whether in manual or automatic systems, also impacts driving dynamics. Faster, smoother gear transitions improve ride quality and fuel economy (Mercedes-Benz, 2021). Driving mode adaptability evaluates how quickly the car transitions between driving modes (e.g., Sport, Eco, Off-road). Advanced systems can adjust throttle response, suspension, and steering sensitivity in real time, improving vehicle behaviour across varied conditions (Kia Corporation, 2024).

Suspension adaptability ensures real-time adjustments in damping and ride height, promoting ride comfort and handling precision. Models like the Porsche Taycan integrate adaptive suspension systems that respond dynamically to road conditions (Porsche AG, 2022). Brake and acceleration responsiveness determine how instantly the car reacts to pedal inputs. Immediate feedback is essential for safety, especially during emergency braking or overtaking manoeuvres, Voice command recognition has become increasingly accurate with advancements in natural language processing (NLP). Responsive voice assistants reduce manual inputs and support safer, hands-free operation (ARS Technical, 2023).

5.2.10 NAVIGATION

In automobile navigation systems, accuracy and functionality are fundamental to delivering a reliable and user-friendly driving experience. These systems guide drivers through real-time route optimization, congestion avoidance, and improved situational awareness, ensuring both safety and efficiency.

One key parameter is the zoom and pan speed within the map interface. Fast, smooth map adjustments enhance usability by allowing drivers to reorient themselves quickly especially in complex urban environments. Lag in these functions can cause confusion or missed turns. Frequent navigation updates are vital for maintaining accuracy. Over-the-air (OTA) map updates ensure that new roads, infrastructure changes, and traffic patterns are reflected in real-time. Navigation apps like Google Maps and HERE Maps perform multiple updates annually to ensure route precision (Smith & Johnson, 2020).

Traffic update delay refers to the lag between real-world traffic events and their display on the navigation system. Low latency in traffic data is crucial for effective re-routing and congestion avoidance. Real-time traffic data is often sourced through crowd-sourced or telematics-based solutions. The refresh rate of the display determines how often visual factors update per second. A higher refresh rate (60 Hz or above) results in smoother animations and clearer cues, improving both visual perception and driver reaction time. Voice guidance clarity is another critical feature. Effective navigation systems use well-timed, clearly pronounced, and volume-adjustable voice prompts to minimize distraction and allow drivers to keep their eyes on the road (Liu et al., 2021).

GPS accuracy is foundational for precise route tracking. Systems that support multiple satellite constellations—such as GPS, enhance location precision, especially in high-rise or forested environments (Kaplan & Hegarty, 2017). Lane change alerts must be timely to help drivers prepare for upcoming lane shifts or exits. Predictive algorithms help optimize the timing of these prompts, reducing last-minute decisions. Turn-by-turn instruction delay—the time between receiving directions and the required manoeuvres—should be minimized. Directions must be delivered early enough to prevent rushed or missed actions (Wang et al., 2016).

Offline maps are essential for continuous navigation when connectivity is unavailable. Applications such as Google Maps and HERE Maps support downloadable map data, ensuring uninterrupted service in rural or remote locations (Smith & Johnson, 2020). Accurate route calculations are dependent on dynamic factors like live traffic, road restrictions, and historical driving behaviour. Poor routing accuracy can lead to longer travel times and increased user frustration (Kaplan & Hegarty, 2017). Lane guidance offers clear visuals and verbal instructions for navigating complex intersections and multi-lane highways. Systems that provide intuitive visuals and timely prompts help reduce driver uncertainty and improve confidence.

Below table 7 shows parameters for each UXD factors as per above mentioned literature.

Table 7: Identified Parameter

Sr No	UXD Factors	Parameter as per literature and Design Expert interaction
1	**Safety**	Crashworthiness Structural Integrity Advanced Driver Assistance Systems (ADAS) Emergency Response Time Visibility & Illumination Airbag Deployment Time Braking Distance Crash test ratings Number of airbags Ground Clearance
2	**Functionality**	Cargo volume Climate Control Time AC Cooling Time Feature Usability Multi-modal Controls Powertrain Efficiency Button & Knob Usability Seating capacity Steering Effort Maintenance interval Hill Hold
3	**Ergonomics**	Steering adjustability Seat adjustability range Driver Fatigue Reduction Reachability of Controls Ingress & Egress Armrest Comfort and Adjustability Seat Cushion Pressure Distribution Arm Reach to Controls Legroom Clearance Steering Wheel Grip Comfort Thigh support

4	**Aesthetics**	Customer satisfaction score Visual Harmony Customer satisfaction score Panel gap consistency Exterior Appeal Brand language Material Finish Quality Dashboard Readability Cabin Ambience (Lighting & Colours) Design awards won Colour option
5	**Sustainability**	Paint Type Recycled materials Material Composition Carbon Footprint End-of-Life Recycling Sustainable Manufacturing Process Recyclable Material Percentage Fuel Efficiency Eco Mode Driving Performance Impact Air Purification and Cabin Filtration
6	**Connectivity**	Multi-User Bluetooth Connection Management Infotainment latency Number of connected apps Device Pairing & Compatibility Vehicle-to-Everything (V2X) Communication Real-time Navigation & Traffic Alerts Bluetooth Pairing Time Infotainment Boot-up Speed Navigation Update Speed Touchscreen Gesture Recognition OTA update frequency
7	**Ease of Use**	Task completion time Dashboard Icon Recognition Quick Access Features Dashboard Readability Voice command accuracy Touchscreen lag Number of Steering mounted controls Time to Start Vehicle Control Familiarity Test Dashboard Icon Recognition Number of connected services

8	**Accessibility**	Door opening width Door Handle Accessibility Seat height range Wheelchair Loading Test Voice Command Success Rate High-Contrast Display Usability Universal Design Features Seat & Steering Adjustability Handicap-Friendly Controls Door & Trunk Accessibility High-Contrast Display Usability
9	**Responsiveness**	0–100kmph acceleration Transmission shift time Locking n Unlocking time delay Screen Touch Delay Steering Input Delay Climate Control Adjustment Speed Brake Response Time Adaptive Cruise Control Accuracy Touchscreen & Input Lag Suspension Adaptability Brake & Acceleration Responsiveness Voice Command Recognition
10	**Navigation**	Map Zoom & Pan Response Traffic update delay GPS Route Accuracy Lane Change Alerts Timing Turn-by-Turn Delay Offline Map Availability Route Accuracy Screen refresh rate Voice guidance clarity Lane Guidance Clarity Map update frequency

Post literature we have taken these parameters with experts to identify parameters which are important for measuring User experience in automobile. We have conducted an expert survey, this survey represents the UXD factor parameter identification process, conducted with 20 industry experts to validate and finalize essential UXD parameters for automobile design. The Delphi method was used to reach a consensus, ensuring that only the most relevant parameters were considered. The results show high agreement (80% or above) for most parameters, confirming their importance in shaping automobile usability, safety, aesthetics, ergonomics, functionality, sustainability, and connectivity. These findings provide data-driven insights that will

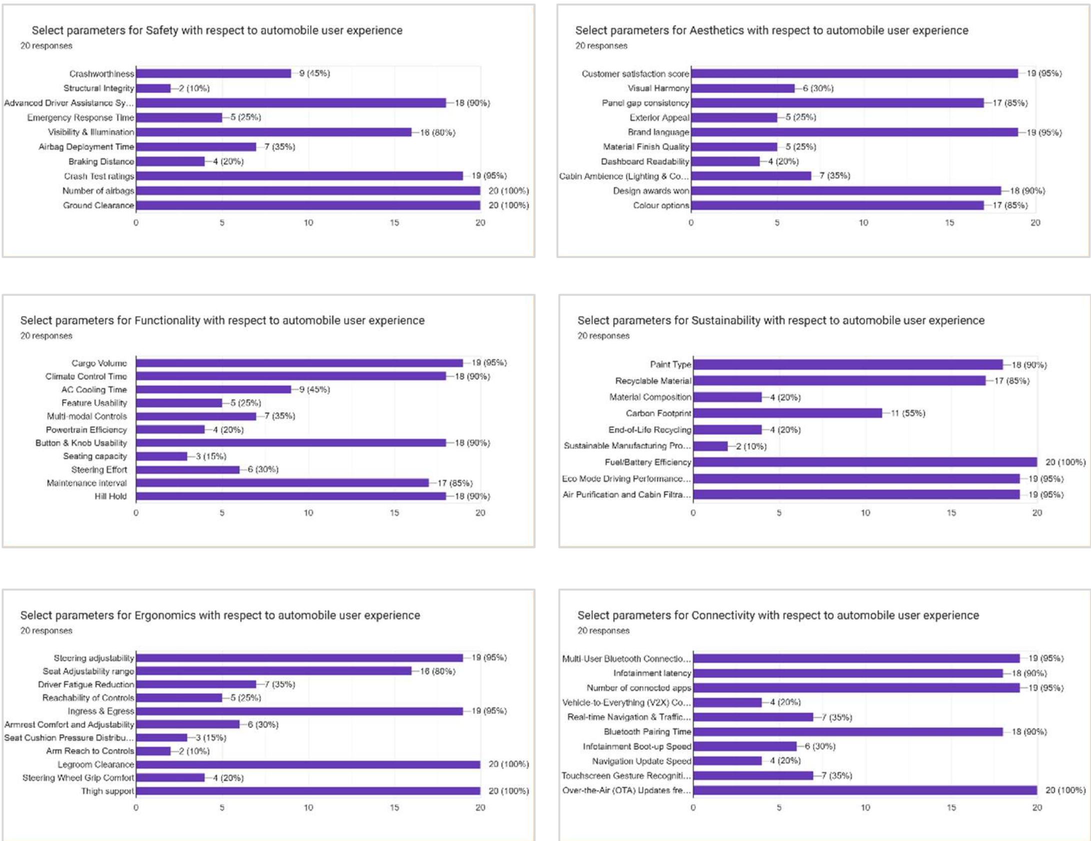


Figure 22: Survey response form UXD factor parameter identification

enhance the user experience in future vehicle designs. Figure 21, represents the survey response.

The final set of identified parameters essential for ensuring a good user experience across various User Experience Design (UXD) factors is presented in Table 8. These parameters were finalized following Delphi method, where expert insights were gathered through a structured survey with industry professionals. This validation process ensured that only critical UXD parameters were selected based on expert consensus. The findings serve as a foundation for enhancing usability, functionality, and overall experience in automobile design.

Table 8: Identified Parameter with their survey percentage

Sr No	UXD Factors	Final parameters after expert validation	Percentage expert survey (%)
1	**Safety**	Advanced Driver Assistance Systems (ADAS) Visibility & Illumination Number of airbags Crash test ratings Ground Clearance	90 80 100 95 100
2	**Functionality**	Cargo volume Climate control time Button & Knob Usability Maintenance interval Hill Hold	95 90 90 85 90
3	**Ergonomics**	Steering adjustability Seat adjustability range Ingress & Egress Legroom Clearance Thigh support	95 80 95 100 100
4	**Aesthetics**	Customer satisfaction score Panel gap consistency Brand language Design awards won Colour option	95 85 95 90 85
5	**Sustainability**	Fuel Efficiency Eco Mode Driving Performance Impact Air Purification and Cabin Filtration Paint Type Recycled materials	100 95 95 90 85
6	**Connectivity**	Multi-User Bluetooth Connection Management Infotainment latency OTA update frequency Bluetooth pairing time Number of connected apps	95 90 100 90 95
7	**Ease of Use**	Task completion time Dashboard Icon Recognition Voice command accuracy Touchscreen lag Number of Steering mounted controls	100 85 80 95 70
8	**Accessibility**	Door opening width Handicap-Friendly Controls Seat height range	100 85 95 95

		Door & Trunk Accessibility High-Contrast Display Usability	95
9	**Responsiveness**	0–100kmph acceleration Screen Touch Delay Transmission shift time Locking n Unlocking time delay Adaptive Cruise Control Accuracy	100 85 95 80 75
10	**Navigation**	Map Zoom & Pan Response Map update frequency Traffic update delay Screen refresh rate Voice guidance clarity	100 95 90 80 80

5.3 GRAPHICAL REPRESENTATION OF FRAMEWORK

The User Experience-Driven Automobile Design (UX-DAD) Framework has been developed with an iterative design and development process in mind. Since automobile design is a complex and evolving field, multiple iterations are often required to align the final product with user expectations and market needs. This framework provides a structured approach to assessing and enhancing user experience (UX) factors in automobile design by integrating key usability, functionality, and performance parameters.

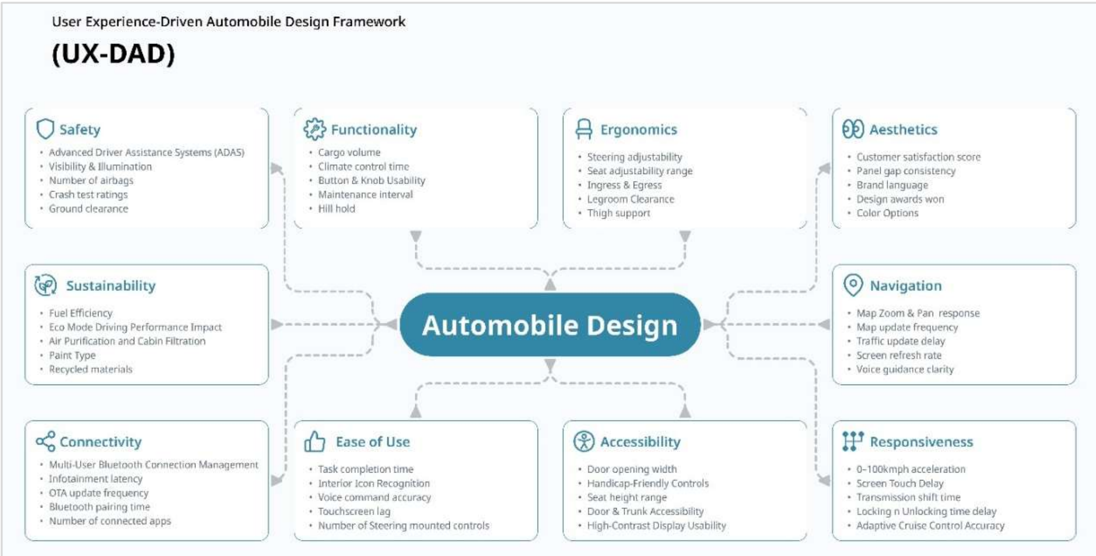


Figure 23: UX-DAD Framework

One of the core principles of this framework is that user experience is highly dependent on personas different users interact with vehicles in unique ways, and their expectations shape the overall UXD evaluation. The UX-DAD framework systematically identifies UXD factors, defines critical parameters, and assesses their validation for an optimal user experience. If any UXD factor is found to be lacking in certain areas, the framework provides a mechanism to analyse and refine design decisions accordingly.

To ensure that every vehicle meets the highest UX standards, the framework incorporates key UXD factors, including:

- **Safety** (ADAS, Visibility, Crash Test Ratings, Number of Airbags)
- **Functionality** (Cargo Volume, Climate Control, Usability of Buttons & Knobs, Maintenance Intervals)
- **Ergonomics** (Steering Adjustability, Ingress & Egress, Thigh Support)
- **Aesthetics** (Brand Language, Colour Options, Panel Gap Consistency)
- **Sustainability** (Fuel Efficiency, Recycled Materials, Air Purification)
- **Connectivity** (Bluetooth Pairing Time, Infotainment Latency, OTA Update Frequency)
- **Ease of Use** (Task Completion Time, Touchscreen Lag, Voice Command Accuracy)
- **Accessibility** (Door Opening Width, High-Contrast Display Usability, Handicap-Friendly Controls)
- **Responsiveness** (Acceleration, Transmission Shift Time, Adaptive Cruise Control)
- **Navigation** (Map Zoom & Pan Response, Traffic Updates, Voice Guidance Clarity)

UXD factors parameters measurement

Since UX is an evolving aspect, the framework supports quick refinements based on real-world user feedback and expert evaluations. If any UXD factor fails to meet the required criteria, the design team can swiftly modify the product, ensuring a user-centric and high-performance automobile. This iterative validation process ensures that vehicles continuously evolve, aligning with user needs and advancing technological innovations.

5.4 Visual Translation of the UX-DAD Framework Using AI Tools

To demonstrate the applied nature of the proposed UX-DAD framework, AI-based image generation tools were utilized to visually translate framework parameters into automobile concepts. Each image represents a synthesis of the ten validated UX design factors mapped through framework logic into tangible design expressions such as form, proportion, surface treatment, and interface integration. The process illustrates how strategic UX parameters can shape early automobile concept directions, thereby bridging user-centered design logic with aesthetic and ergonomic representation. Figures (80–89) shows these conceptual outputs across multiple car segments, generated using controlled prompts derived directly from UX-DAD parameters.

CHAPTER 6:

ANALYSING THE FRAMEWORK WITH DIFFERENT CAR SEGMENTS

This section examines the framework with the assistance of two case studies with car segments such as compact SUVs and Hatchback since both the segments are dominating number sales of last 10+ years in Indian automobile sector as discussed in chapter 2. Case studies are evaluating whether current automobiles designs are compatible with the parameters of factors for good user experience (UX) design. The analyses are organized within 10 parameters that characterize UXD in car design to ensure thorough insight into their influence on users' comfort, happiness, and perception. These parameters are ANALYSED within actual situations to see to what extent they facilitate a smooth and user-friendly experience. Based on this evaluation, User Experience Driven Automobile Design (UX-DAD) analysis is conducted. The research from the case study will aid in the refinement of UX practices in car design so that cars in the future will better suit user needs and preferences.

6.1 PROCEDURE

104 This chapter explains the methodology used in analysing the framework proposed in the study using comparative evaluation of two case studies with varying vehicle segments. The evaluation process includes three main phases: assessment of user experience parameters through the Likert scale, execution of user experience surveys among users and prospective users, and a comparison of results to gauge the effectiveness of the framework. The overall method provides a synergy between quantitative measurements and qualitative data, which collectively allows for a powerful evaluation.

6.1.1. Framework Parameter Assessment Using the Likert Scale

Parameter Identification and Ratings: Parameters defined in chapter 5 will be considered during these case studies.

6.1.1.1 SAFETY:

Safety in automobile design is a crucial UXD factor that encompasses multiple parameters to enhance occupant protection and driving security. One key aspect is Advanced Driver Assistance Systems (ADAS), which function at various levels of autonomy to reduce driver workload and improve accident prevention. 30 These levels range from Level 0, where the driver has full control, to Level 5, where the vehicle operates autonomously. However, for budget-segment vehicles, only Levels 1 to 4 are considered, 23 incorporating features such as lane-keeping assistance, adaptive cruise control, and automated decision-making under certain driving conditions. (NetApp, 2023).

Figure 24: Level of Autonomy_ADAS

Another critical safety factor is Visibility & Illumination, which ensures clear vision for both drivers and passengers under diverse lighting and weather conditions. Proper lighting systems, including headlights, interior illumination, and visibility aids such as mirrors, cameras, and HUDs, contribute to a more intuitive and safer driving experience. Studies by the National Highway Traffic Safety Administration (NHTSA) and Euro NCAP highlight that optimized illumination significantly reduces accident risks, especially in adverse conditions like night driving or fog (NHTSA, 2022; Euro NCAP, 2022).

The Number of Airbags is another essential safety parameter, as airbags function alongside seat belts and sensors to provide impact protection during collisions. The strategic placement and count of airbags directly influence occupant safety (Global NCAP, 2021).

Additionally, Crash Tests play a vital role in evaluating a vehicle's structural integrity and overall crashworthiness. Standardized tests conducted by organizations such as NCAP, Bharat NCAP, and Global NCAP help certify vehicles for compliance with safety regulations and contribute to continuous improvements in automobile safety designs (Global NCAP, 2021; Bharat NCAP, 2023).

Lastly, Ground Clearance is an important factor that affects both vehicle stability and safety. Defined as the vertical distance between the vehicle's lowest structural component and the ground, adequate ground clearance ensures smooth manoeuvrability over different terrains while preventing underbody damage. Research suggests that optimal ground clearance enhances drivability and adaptability, thereby contributing to safer and more comfortable driving experiences (NHTSA, 2022). These combined safety parameters play a pivotal role in shaping the user experience in modern automobile design.

Table 9: Safety Parameters and scale measurement

Sr No	UXD factor	Parameter	Likert Scale measurement
1	Safety	ADAS	Level 0= 1 (Strongly Unsatisfied) Level 1= 2 (Unsatisfied) Level 2= 3 (Neutral) Level 3= 4 (Satisfied) Level 4= 5 (Strong Satisfied)
2		Visibility	Headlight LED + Fog Lamp LED+ NO DRLs = 1 Headlight projector + Fog Lamp LED + DRLs = 2 Headlight LED + Fog Lamp LED + DRLs = 3 (Neutral) Headlight LED + Fog Lamp Projector + DRLs = 4 (Satisfied) Headlight projector + Fog Lamp Projector + DRLs = 5
3		Airbags	0 Airbags= 1 (Strongly Unsatisfied) 1-2 Airbags =2 (Unsatisfied) 2-3 Airbags = 3(Neutral) 3-4 Airbags =4 (Satisfied) 5 Airbags =5 (Strong Satisfied)
4		Crash Test	0 *= 1 (Strongly Unsatisfied) 1-2 * =2 (Unsatisfied) 2-3 * = 3(Neutral) 3-4 *=4 (Satisfied) 5 * =5 (Strong Satisfied)
5		Ground Clearance	>180mm = 1 (Strongly Unsatisfied) 181-190mm= 2 (Unsatisfied) 191-200mm=3 (Neutral) 201-210mm=4 (Satisfied) 211-220mm=5 (Strong Satisfied)

6.1.1.2. FUNCTIONALITY

Functionality in automobile design is a key UXD factor that influences usability, convenience, and overall driving satisfaction. One critical parameter is Cargo Volume, which refers to the total internal storage capacity of a vehicle's cargo compartment, including both visible and hidden spaces such as underfloor storage. Measured in litres or cubic feet, cargo volume is an essential consideration for users who prioritize storage for travel, family needs, or commercial purposes. Studies indicate that cargo space is among the top five factors influencing vehicle purchase decisions, particularly for families and frequent travellers (J.D. Power, 2023).

Another important aspect of functionality is Climate Control Time, which measures how quickly a vehicle's HVAC (Heating, Ventilation, and Air Conditioning) system can achieve the desired cabin temperature. This includes heating, cooling, defogging, and airflow adjustments. Efficient climate control enhances passenger comfort, safety, and energy efficiency, particularly in extreme weather conditions. Systems that are slow to respond may cause discomfort, while overly aggressive climate controls can lead to temperature fluctuations, negatively impacting the user experience.

Figure 25: Cargo volume in car (Maruti Suzuki Brezza)

Button & Knob Usability is another crucial factor that affects driver interaction with vehicle controls. Research by the National Highway Traffic Safety Administration (NHTSA) and Human Factors and Ergonomics Society (HFES) highlights that well-designed buttons and knobs minimize driver distraction, improve accessibility, and enhance overall satisfaction. Poorly designed controls can lead to confusion, frustration, and safety hazards. This study focuses on the usability of climate controls and infotainment system interfaces, considering designs that provide tactile feedback through buttons and knobs, along with visual confirmation indicators to improve task accuracy and efficiency.

Additionally, Maintenance Interval plays a crucial role in vehicle reliability and ownership experience. Defined as the time or distance between scheduled maintenance services recommended by manufacturers, well-structured maintenance schedules enhance vehicle longevity, reduce unexpected breakdowns, and improve driver confidence. Research by the Society of Automobile Engineers (SAE) and J.D. Power Vehicle Dependability Reports underscores the importance of clear and user-friendly maintenance guidelines in ensuring a positive ownership experience.

Finally, the Auto Hold (Hill Hold) Feature Effectiveness is a significant functionality parameter that enhances driving safety and convenience. By preventing vehicle rollback on inclines, reducing driver fatigue, and ensuring smooth acceleration transitions, this feature improves overall drivability. With advancements in automobile technology, sensor-based adaptive hill hold systems and intelligent terrain detection are further refining this functionality, making driving safer and more intuitive for users.

These functionality parameters collectively enhance vehicle usability, convenience, and the overall user experience, ensuring a more practical and efficient driving environment.

Table 10: Functionality Parameters and scale measurement

Sr No	**UXD factor**	**Parameter**	**Likert Scale measurement**
1	Functionality	Cargo volume	250L =1 (Strongly Unsatisfied) 251-300L = 2 (Unsatisfied) 301-360L =3 (Neutral) 361-400L =4 (Satisfied) 401+L = 5 (Strong Satisfied)
2		Climate control time	25+ mins = 1 (Strongly Unsatisfied) 21-25 mins= 2 (Unsatisfied) 16-20 mins= 3 (Neutral) 11-15 mins= 4 (Satisfied) Under 10 min= 5 (Strong Satisfied)
3		Button & Knob Usability	All Touch controls =1(Strongly Unsatisfied) Touch + Visual Feedback=2 (Unsatisfied) Touch+ button+ Visual Feedback= 3 (Neutral) Touch+ Knob+ button= 4 (Satisfied) Touch+ Knob+ button+ Visual Feedback = 5 (Strong Satisfied)
4		Maintenance interval	Every 5000km = 1 (Strongly Unsatisfied) Every 8000km = 2 (Unsatisfied) Every10000 = 3 (Neutral) Every 15000 = 4 (Satisfied) 15000km + = 5 (Strong Satisfied)
5		Hill Hold	Not available in any model = 1 (Strongly Unsatisfied) Available only in top models = 2 (Unsatisfied) Available in a few models = 3 (Neutral) Available in most models = 4 (Satisfied) Available in all models = 5 (Strong Satisfied)

6.1.1.3. ERGONOMICS

Ergonomics in automobile design is a critical UXD factor that significantly impacts driver and passenger comfort, accessibility, and overall usability. One of the key parameters is Steering Adjustability, which allows drivers of various body types to achieve an optimal driving posture, reducing fatigue and enhancing vehicle control. Adjustable steering ensures better visibility and accessibility, leading to a safer and more comfortable driving experience. Future advancements, such as AI-based automatic adjustments and biometric recognition, will further refine this feature, making steering customization more intuitive and personalized (American Honda Motor Co, 2022).

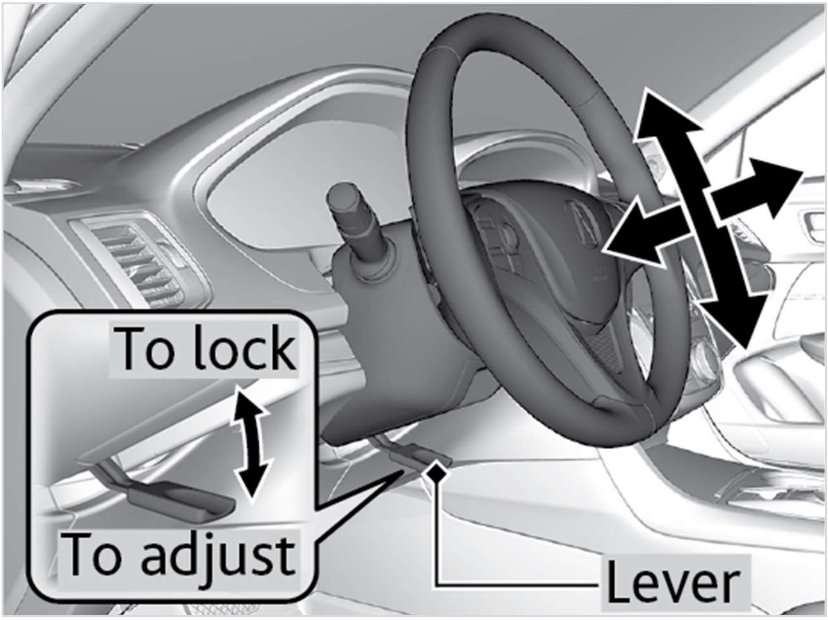


Figure 26: Steering Adjustability

Another essential ergonomic factor is Seat Adjustment Range, which directly affects driving comfort, visibility, and overall convenience. A well-designed seat adjustment system enables drivers to maintain a proper posture, reducing fatigue and enhancing control. Different driving scenarios demand varying seat positions—for instance, higher seating positions improve visibility in city driving and off-road conditions, while lower positions enhance stability for performance driving. Power-adjustable seats are particularly beneficial for elderly drivers and those with mobility impairments. Research suggests that an optimal adjustment range of 4–9 inches (10–23 cm) enhances user comfort and adaptability (Cornell University Ergonomics Study, 2023).

Ingress and Egress, referring to the ease of entering and exiting a vehicle, are crucial considerations for ergonomics. The door opening angle, length, and width significantly influence accessibility, particularly for elderly passengers, individuals with mobility challenges, and families with young children. Vehicles with wide door openings and well-positioned seating enhance overall convenience, reducing strain during ingress and egress.

Legroom Clearance plays a pivotal role in ensuring a comfortable driving and passenger experience. Sufficient legroom allows for relaxed posture, reducing strain on the knees and lower back during long drives (Life, 2018). According to industry research, a legroom clearance of 91–100 cm or more is associated with higher user satisfaction, as it improves comfort and flexibility, particularly for taller passengers.

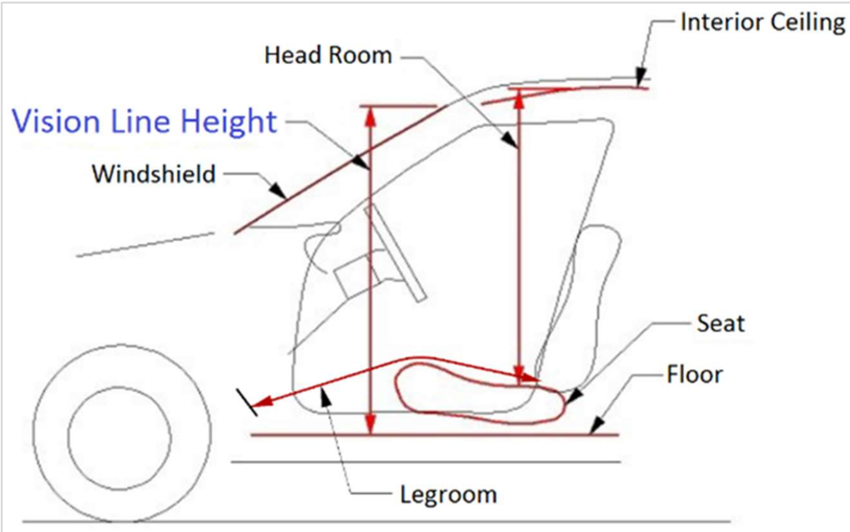


Figure 27: Vehicle clearance/room measurement

Another key ergonomic factor is Thigh Support, which impacts overall seating comfort, weight distribution, and fatigue reduction. Thigh support is measured by the distance from the "H-point," with an optimal mean value of 352.6 mm contributing to better leg support and reduced muscle strain (Romelfanger & Kolich, 2018). Proper thigh support ensures a balanced seating position, particularly for long drives, and enhances the overall ergonomic experience.

These ergonomic parameters collectively contribute to a safer, more accessible, and more comfortable driving experience. By integrating advanced ergonomic features and adaptive design solutions, automobile manufacturers can significantly enhance vehicle usability and user satisfaction.

All Measurement are considered with 95% Average Indian male with Height range of 5.8to5.10 feet or 172.72 to 177cm, and Female with Height range of 5to5.4 feet or 152.4 to 162.5cm.

Table 11: Ergonomics Parameters and scale measurement

Sr No	UXD factor	Parameter	Likert Scale measurement
1	Ergonomics	Steering adjustability	No Adjustment= 1 (Strongly Unsatisfied) Tilt = 2 (Unsatisfied) Telescopic= 3 (Neutral) Manual (Tilt + Telescopic) = 4 (Satisfied) Electronic (Tilt+ Telescopic) = 5 (Strong Satisfied)
2		Seat adjustability range (inches/cm for height/lumbar).	No seat adjustment range= 1 (Strongly Unsatisfied) 4-5 inches= 2 (Unsatisfied) 5-6 inches= 3 (Neutral) 6-7 inches= 4 (Satisfied) 7+ inches= 5 (Strong Satisfied)
3		Ingress & Egress	Smallest=1 (Strongly Unsatisfied) Small=2 (Unsatisfied) Medium=3 (Neutral) Big =4 (Satisfied) Biggest=5 (Strong Satisfied)
4		Legroom Clearance	70= 1 (Strongly Unsatisfied) 71-80 =2 (Unsatisfied) 81-90= 3 (Neutral) 91-100= 4 (Satisfied) 100cm+= 5 (Strong Satisfied)
5		Thigh support	270mm=1 (Strongly Unsatisfied) 271-290=2 (Unsatisfied) 291-310=(Neutral) 311-331= 4 (Satisfied) 331+= 5 (Strong Satisfied)

6.1.1.4. AESTHETICS

Aesthetics significantly influence user perception, emotional engagement, and brand loyalty in automobile design. Key parameters in evaluating automobile aesthetics include:

- **Customer Satisfaction Score (CSS):** This metric reflects user sentiment regarding a vehicle's visual appeal, design coherence, and overall aesthetic experience. Higher CSS values indicate positive emotional responses, reinforcing brand value and consumer trust. Research indicates that aesthetics can influence up to 60% of car buying decisions in certain segments (Burnap et al., 2019).
- **Panel Gap Consistency:** This assesses the precision of fit and finish in vehicle assembly. Consistent panel gaps contribute to perceived quality and premium

craftsmanship, while inconsistent gaps can detract from a vehicle's aesthetic appeal (Duraiswamy et al., 2018).

- **Brand Language:** Encompassing visual factors that distinguish a brand, brand language includes:
  - *Brand Identity:* Visual components that differentiate the brand.
  - *Brand Voice:* The brand's personality in communication.
  - *Design Language:* A consistent visual framework across all brand touchpoints.
- A cohesive brand language strengthens user connection by aligning design factors with consumer expectations, enhancing brand recognition and desirability (Raji et al., 2019).
- **Recognition through Design Awards:** Receiving prestigious design awards is associated with superior craftsmanship, innovation, and artistic excellence, reinforcing a brand's credibility and commitment to aesthetic refinement.
- **Colour Options:** Offering a diverse range of colour choices allows consumers to personalize their vehicles, aligning with individual styles and preferences. colour availability significantly affects consumer decision-making, with a broader palette enhancing user satisfaction and engagement (Labrecque et al., 2013).

These aesthetic parameters collectively enhance a vehicle's desirability, market appeal, and emotional connection with consumers. By upholding high standards in design quality, brand identity, and personalization, automobile manufacturers can elevate the user experience and foster brand loyalty.

Table 12: Aesthetics Parameters and scale measurement

Sr No	UXD factor	Parameter	**Likert Scale measurement**
1	Aesthetics	Customer satisfaction score (survey rating out of 5).	1= 1 (Strongly Unsatisfied) 2= 2 (Unsatisfied) 3= 3 (Neutral) 4= 4 (Satisfied) 5+= 5 (Strong Satisfied)
2		Panel gap consistency (mm variance between body panels).	5 + mismatch= 1 (Strongly Unsatisfied) 4 + mismatch=2 (Unsatisfied) 3 + mismatch= 3(Neutral) 2 + mismatch=4 (Satisfied) 1 mismatch= 5 (Strong Satisfied)
3		Brand language	Brand Voice= 1(Strongly Unsatisfied) Brand Voice+ Identity= 2 (Unsatisfied) Brand Voice+ Design language= 3 (Neutral)

40

			Brand Identity+ Design language=4 (Satisfied) Brand Voice+ Identity+ Design language=5 (Strong Satisfied)
4		Design awards won (number of industry recognitions).	1= 1 (Strongly Unsatisfied) 2= 2 (Unsatisfied) 3= 3 (Neutral) 4= 4 (Satisfied) 5+= +5 (Strong Satisfied)
5		Colour Options	0-4= 1 (Strongly Unsatisfied) 5-6= 2 (Unsatisfied) 7-8= 3 (Neutral) 9-10= 4 (Satisfied) 10+= +5 (Strong Satisfied)

6.1.1.5. SUSTAINABILITY

Sustainability has become a crucial factor in modern automobile design, influencing environmental impact, resource efficiency, and user perception. Key parameters contributing to sustainability include:

Fuel Efficiency: Measures a vehicle's ability to optimize fuel consumption. Higher fuel efficiency reduces emissions and offers cost savings to users, enhancing desirability in an eco-conscious market. For instance, the fuel efficiency for new 2022 models is estimated at 26.4 miles per gallon (mpg), up 35.4% from 19.5 mpg in 2002 (LendingTree, 2022).

Performance Modes: Allow users to adapt their driving style based on different needs. Vehicles offering multiple modes, such as City, Eco, Sport, and Off-road, provide a balance between fuel conservation and driving dynamics, catering to diverse user requirements.

Air Purification and Cabin Filtration: Improve in-cabin air quality by reducing pollutants. Advanced filtration technologies enhance user satisfaction by providing a healthier driving environment. For example, Hummel emphasizes filtration as key to sustainability in the automobile industry (Mann Hummel, 2023).

Paint Type: Eco-friendly water-based paints minimize environmental impact while maintaining visual appeal and durability. Water-based paints are considered more sustainable due to their lower volatile organic compound (VOC) emissions.

Recycled Materials: Integration of recycled content in vehicle manufacturing contributes to waste reduction and resource conservation. The proposed End-of-Life

Vehicle Regulation (ELVR) sets a 25% target for recycled plastic content in new vehicles, with at least 25% of this coming from end-of-life vehicle plastics (ECOS, 2023).

By integrating these sustainability-focused parameters, automobile manufacturers can enhance user satisfaction while reducing environmental impact. Fuel-efficient engines, adaptable performance modes, clean air filtration, sustainable paint choices, and recycled materials collectively contribute to a more responsible and eco-conscious driving experience.

Table 13: Sustainability Parameters and scale measurement

Sr No	**UXD factor**	**Parameter**	**Likert Scale measurement**
1	Sustainability	Fuel Efficiency	10 = 1 (Strongly Unsatisfied) 11-14= 2 (Unsatisfied) 15-18= 3 (Neutral) 19-23= 4 (Satisfied) 23+= 5 (Strong Satisfied)
2		Eco Mode Driving Performance Impact	City= 1 (Strongly Unsatisfied) Eco+ City= 2 (Unsatisfied) City, Eco, Sports = 3 (Neutral) City, Eco, Sports, Performance = 4 (Satisfied) City, Eco, Sports, Performance, Off road = +5 (Strong Satisfied)
3		Air Purification and Cabin Filtration	Not available = 1 (Strongly Unsatisfied) Cabin Filter = 2 (Unsatisfied) Air filter = 3 (Neutral) Cabin and Air Filter = 4 (Satisfied) Cabin and Air Filter and More 5 (Strong Satisfied)
4		Paint Type	Simple + Oil-Based Paint = 1 (Strongly Unsatisfied) Simple + Water-Based = 2 (Unsatisfied) Simple + Metallic Paint = 3 (Neutral) Oil-Based + Metallic Paint = 4 (Satisfied) Water-Based + Pearl Paint = 5 (Strong Satisfied)
5		Recycled materials	5% = 1 (Strongly Unsatisfied) 6-10 % = 2 (Unsatisfied) 11-15% = 3 (Neutral) 16-20% = 4 (Satisfied) 21+ = 5 (Strong Satisfied)

6.1.1.6. CONNECTIVITY

Connectivity has become a fundamental aspect of modern automobile design, significantly enhancing user convenience, in-car entertainment, and seamless digital integration. Key parameters influencing connectivity include:

Multi-User Bluetooth Connection Management: This parameter determines the number of users that can simultaneously connect to the vehicle's Bluetooth system. While specific studies on optimal user numbers are limited, effective multi-user management allows multiple passengers to connect and switch between devices effortlessly, enhancing user satisfaction (Ratazzi et al., 2014).

Infotainment Latency: Measures the response time of the vehicle's infotainment system. Reduced lag ensures a smoother user experience. Studies have shown that delays in infotainment systems can impair driver reaction times more than alcohol consumption, highlighting the importance of minimizing latency (Tudose, 2020).

Over-the-Air (OTA) Update Frequency: Refers to how often vehicles receive software enhancements and security patches remotely. Regular OTA updates ensure that infotainment systems, navigation, and safety features remain current and optimized. The global automobile OTA market is projected to grow significantly, indicating the increasing emphasis on frequent updates (Transparency Market Research, 2023).

Bluetooth Pairing Time: Affects how quickly a device can establish a connection with the vehicle. Faster pairing times improve convenience and reduce driver distraction. Efforts to reduce Bluetooth connection times have shown improvements, with pairing times decreasing from 30 to 20 seconds for streaming music and from 22 to 15 seconds for making calls (Teledyne LeCroy, n.d.).

Number of Connected Apps: Determines the level of digital integration within the vehicle. Infotainment systems supporting a broad range of apps enhance the user experience by offering services such as navigation, streaming, and smart assistant functionalities. The in-vehicle apps market is projected to reach USD 55.9 billion in 2023, reflecting the growing demand for connected applications (Cognitive Market Research, 2022).

By optimizing these connectivity parameters, automobile manufacturers can enhance the digital experience within vehicles, offering seamless, responsive, and user-friendly interactions. Improved Bluetooth connectivity, low infotainment latency, frequent OTA updates, fast pairing times, and robust app integration collectively contribute to a more connected and enjoyable driving experience.

Table 14: Connectivity Parameters and scale measurement

Sr No	UXD factor	Parameter	Likert Scale measurement
1	Connectivity	Multi-User Bluetooth Connection Management	1user = 1 (Strongly Unsatisfied) 2-3 = 2 (Unsatisfied) 4-5 = 3 (Neutral) 6-7 = 4 (Satisfied) 8+ = 5 (Strong Satisfied)
2		Infotainment latency (milliseconds for touch response). Mobile top car sound output time delay	5 sec = 1 (Strongly Unsatisfied) 4 Sec= 2 (Unsatisfied) 3 Sec = 3 (Neutral) 2 Sec= 4 (Satisfied) 1 Sec= 5 (Strong Satisfied)
3		OTA update frequency (number per year).	0 one time = 1 (Strongly Unsatisfied) 1 update a year = 2 (Unsatisfied) 2 update a year= 3 (Neutral) 3 update a year = 4 (Satisfied) 4+ update a year= 5 (Strong Satisfied)
4		Bluetooth pairing time (seconds).	10+ sec = 1 (Strongly Unsatisfied) 10 Sec= 2 (Unsatisfied) 7 Sec = 3 (Neutral) 5 Sec= 4 (Satisfied) 3 Sec= 5 (Strong Satisfied)
5		Number of connected services (e.g., apps, integrations).	4 Apps = 1 (Strongly Unsatisfied) 6 App= 2 (Unsatisfied) 8 App = 3 (Neutral) 10 App= 4 (Satisfied) 10+ App= 5 (Strong Satisfied)

6.1.1.7. EASE OF USE

Ease of use is a critical factor in automobile user experience design, enhancing driver interaction, reducing cognitive load, and improving overall satisfaction. Key parameters influencing ease of use include:

Task Completion Time: This metric assesses the duration required for drivers to complete common infotainment tasks, such as programming navigation or tuning the radio. Research indicates that older drivers (ages 55-75) took their eyes off the road for more than eight seconds longer than younger drivers (ages 21-36) when performing these tasks, highlighting the importance of minimizing task completion times to reduce distractions and enhance safety.

Dashboard Icon Recognition: Effective icon design is essential for intuitive interaction with vehicle interfaces. Icons should be simple, modern, and friendly, reduced to their minimal form to express essential characteristics, thereby facilitating quick recognition and reducing driver distraction.

31 **Voice Command Accuracy:** Accurate voice recognition systems enable drivers to control various functions hands-free, thereby minimizing manual interactions and enhancing safety. However, studies have shown that it can take up to 27 seconds for drivers to regain full attention after issuing voice commands, underscoring the need for systems that not only recognize commands accurately but also process them swiftly to reduce cognitive distraction.

Touchscreen Lag: The responsiveness of touchscreens is vital for seamless user interaction. High latency in touchscreen systems can lead to driver frustration and increased distraction, emphasizing the need for immediate feedback and smooth operation to maintain safety and user satisfaction (Auto Express, 2024).

Number of Steering-Mounted Controls: Integrating multiple controls on the steering
31 wheel allows drivers to operate various functions without removing their hands from the wheel, thereby enhancing safety and convenience. While specific optimal numbers may vary, a greater number of well-organized steering-mounted controls can improve usability by providing easy access to essential functions

By optimizing these ease-of-use parameters, automobile manufacturers can create a more intuitive and efficient driving experience. Faster infotainment response times, clear iconography, accurate voice commands, lag-free touchscreens, and well-placed steering controls collectively contribute to a user-friendly and seamless vehicle interface.

Table 15: Ease of Use Parameters and scale measurement

Sr No	UXD factor	Parameter	Likert Scale measurement
1		Task completion time (seconds for common infotainment tasks).	20+ Sec = 1 (Strongly Unsatisfied) 20 Sec= 2 (Unsatisfied) 15 Sec= 3 (Neutral) 10 Sec = 4 (Satisfied) 8 sec= 5 (Strong Satisfied)
2		Dashboard Icon Recognition	No consistency = 1 (Strongly Unsatisfied) Line+ Filled = 2 (Unsatisfied) Line+ Filled + Visibility = 3 (Neutral)

			Line+ Visibility = 4 (Satisfied) Line +Filled+ Design consistency +Visibility = 5 (Strong Satisfied)
3	Ease of Use	Voice command accuracy (percentage of correct responses).	10%= 1 (Strongly Unsatisfied) 30%= 2 (Unsatisfied) 50%c= 3 (Neutral) 80% = 4 (Satisfied) 100%= 5 (Strong Satisfied)
4		Touchscreen lag (milliseconds).	3+ sec = 1 (Strongly Unsatisfied) 3 Sec= 2 (Unsatisfied) 2 Sec = 3 (Neutral) 1 Sec= 4 (Satisfied) 0 Sec= 5 (Strong Satisfied)
5		Number of Steering mounted controls	0 = 1 (Strongly Unsatisfied) 1-4 Sec= 2 (Unsatisfied) 5-8 = 3 (Neutral) 9-12= 4 (Satisfied) 12+ = 5 (Strong Satisfied)

6.1.1.8. ACCESSIBILITY

Accessibility is a critical aspect of automobile UX design, ensuring ease of entry, operation, and interaction for all users, including individuals with mobility challenges. One key parameter influencing accessibility is Door Opening Width, which determines how easily passengers can enter and exit a vehicle. A wider door opening (46-51 inches / 1168-1295 mm) enhances accessibility, particularly for families, elderly passengers, and individuals with disabilities. Narrower door openings can make entry and exit difficult, leading to user dissatisfaction.

Another crucial factor is Handicap-Friendly Controls, which improve inclusivity by offering features such as push-pull brake/accelerator and hand-operated throttles. Vehicles that integrate these controls across all models provide a higher level of accessibility, ensuring that individuals with physical impairments can operate the vehicle safely and comfortably. Limited availability of such controls reduces overall user satisfaction and restricts mobility options.

Door Handle Accessibility plays a significant role in ease of use, particularly for individuals with limited mobility or shorter reach. Ergonomically positioned door handles, designed at an optimal height and angle, improve usability by allowing effortless access. Handles that require stretching or awkward hand positioning can cause frustration and discomfort, impacting the overall user experience (Vive Health, n.d.).

Similarly, Trunk Gate Handle Accessibility affects the ease of opening and closing the trunk. An ergonomic and easily reachable handle ensures convenience, particularly for users carrying heavy loads or those with limited mobility. Poorly positioned trunk handles may require excessive stretching, making the feature less user-friendly.

Lastly, High-Contrast Display Usability enhances the visibility and readability of digital screens, especially in varying lighting conditions. An excellent high-contrast display, capable of adjusting brightness automatically, ensures optimal legibility even in bright sunlight. Poor contrast or slow auto-brightness adjustments can make information difficult to read, reducing the effectiveness of infotainment and navigation systems.

By optimizing these accessibility parameters, automobile manufacturers can improve vehicle usability for a broader range of users. Wider door openings, inclusive handicap-friendly controls, well-positioned door and trunk handles, and high-contrast displays collectively contribute to a more comfortable, convenient, and user-friendly driving experience.

Table 16: Accessibility Parameters and scale measurement

Sr No	UXD factor	Parameter	Likert Scale measurement
1	Accessibility	Door opening width (inches/cm).	Very Narrow (Below 32 inches / <815 mm) = 1 (Strongly Unsatisfied) Narrow (32-34 inches / 815-864 mm) = 2 (Unsatisfied) Moderate (35-39 inches / 865-990 mm) = 3 (Neutral) Wide (40-45 inches / 991-1143 mm) = 4 (Satisfied) Very Wide (46-51 inches / 1168-1295 mm) = 5 (Strong Satisfied)
2		Handicap-Friendly Controls	Not available in any model = 1 (Strongly Unsatisfied) Available only in top models = 2 (Unsatisfied) Available in a few models = 3 (Neutral) Available in most models = 4 (Satisfied) Available in all models = 5 (Strong Satisfied)
3		Door handle Accessibility	Difficult to Reach = 1 (Strongly Unsatisfied) Slightly Inconvenient = 2 (Unsatisfied) Neutral Position = 3 (Neutral) Comfortable Position = 4 (Satisfied)

			Ergonomic & Easily Reachable = 5 (Strong Satisfied)
4		Trunk gate handle Accessibility	Difficult to Reach = 1 (Strongly Unsatisfied) Slightly Inconvenient = 2 (Unsatisfied) Neutral Position = 3 (Neutral) Comfortable Position = 4 (Satisfied) Ergonomic & Easily Reachable = 5 (Strong Satisfied)
5		High-Contrast Display Usability	Very Poor Visibility= 1 (Strongly Unsatisfied) Poor Visibility = 2 (Unsatisfied) Acceptable Visibility = 3 (Neutral) Good Visibility = 4 (Satisfied) Excellent Visibility = 5 (Strong Satisfied)

6.1.1.9. RESPONSIVENESS

Responsiveness is a crucial UXD factor in automobile design, influencing the vehicle's performance, user interaction efficiency, and real-time system feedback. One of the key parameters is 0–100 km/h Acceleration, which measures how quickly a vehicle can reach high speeds. Faster acceleration enhances driving dynamics, with a 0-4 second acceleration time being the most desirable. Vehicles that take 16 seconds or more to reach 100 km/h are considered sluggish, negatively impacting user satisfaction, particularly in high-performance or highway-driving scenarios.

Another important aspect is Screen Touch Delay, which affects the responsiveness of in-car digital interfaces. A zero-second delay ensures a seamless infotainment experience, allowing users to interact with touchscreens without noticeable lag. Slow touch response times can lead to frustration, misinputs, and inefficient interaction, diminishing the overall usability of the infotainment system.

Transmission Shift Performance plays a significant role in driving comfort and responsiveness. A very smooth transmission with minimal sound provides a refined and satisfying driving experience, whereas noticeable delays and excessive transmission noise reduce perceived quality and performance. Smooth gear transitions ensure better control, fuel efficiency, and an engaging drive.

Locking and Unlocking Time Delay impacts the convenience and security of vehicle access. A zero-click unlocking system, which provides instant access upon detection, is the most satisfying experience for users. Delays requiring multiple attempts to lock or unlock a vehicle can cause frustration and security concerns.

Lastly, Adaptive Cruise Control Accuracy determines how effectively a vehicle maintains speed and adapts to surrounding traffic. Highly accurate adaptive cruise control ensures smooth acceleration and deceleration, reducing driver effort while maintaining safety. Systems with significant delays may struggle to adjust to traffic conditions, leading to an inconsistent or uncomfortable driving experience (MDPI, 2021).

By optimizing these responsiveness parameters, automobile manufacturers can enhance driving performance, infotainment efficiency, and real-time system interactions. Faster acceleration, responsive touchscreens, smooth transmission shifts, instant locking/unlocking, and precise adaptive cruise control collectively contribute to a more seamless and dynamic driving experience.

Table 17: Responsiveness Parameters and scale measurement

Sr No	UXD factor	Parameter	Likert Scale measurement
1	Responsiveness	0–100kmph acceleration (seconds).	16+ Sec = 1 (Strongly Unsatisfied) 13-16 Sec = 2 (Unsatisfied) 9-12 Sec = 3 (Neutral) 5-8 Sec = 4 (Satisfied) 0-4Sec = 5 (Strong Satisfied)
2		Screen Touch Delay	3+ sec = 1 (Strongly Unsatisfied) 3 Sec= 2 (Unsatisfied) 2 Sec = 3 (Neutral) 1 Sec= 4 (Satisfied) 0 Sec= 5 (Strong Satisfied)
3		Transmission shift performance	Delay+ Sound = 1 (Strongly Unsatisfied) Delay = 2 (Unsatisfied) Normal = 3 (Neutral) Smooth +Sound = 4 (Satisfied) Very Smooth+ Sound = 5 (Strong Satisfied)
4		Locking n Unlocking time delay (No of clicks)	4+ = 1 (Strongly Unsatisfied) 3-4 = 2 (Unsatisfied) 2-3 = 3 (Neutral) 1-2 = 4 (Satisfied) 0= 5 (Strong Satisfied)
5		Adaptive Cruise Control Accuracy	Significant Delay = 1 (Strongly Unsatisfied) Slight Delay = 2 (Unsatisfied) Normal = 3 (Neutral) Fairly Accurate= 4 (Satisfied) Highly Accurate = 5 (Strong Satisfied)

9

6.1.1.10. NAVIGATION

Navigation plays a critical role in enhancing the driving experience by providing accurate, real-time guidance and improving situational awareness. One of the key parameters affecting navigation usability is Map Zoom & Pan Response, which determines how quickly users can interact with the digital map. A zero-second response time ensures a smooth and efficient user experience, allowing drivers to zoom in and out or pan the map effortlessly. Lag in response time can lead to frustration, especially when making quick route adjustments while driving.

Another essential factor is Map Update Frequency, which ensures that navigation data remains current with new roads, landmarks, and points of interest. A higher update frequency, ideally four or more times per year, enhances accuracy and usability, reducing the chances of drivers encountering outdated routes. Limited or infrequent updates can lead to incorrect navigation and route inefficiencies.

Traffic Update Delay measures how quickly real-time traffic data is processed and displayed. Instant traffic updates (0-second delay) provide drivers with up-to-date congestion, accident, and alternate route information, enabling them to make timely decisions. Delays in traffic updates can reduce route efficiency and lead to unnecessary travel time.

Screen Refresh Rate also plays a role in navigation performance, influencing the smoothness of map transitions and movement. A higher refresh rate ensures clear, fluid animations, reducing motion blur and improving the overall visual experience.

Lastly, Voice Guidance Clarity affects how well drivers can understand spoken directions. A system with 100% intelligibility provides clear, precise voice commands, reducing the need for drivers to look at the screen while navigating. Poor voice clarity can lead to misinterpretation of directions, increasing the likelihood of missed turns or wrong routes (Yuan, et ah, 2010).

By optimizing these navigation parameters, automobile manufacturers can provide a seamless and intuitive navigation experience. Fast map interactions, frequent updates, real-time traffic accuracy, high refresh rates, and clear voice guidance collectively contribute to improved route planning, reduced travel stress, and enhanced overall user satisfaction.

Table 18: Navigation Parameters and scale measurement

Sr No	UXD factor	Parameter	Likert Scale measurement
1		Map Zoom & Pan response	3+ sec = 1 (Strongly Unsatisfied) 3 Sec= 2 (Unsatisfied) 2 Sec = 3 (Neutral)

	Navigation		1 Sec= 4 (Satisfied) 0 Sec= 5 (Strong Satisfied)
2		Map update frequency (times per year).	0 one time = 1 (Strongly Unsatisfied) 1 update a year = 2 (Unsatisfied) 2 update a year= 3 (Neutral) 3 update a year = 4 (Satisfied) 4+ update a year= 5 (Strong Satisfied)
3		Traffic update delay (seconds for real-time data).	3+ sec = 1 (Strongly Unsatisfied) 3 Sec= 2 (Unsatisfied) 2 Sec = 3 (Neutral) 1 Sec= 4 (Satisfied) 0 Sec= 5 (Strong Satisfied)
4		Screen refresh rate (Hz for displays).	0= 1 (Strongly Unsatisfied) 30Hz= 2 (Unsatisfied) 60Hz= 3 (Neutral) 90Hz= 4 (Satisfied) 120Hz+= 5 (Strong Satisfied)
5		Voice guidance clarity (intelligibility score out of 100%).	10%= 1 (Strongly Unsatisfied) 30%= 2 (Unsatisfied) 50%c= 3 (Neutral) 80% = 4 (Satisfied) 100%= 5 (Strong Satisfied)

- **Score Aggregation:** Sum the ratings to obtain an overall score for each vehicle.
- **Determination of the Winner:** Declare the vehicle with the greater overall score as the initial winner.

6.1.2 User Experience Survey

6.1.2.1 User Selection Criteria

The users of the study were selected according to the following criteria:

- **Existing Car Owners:** Consumers who already own and use a compact SUV/Hatchback.
- **Potential Buyers:** Those thinking about buying a compact SUV/Hatchback and seriously considering both vehicles.

This pick provides an evenly weighted viewpoint both from established customers and from newer voices as buyers.

6.1.2.2 User Journey Experience

Before answering the questionnaire, each participant was guided through a structured journey designed to create an immersive interaction with the vehicle. The sequence of actions followed is as below, also depicted in figure 20 below:

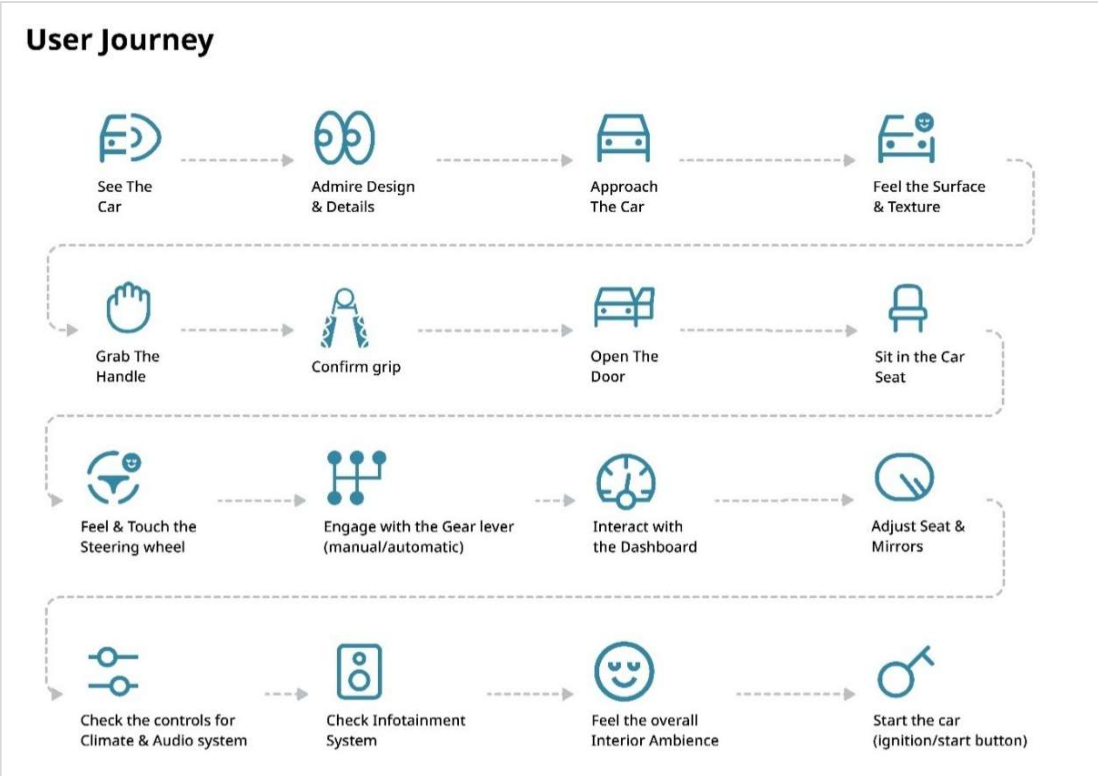


Figure 28: User journey which will be assigned to users before questioners

Following the user journey, the next step is survey administration, where participants respond to ten questions based on the ten key UXD factors. These questions are designed to assess their subjective experience with the vehicle in a structured manner, ensuring that responses provide meaningful insights into the overall usability and appeal of each model.

Case studies details are

The study is conducted on two distinct car segments:

- **Case Study 1:** Compact SUVs – Maruti Suzuki Brezza and Tata Nexon
- **Case Study 2:** Hatchbacks – Maruti Suzuki Fronx and Hyundai i20

6.1.3 Comparison and Validation

A thorough comparison of the findings from the user experience survey and the Likert scale rating is part of the study's last step. By ensuring that quantitative evaluations and qualitative comments agree, this phase strengthens the framework's dependability. Finding out if the professional assessment of UXD factors aligns with the real-world experiences that actual users and prospective purchasers share is the goal. If both methods arrive at the same winner, the framework is considered validated for assessing user experience in automobiles.

6.2 CASE STUDY 1: COMPACT SUVS - MARUTI SUZUKI BREZZA AND TATA NEXON

Cars available in market are shown in figure. 21, 22 were considered in this case study. In this car were chosen as a product for evaluation as it served well for users' needs in their respective day to day activities with automobile. Figure.21shown Maruti Brezza and figure.21Tata Nexon are market leading models in terms of sales since their day of launch.

Figure 30: Tata Nexon (Tata Nexon 2024. N.d.)

Figure 29: Maruti Suzuki Brezza (New Brezza, N.d.)

6.2.1 Framework Parameter Assessment Using the Likert Scale

In this case study each UXD factors parameter are monitored by using Likert Scale during actual scenarios with respect to User Experience Driven Automobile Design (UX-DAD). Actual measurements, performance being measured during the case study for each parameter. Each UXD factors Likert scale outcome is being mapped in a tabular format from table no 17 to 27.

6.2.1.1 SAFETY

As safety being the very important UXD factors Brezza scored 3.2/5 and Nexon scored 4/5 shown in table 19 and final table 29 shows sum ratings to obtain an overall score for each vehicle. Each parameter is measured with the help of measurement scale defined in table no 9. Below figure shows the safety parameters measurements right side shows for tata Nexon and left side shows for Maruti Suzuki Brezza. Figure 30 shows the ADAS level for cars along with this figure 32 shows visual representation of visibility of the cars. Airbags are measured from their respective brand official websites shows number of airbags available in cars 2 in Brezza and 6 in Nexon refer figure. 32. In last we monitored ground clearance which a very important factor for Brezza it is only 198mm while for Tata Nexon 208 mm.

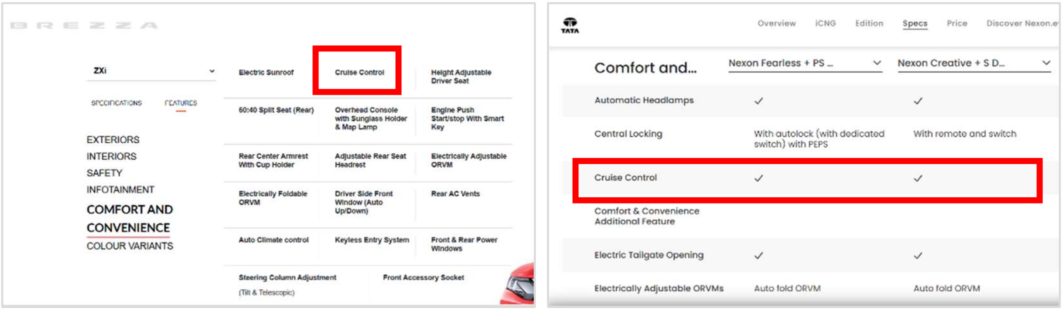


Figure 31: ADAS_Cruise Control level (Source: Tatamotors, n.d., MarutiSuzuki, n.d.)

Figure 32: Visibility & Illumination Scaling (Source: Tatamotors, n.d., MarutiSuzuki, n.d.)

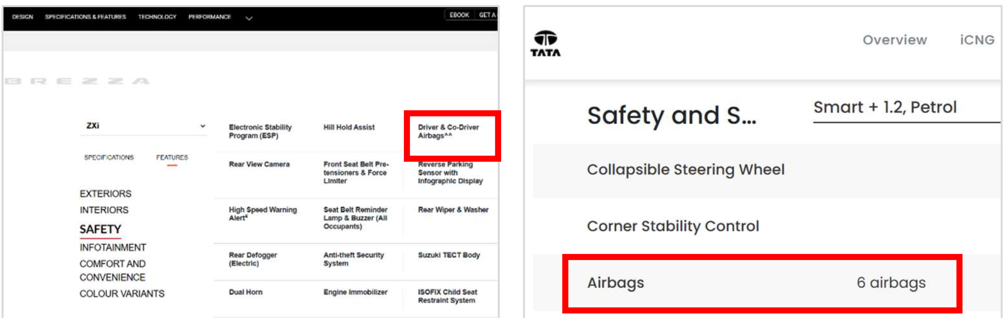


Figure 33: Number of Airbags (Source: Tatamotors, n.d., MarutiSuzuki, n.d.)

Figure 34: Ground Clearance (Source: Tatamotors, n.d)

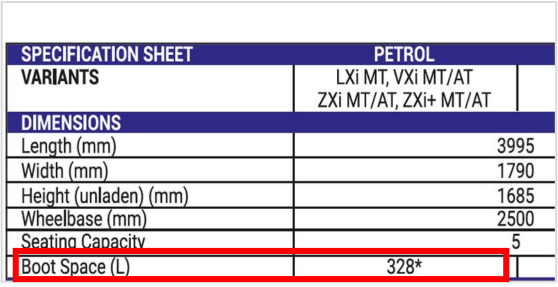
Table 19: Safety Parameters Ratings

Sr No	UXD factor	Parameter	Brezza	Nexon
1		Advanced Driver Assistance Systems ADAS	2	2
2	Safety	Visibility & Illumination	5	5
3		Number of Airbags	2	4
4		Crash Test	4	5
5		Ground Clearance	3	4
			16	20

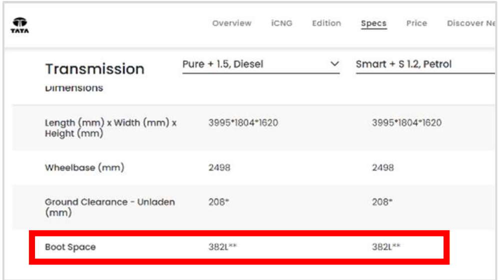
Brezza Score: 3.2/5
Nexon Score: 4/5

6.2.1.2 Functionality

Functionality is one of the key UXD factors, the Maruti Suzuki Brezza received a score of 3.2/5, while the Tata Nexon scored 3/5, as presented in Table 20. The final overall ratings, shown in Table 29, summarize the total scores across all UXD parameters for each vehicle. Each parameter, including functionality, has been assessed using the measurement scale outlined in Table 10. The figure below illustrates the functionality parameter measurements, with the left side representing the Maruti Suzuki Brezza and the right side showing the corresponding scores for the Tata Nexon. As per brand official website boot space for Brezza 328 and for Nexon 382liter. Climate control measurement was done with the help of temperature meter Brezza took 22 mins were Nexon was behind Brezza with 26.5mins. For button and knob usability we have found that both Brezza and Nexon have Touch+ button+ Visual Feedback so as per Likert scale it comes as neutral with 3 rating. Maintained interval for both cars are different as per user manual of Brezza (10000km or 12 months) and Nexon (15000Km or 12 Months). In case of hill hold all models of Brezza have this as standard but in case of Nexon few models have hill hold.



SPECIFICATION SHEET	PETROL
VARIANTS	LXi MT, VXi MT/AT ZXi MT/AT, ZXi+ MT/AT
DIMENSIONS	
Length (mm)	3995
Width (mm)	1790
Height (unladen) (mm)	1685
Wheelbase (mm)	2500
Seating Capacity	5
Boot Space (L)	328*



Overview iCNG Edition Specs Price Discover Ne

Transmission	Pure + 1.5, Diesel	Smart + S 1.2, Petrol
Dimensions		
Length (mm) x Width (mm) x Height (mm)	3995*1804*1620	3995*1804*1620
Wheelbase (mm)	2498	2498
Ground Clearance - Unladen (mm)	208*	208*
Boot Space	382L**	382L**

Figure 35: Boot space of Brezza and Nexon (Source: Tatamotors, n.d., MarutiSuzuki, n.d.)

Figure 36: Button & Knob usability for Brezza (Left) and Nexon (Right) (Source: Tatamotors, n.d., MarutiSuzuki, n.d.)

Table 20: Functionality Parameters Rating Brezza and Nexon

Sr No	UXD factor	Parameter	Brezza	Nexon
1	Functionality	Cargo Volume	3	4
2		Climate Control Time	2	1
3		Button & Knob Usability	3	3
4		Maintenance Interval	3	4
5		Auto Hold Feature Effectiveness	5	3
			16	**15**

Brezza Score: 3.2/5
Nexon Score: 3/5

6.2.1.3. Ergonomics

As ergonomics is one of the key UXD factors, Brezza and Nexon were evaluated based on multiple ergonomic parameters, as shown in Table 21. Brezza received a score of 3.4/5, while Nexon scored slightly higher at 3.6/5. The overall score was calculated by summing individual parameter ratings, with the final results presented in Table 29. Each parameter was assessed using the measurement scale detailed in Table 11. The ergonomic evaluation included factors such as steering adjustability, seat adjustability range, ingress and egress ease, legroom clearance, and thigh support. The figure below illustrates the ergonomic parameter ratings, where the values on the right represent Tata Nexon and those on the left indicate Maruti Suzuki Brezza.

Brezza and Nexon both have tilt steering wheel but Brezza also have telescopic adjustment shows in figure 36. Door opening angle Brezza is slightly less than Nexon as all Tata cars have bigger door opening angle as shown in figure 37. Thigh support in Nexon is better than Brezza with 297mm were Nexon was slightly more with 323mm.

Figure 37: Steering Adjustment Brezza (Tilt & Telescopic) and Nexon (Tilt)

Figure 38: Door opening angle Brezza

Table 21: Ergonomics Parameters Rating Brezza and Nexon

Sr No	UXD factor	Parameter	Brezza	Nexon
1	Ergonomics	Steering adjustability	4	2
2		Seat adjustability range	4	4
3		Ingress & Egress	3	5
4		Legroom Clearance	3	3
5		Thigh support	3	4
			17	**18**

Brezza Score: 3.4/5
Nexon Score: 3.6/5

6.2.1.4. Aesthetics

As aesthetics is very important UXD factors, Maruti Suzuki Brezza received a score of 4.0/5, while Tata Nexon scored slightly higher with 4.2/5, as presented in Table 22. The final cumulative ratings used to arrive at an overall UXD score for each vehicle are summarized in Table 29. Each aesthetic parameter was evaluated using the measurement scale defined in Table 12. The aesthetic parameters include customer satisfaction score, panel gap consistency, brand language, design awards won, and color options. While Brezza excelled in customer satisfaction and panel gap consistency, Nexon demonstrated strength in brand language and color options, leading to a balanced comparative aesthetic profile between the two vehicles.

Figure 40: Panel gaps for Brezza and Nexon

Figure 39: Nexon Sales Celebration (Source: Tatamotors, 2024)

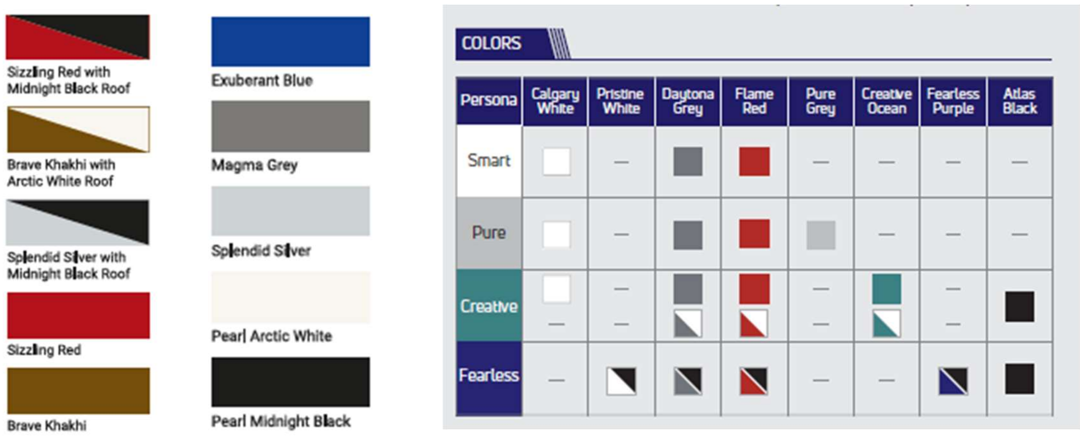


Figure 41: Colour Options in Brezza and Nexon

Table 22: Aesthetics Parameters Rating Brezza and Nexon

Sr No	UXD factor	Parameter	Brezza	Nexon
1		Customer satisfaction score	5	4
2		Panel gap consistency	4	2
3	Aesthetics	Brand language	2	5
4		Design awards won	5	5
5		Color Options	4	5
			20	**21**

Brezza Score: 4/5
Nexon Score: 4.2/5

6.2.1.5. Sustainability

As sustainability is a significant UXD factor, the Maruti Suzuki Brezza scored 3.2/5, while the Tata Nexon scored 3.8/5, as illustrated in Table 22. The final consolidated ratings, which contribute to the overall UXD score for each vehicle, are detailed in Table 29. Each sustainability-related parameter was assessed using the measurement scale outlined in Table 13. The figure below displays the individual parameter evaluations, with the left side representing Brezza and the right side representing Nexon. The sustainability parameters include fuel efficiency, eco mode driving performance impact, air purification and cabin filtration, water-based paint usage, and the incorporation of recycled materials. While both vehicles performed equally well in fuel efficiency and use of water-based paint, Nexon showed a relatively better performance in eco mode impact and recycled material usage, leading to a marginally higher overall score in sustainability.

Figure 42: Fuel Efficiency of Brezza (Source: Maruti Suzuki Brezza Brochure)

Figure 43: Driving mode of Tata Nexon (Source: Tata Nexon Brochure)

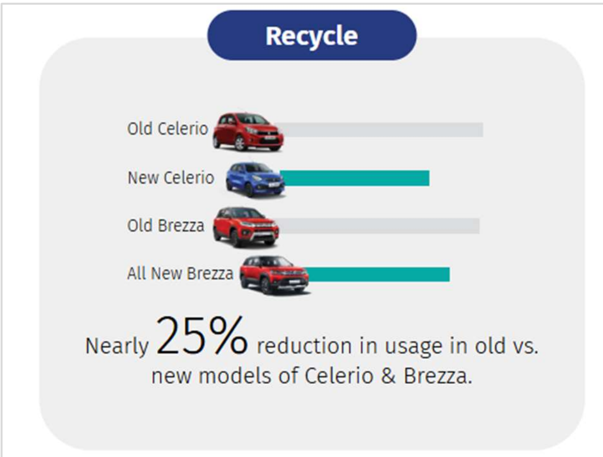


Figure 44: Recycling details of Maruti Suzuki with their respective models (Source: MarutiSuzuki, n.d.)

Table 23: Sustainability Parameters Rating Brezza and Nexon

Sr No	UXD factor	Parameter	Brezza	Nexon
1		Fuel Efficiency	5	5
2	Sustainability	Eco Mode Driving Performance Impact	1	3
3		Air Purification and Cabin Filtration	2	2
4		Water-Based Paint	4	4
5		Recycled materials	4	5
			16	**19**

Brezza Score: 3.2/5
Nexon Score: 3.8/5

6.2.1.6. Connectivity

As connectivity is an essential UXD factor, both the Maruti Suzuki Brezza and Tata Nexon achieved identical scores of 4.0/5, as shown in Table 24. The final cumulative scores used to determine the overall UXD rating for each vehicle are summarized in Table 29. Each connectivity parameter was evaluated using the measurement scale specified in Table 14. The figure below illustrates the parameter-wise measurements, with the left side representing Brezza and the right side representing Nexon. The connectivity parameters assessed include multi-user Bluetooth connection management, infotainment latency, OTA update frequency, Bluetooth pairing time, and the number of connected services. Both vehicles performed equally across all parameters, reflecting a balanced and consistent offering in terms of connectivity features.

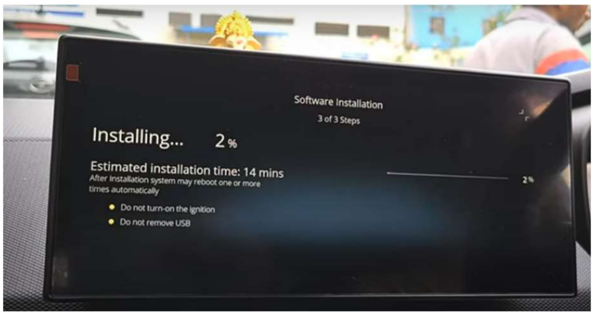


Figure 46: Tata Nexon Software Installation

Figure 45: Maruti Suzuki Connect for their Cars (Source: Corporate Communication, 2021)

Table 24: Connectivity Parameters Rating Brezza and Nexon

Sr no	UXD factor	Parameter	Brezza	Nexon
1	Connectivity	Multi-User Bluetooth Connection Mangt.	5	5
2		Infotainment latency	4	4
3		OTA update frequency	5	5
4		Bluetooth pairing time	1	1
5		Number of connected services	5	5
			20	**20**

Brezza Score: 4/5
Nexon Score: 4/5

6.2.1.7. Ease of use

As ease of use is a crucial UXD factor, the Maruti Suzuki Brezza scored 3.8/5, while the Tata Nexon slightly outperformed with a score of 4.0/5, as presented in Table 25. The final aggregate ratings, which contribute to the overall UXD score for each vehicle, are detailed in Table 29. Each parameter was assessed using the measurement scale defined in Table 15. The figure below illustrates the ease of use parameter measurements, with the left side representing Brezza and the right side representing Nexon.

Key parameters evaluated include task completion time, interior icon recognition shown in figure 46, voice command accuracy, touchscreen responsiveness (lag), and the number of steering-mounted controls are shown in figure 47. While both vehicles showed identical scores in interior icon recognition, voice command accuracy, touchscreen lag, and steering-mounted controls, the Nexon had a slight edge in task completion time, contributing to its marginally higher overall ease of use rating.

Figure 48: Steering mounted controls for Brezza and Nexon (Source: MarutiSuzuki, n.d, Tatamotors, n.d.)

Figure 47: Dash broad Icons for Brezza and Nexon (Source: MarutiSuzuki, n.d, Tatamotors, n.d.)

Table 25: Ease of Use Parameters Rating Brezza and Nexon

Sr No	UXD factor	Parameter	Brezza	Nexon
1	Ease of Use	Task completion time	3	4
2		Dashboard Icon Recognition	5	5
3		Voice command accuracy	3	3
4		Touchscreen lag	3	3
5		Number of Steering mounted controls	5	5
			19	**20**

Brezza Score: 3.8/5
Nexon Score: 4.0/5

6.2.1.8. Accessibility

As accessibility is an important UXD factor, the Maruti Suzuki Brezza scored 2.8/5, while the Tata Nexon scored slightly lower at 2.6/5, as indicated in Table 26. The final cumulative ratings that contribute to the overall UXD score for each vehicle are summarized in Table 29. Each accessibility parameter was evaluated using the measurement scale outlined in Table 16. The figure below displays the individual parameter measurements, with the left side representing Brezza and the right side representing Nexon. The assessed parameters include door opening width, handicap-friendly controls, door handle accessibility, trunk gate handle accessibility, and high-contrast display usability. While both vehicles performed equally across most parameters, Brezza gained a slight advantage due to its wider door opening, resulting in a marginally higher overall accessibility score.

Figure 49: Door Opening for Brezza and Nexon

Figure 50: Door Handle Accessibility

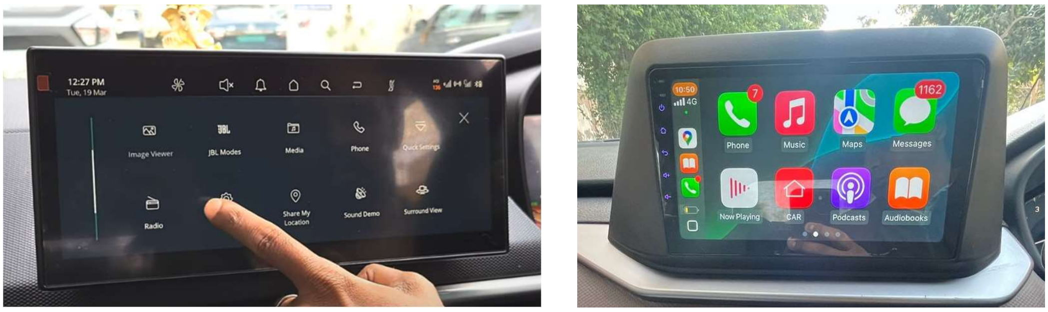


Figure 51: High-Contrast Display Usability For Brezza and Nexon

Figure 52: Brezza Trunk gate handle

Table 26: Accessibility Parameters Rating Brezza and Nexon

Sr No	UXD factor	Parameter	Brezza	Nexon
1	Accessibility	Door opening width (inches/cm).	4	3
2		Handicap-Friendly Controls	1	1
3		Door handle Accessibility	3	3
4		Trunk gate handle Accessibility	3	3
5		High-Contrast Display Usability	3	3
			14	**13**

Brezza Score: 2.8/5
Nexon Score: 2.6/5

6.2.1.9. Responsiveness

As responsiveness is a key UXD factor, the Maruti Suzuki Brezza received a score of 3.2/5, while the Tata Nexon scored slightly higher at 3.4/5, as shown in Table 27. The final cumulative scores that contribute to the overall UXD rating for each vehicle are provided in Table 29. Each responsiveness parameter was evaluated based on the measurement scale outlined in Table 17. The figure below illustrates the parameter-wise responsiveness scores, with the left side representing Brezza and the right side representing Nexon.

Parameters assessed under responsiveness include 0–100 kmph acceleration, screen touch delay, transmission shift performance, locking/unlocking time delay, and adaptive cruise control accuracy. Both vehicles performed similarly across most metrics; however, Nexon gained a slight edge due to its better performance in adaptive cruise control accuracy, leading to a marginally higher responsiveness rating.

Figure 53: Cruise Controls button in Brezza and Nexon

Table 27: Responsiveness Parameters Rating Brezza and Nexon

Sr No	UXD factor	Parameter	Brezza	Nexon
1	Responsiveness	0–100kmph acceleration (seconds)	3	3
2		Screen Touch Delay	3	3
3		Transmission shift performance	3	3
4		Locking/ Unlocking time delay	4	4
5		Adaptive Cruise Control Accuracy	3	4
			16	**17**

Brezza Score: 3.2/5
Nexon Score: 3.4/5

6.2.1.10. Navigation

As navigation is an important UXD factor, both the Maruti Suzuki Brezza and Tata Nexon scored equally with 3.0/5, as shown in Table 28. The overall UXD score for each vehicle, based on the sum of individual parameter ratings, is provided in Table 29. All navigation parameters were assessed using the measurement scale defined in Table 18. The figure below presents the navigation parameter measurements, with the left side representing Brezza and the right side representing Nexon. The evaluated parameters include map zoom and pan response, map update frequency, traffic update delay, screen refresh rate, and voice guidance clarity. While both vehicles performed similarly across most metrics, Brezza had a slight edge in traffic update delay, whereas Nexon performed slightly better in voice guidance clarity. These differences balanced out, resulting in an equal overall navigation score for both vehicles.

Figure 54: Map Navigation for Brezza and Nexon

Table 28: Navigation Parameters Rating Brezza and Nexon

Sr No	UXD factor	Parameter	Brezza	Nexon
1	Navigation	Map Zoom & Pan response	4	4
2		Map update frequency	1	1
3		Traffic update delay	4	3
4		Screen refresh rate (Hz for displays).	3	3
5		Voice guidance clarity	3	4
			15	**15**

Brezza Score: 3/5
Nexon Score: 3/5

Based on the evaluation across ten key User Experience Design (UXD) factors, the Maruti Suzuki Brezza achieved a total score of 33.8 out of 50, while the Tata Nexon scored slightly higher with 35.6 out of 50.

In terms of Safety, Brezza scored 3.2, whereas Nexon performed better with a score of 4.0. For Functionality, Brezza and Nexon scored 3.2 and 3.0 respectively. Under Ergonomics, Nexon slightly outperformed Brezza with a score of 3.6 compared to 3.4. When evaluating Aesthetics, Brezza received 4.0 while Nexon scored marginally higher at 4.2. In Sustainability, Nexon again led with 3.8, while Brezza scored 3.2. Both vehicles performed equally in Connectivity, scoring 4.0 each. In the Ease of Use category, Nexon scored 4.0, slightly above Brazza's 3.8. Under Accessibility, Brezza scored 2.8, slightly ahead of Nexon's 2.6. For Responsiveness, Nexon achieved 3.4, while Brezza scored 3.2. Finally, in Navigation, both vehicles scored equally with 3.0.

Overall, while both vehicles performed competitively, the Tata Nexon maintained a marginal lead over the Maruti Suzuki Brezza in terms of total UXD score.

Table 29: Framework Parameter Assessment Using the Likert Scale

Category	**Maruti Suzuki Brezza**	**Tata Nexon**
Safety	3.2	4
Functionality	3.2	3
Ergonomics	3.4	3.6
Aesthetics	4	4.2
Sustainability	3.2	3.8
Connectivity	4	4
Ease of Use	3.8	4
Accessibility	2.8	2.6
Responsiveness	3.2	3.4
Navigation	3	3
Total	**33.8**	**35.6**

Overall Total Score:

- **Brezza: 33.8**
- **Nexon: 35.6**

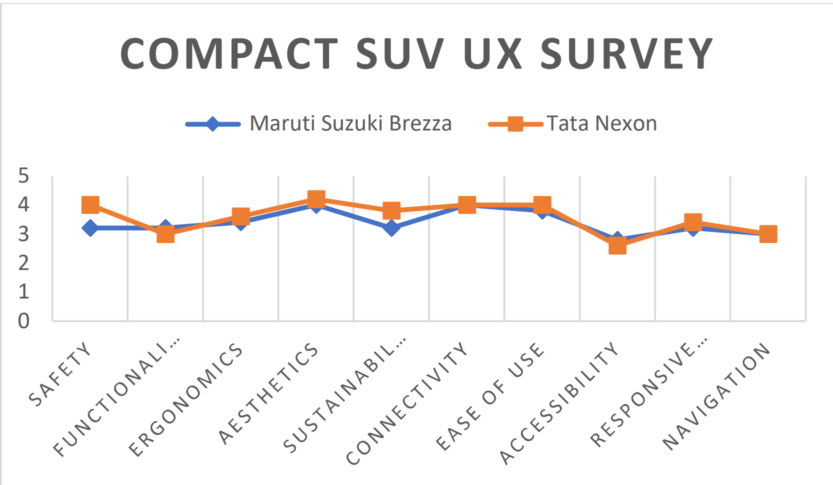


Figure 55: Line graph after Framework Parameter assessment (Brezza & Nexon)

Figure.23 shows score aggregation clearly identify the vehicle with the higher total score as the preliminary winner is Tata Nexon.

- The Tata Nexon scores higher overall, particularly in Safety, and Sustainability.
- The Maruti Suzuki Brezza performs well in Accessibility and Functionality.
- Both vehicles are competitive, with the Nexon having a slight edge due to its superior safety features.

6.2.2 User Experience Survey

To capture authentic user perspectives, the second phase involves conducting surveys with current users and potential buyers of the vehicles. Participants are guided through a predefined user journey with the vehicle, ensuring a consistent experience. Subsequently, they responded to questions designed to elicit insights into their user experience with the vehicle. This whole interaction is than mapped in a tabular format mapping each user with the help of Likert scale 1-Strongly disagree, 2-Disagree, 3-Neutral, 4- Agree, and 5- Strongly Agree.

Table 30: Maruti Suzuki Brezza User Experience Survey Result

User	Safety	Functionality	Ergonomics	Aesthetics	Sustainability	Connectivity	Ease of se	Accessibility	Responsiveness	Navigation	Total core
1	4	3	3	4	3	3	3	3	5	3	**34**
2	3	4	4	5	4	5	5	4	5	4	**43**
3	3	3	3	4	3	3	3	3	3	3	**31**
4	2	4	3	4	4	4	3	4	3	4	**35**
5	3	3	3	4	3	3	3	3	3	3	**31**
6	3	4	4	5	4	3	4	4	4	4	**39**
7	3	4	3	4	3	3	3	3	3	3	**32**
8	3	3	3	4	3	3	3	3	3	3	**31**
9	3	4	3	3	3	4	3	4	3	4	**34**
10	2	3	4	4	3	3	3	3	3	3	**31**

Total 341 points and Mean 34.1

Table 31: Tata Nexon User Experience Survey Result

User	Safety	Functionality	Ergonomics	Aesthetics	Sustainability	Connectivity	Ease of Use	Accessibility	Responsiveness	Navigation	Total Score
1	5	3	3	4	3	3	3	4	3	3	**34**
2	5	4	4	5	4	4	5	4	3	4	**42**
3	5	3	3	4	3	2	4	3	2	2	**31**
4	5	4	4	5	4	4	4	3	3	4	**40**
5	5	3	4	4	3	3	3	4	2	2	**33**
6	5	4	4	5	4	3	4	4	3	4	**40**
7	5	4	3	4	4	2	4	3	2	3	**34**
8	5	3	4	4	3	3	4	2	3	2	**33**
9	5	4	3	4	4	4	4	3	2	4	**37**
10	5	3	4	4	4	3	4	3	3	3	**36**

Total 360 points and Mean 36.0

Below figure.24 shows the comparison line graph of Maruti Suzuki Brezza with mean 34.1 and Tata Nexon with mean 36.0. It clearly shows that Nexon is a clear winner in the user experience survey with clear margin of 1.9.

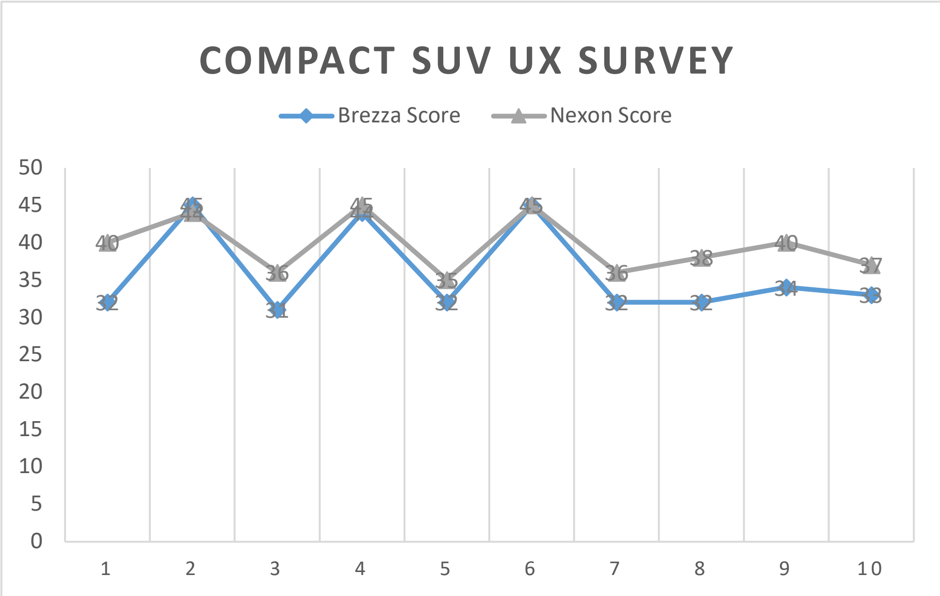


Figure 56: Comparison line graph after user experience survey (Brezza & Nexon)

As chart and score shows that Tata Nexon is a clear winner during user experience survey and framework parameter validation. This clearly show that by using our framework any product can enhance their user experience.

6.3 CASE STUDY 2: HATCHBACKS –MARUTI SUZUKI FRONX AND HYUNDAI I20

Cars available in market are shown in figure 57-58 were considered in this case study. In this car were chosen as a product for evaluation as it served well for users' needs in their respective day to day activities with automobile. Figure57 shown Maruti Suzuki Fronx and Figure 56 Hyundai I20.

*Figure 58: Maruti Suzuki Fronx (*Nexa Fronx, n.d.)

Figure 57: Hyundai i20 (Hyundai I20, n.d.)

6.3.1 Framework Parameter Validation Using the Likert Scale

In this case study each UXD factors parameter are monitored by using Likert Scale during actual scenarios with respect to User Experience Driven Automobile Design (UX-DAD). Actual measurements, performance being measured during the case study for each parameter. Each UXD factors Likert scale outcome is being mapped in a tabular format from table no 30 to 40.

6.3.1.1 Safety

61 As safety remains a highly significant UXD factor, the Maruti Suzuki Fronx and Hyundai i20 were evaluated across key safety parameters to understand their performance in this domain. As shown in Table 32, Fronx received an overall safety score of 2.6/5, while the i20 scored slightly higher at 3.0/5. The final cumulative ratings for each vehicle are detailed in Table 43. Each safety parameter was assessed using the standardized measurement scale defined in Table 9. Both vehicles offer basic Advanced Driver Assistance Systems (ADAS), scoring 2 out of 5 in this parameter. In terms of visibility and illumination, both Fronx and i20 performed well as shown in figure 59 with score 5/5, indicating clear driver visibility and effective lighting design. The number of airbags, as confirmed from official brand sources, is four in both

Figure 59: Airbags in Fronx and I20

models an image in figure 58 shows the placement of airbags. However, a notable difference was observed in crash test performance: the Fronx currently has no officially published crash test score, while the i20 scored 3, giving it an advantage in safety validation. Ground clearance was another distinguishing factor, where the Fronx outperformed the i20 with a measurement of 190mm versus i20's 170mm as shown in figure 60.

Figure 61: Ground Clearance for Fronx and I20 (Source: NexaExperience, n.d.)

Table 32: Safety Parameters Rating Fronx and I20

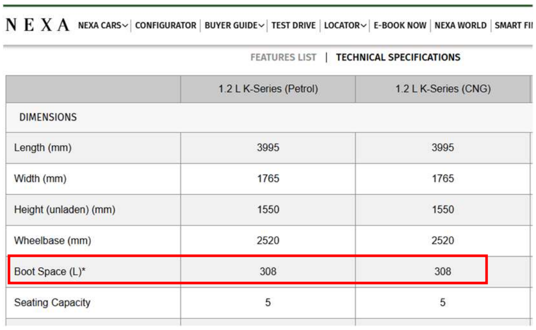
Sr No	UXD factor	Parameter	Fronx	I20
1	Safety	Advanced Driver Assistance Systems ADAS	2	2
2		Visibility & Illumination	5	5
3		Number of Airbags	4	4
4		Crash Test	0	3
5		Ground Clearance	2	1
			13	**15**

Fronx Safety Score: 2.6/5
I20 Safety Score: 3/5

6.3.1.2. Functionality

As functionality is a core UXD factor influencing day-to-day usability and user satisfaction, both the Maruti Suzuki Fronx and Hyundai i20 were assessed across five key parameters. As illustrated in Table 33, the Fronx achieved a total functionality score of 3.6/5, whereas the i20 scored 2.8/5. These values contribute to the overall UXD scores outlined in Table 42. The assessment of each parameter was based on the measurement scale defined in Table 10.

In terms of cargo volume, both vehicles performed equally with a moderate score of 3, indicating standard storage capacity for their segment shown in figure 61. The Fronx showed better performance in climate control time, scoring 4 compared to the i20's 3, suggesting quicker cabin cooling and temperature adjustment. Both vehicles offered similar usability in buttons and knobs, scoring 3 each, which reflects average tactile feedback and layout efficiency figure 62 shown the same. Maintenance intervals were also rated equally, pointing to comparable service schedules. However, a major functional advantage for the Fronx lies in its auto hold feature, scoring 5, compared to a lower 2 for the i20. This highlights the Fronx's edge in providing added driving comfort and safety in stop-and-go traffic conditions.



	1.2 L K-Series (Petrol)	1.2 L K-Series (CNG)
DIMENSIONS		
Length (mm)	3995	3995
Width (mm)	1765	1765
Height (unladen) (mm)	1550	1550
Wheelbase (mm)	2520	2520
Boot Space (L)*	308	308
Seating Capacity	5	5

Figure 62: Cargo Space in Fronx And I20 (Source: NexaExperience, n.d, Hyundai, n.d.)

Figure 63: Button & Knobs in interior in Brezza and Nexon (Source: NexaExperience, n.d, Hyundai, n.d.)

Table 33: Functionality Parameters Rating Fronx and I20

Sr No	UXD factor	Parameter	Fronx	I20
1	Functionality	Cargo volume	3	3
2		Climate control time	4	3
3		Button & Knob Usability	3	3
4		Maintenance interval	3	3
5		Auto Hold Feature Effectiveness	5	2
			18	**14**

Fronx Score: 3.6/5
I20 Score: 2.8/5

6.3.1.3. Ergonomics

As ergonomics plays a vital role in enhancing overall comfort and user experience, both the Maruti Suzuki Fronx and Hyundai i20 were evaluated based on key ergonomic parameters. According to Table 34, the Fronx scored 3.8/5, slightly ahead of the i20 which scored 3.6/5. These scores contribute to the final UXD ratings, as summarized in Table 42. Each parameter was assessed using the measurement scale defined in Table 11.

Both vehicles performed equally well in terms of steering and seat adjustability, each scoring 4, indicating adequate flexibility to cater to drivers of different body types. The Fronx showed a slight edge in ingress and egress, scoring 4 compared to the i20's 3, suggesting easier entry and exit. Similarly, legroom clearance was better in the Fronx (4) than in the i20 (3), enhancing comfort during longer drives. However, the i20 performed marginally better in thigh support with a score of 4, against Fronx's 3, indicating better seat cushioning for extended seating. Overall, while both vehicles offer strong ergonomic support, the Fronx demonstrated slightly better consistency across the evaluated parameters.

Figure 64: Door Opening Angle (Red), Thigh Support (Yellow), Seat adjustment range (Green) for Fronx and I20

Table 34: Ergonomics Parameters Rating Fronx and I20

Sr No	UXD factor	Parameter	Fronx	I20
1	Ergonomics	Steering adjustability	4	4
2		Seat adjustability range	4	4
3		Ingress & Egress	4	3
4		Legroom Clearance	4	3
5		Thigh support	3	4
			19	**18**

Fronx Score: 3.8/5
I20 Score: 3.6/5

6.3.1.4. Aesthetics

As aesthetics is a critical UXD factor that greatly influences consumer perception and emotional connection with the vehicle, both the Maruti Suzuki Fronx and Hyundai i20 were assessed across key aesthetic parameters. As presented in Table 35, the Fronx received a score of 4.2/5, while the i20 scored slightly higher at 4.4/5. These scores are included in the overall UXD evaluations shown in Table 42. Each parameter was measured using the scale defined in Table 12.

The Fronx scored high on customer satisfaction (5), panel gap consistency (4), and colour options (5), reflecting a well-executed exterior and interior appeal. The Hyundai i20, on the other hand, showed stronger alignment with brand language (4 vs. Fronx's 3) and had an advantage in design recognition, scoring 5 for design awards won compared to Fronx's 4. Both vehicles offered excellent variety in colour options (5 each) and demonstrated solid build quality with consistent panel gaps (4 each). Overall, while the Fronx emphasizes customer satisfaction and vibrant visual choices, the i20 edges ahead with refined brand identity and industry recognition in design aesthetics.

Figure 65: Panel Gaps for Fronx and I20 (Source: NexaExperience, n.d.)

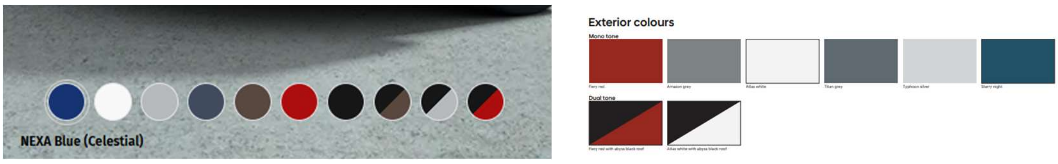


Figure 66: Color Options in Fronx and I20 (Source: NexaExperience, n.d, Hyundai, n.d.)

Table 35: Aesthetics Parameters Rating Fronx and I20

Sr No	UXD factor	Parameter	Fronx	I20
1	Aesthetics	Customer satisfaction score	5	4
2		Panel gap consistency	4	4
3		Brand language	3	4
4		Design awards won	4	5
5		Color Options	5	5
			21	**22**

Fronx Score: 4.2/5
I20 Score: 4.4/5

6.3.1.5. Sustainability

As sustainability continues to gain importance as a UXD factor in modern automobile design, both the Maruti Suzuki Fronx and Hyundai i20 were evaluated based on key sustainability-related parameters. As indicated in Table 36, the Fronx scored 3.2/5, while the i20 achieved a slightly higher score of 3.4/5. These scores contribute to the final overall UXD assessment as outlined in Table 42. Each parameter was rated using the measurement scale described in Table 13.

In terms of fuel efficiency, the Fronx performed exceptionally well, scoring 5, compared to the i20's 4, highlighting its strength in delivering economical mileage. However, when it comes to eco mode driving performance, the Fronx lagged behind with a score of 1, while the i20 scored 3, indicating better responsiveness and drivability in eco mode. Both vehicles received equal scores for air purification and cabin filtration (2), water-based paint usage (4), and recycled materials (4), showcasing a balanced approach to sustainable material usage and environmental considerations. Overall, while the Fronx leads in fuel economy, the i20's better eco-driving performance gives it a slight edge in overall sustainability.

N E X A NEXA CARS | CONFIGURATOR | BUYER GUIDE | TEST DRIVE | LOCATOR | E-BOOK NOW | NEXA WORLD | SMART FINANCE | OUR PHILOSOPHY | SERVICE

Max Torque (Nm@rpm)	113@4400	113@4 400 (Petrol) 98.5@4 300 (CNG)***	147.6@2000-4500*
Fuel-Efficiency	21.8(MT), 22.89(AMT)	28.51(MT) km/kg	21.5(MT), 20.02(AT)
Fuel Tank Capacity (L)	37	Petrol: 37 CNG: 55L (Water Equivalent)	37
Idle Start Stop	✓	–	✓
Regenerative Braking	–	–	✓

Figure 67: Fronx Fuel Efficiency (Source: NexaExperience, n.d.)

Table 36: Sustainability Parameters Rating Fronx and I20

Sr No	UXD factor	Parameter	Fronx	I20
1	Sustainability	Fuel Efficiency	5	4
2		Eco Mode Driving Performance Impact	1	3
3		Air Purification and Cabin Filtration	2	2
4		Water-Based Paint	4	4
5		Recycled materials	4	4

Fronx Score: 3.2/5
I20 Score: 3.4/5

6.3.1.6. Connectivity

As connectivity is a key UXD factor shaping modern in-car digital experiences, both the Maruti Suzuki Fronx and Hyundai i20 were evaluated across five essential parameters. As shown in Table 37, both vehicles received an identical score of 4.0/5 for connectivity, contributing equally to their overall UXD scores summarized in Table 42. Each parameter was measured using the standardized scale defined in Table 14.

Both vehicles delivered consistent performance across all evaluated parameters. They scored the highest marks (5/5) in multi-user Bluetooth connection management, OTA (Over-The-Air) update frequency, and the number of connected services—highlighting their strong integration of connected technologies. Infotainment latency

Figure 68: Infotainment System (Source: NexaExperience, n.d, Hyundai, n.d.)

was rated 4/5 for both vehicles, indicating reasonably fast and responsive interfaces. However, Bluetooth pairing time was a shared area of improvement for both, scoring only 1/5, suggesting delays in initial device connectivity. Overall, the Fronx and i20 performed equally well in connectivity, reflecting a well-balanced digital ecosystem suitable for modern user expectations.

Table 37: Connectivity Parameters Rating Fronx and I20

Sr no	UXD factor	Parameter	**Fronx**	**I20**
1	Connectivity	Multi-User Bluetooth Connection Management	5	5
2		Infotainment latency	4	4
3		OTA update frequency	5	5
4		Bluetooth pairing time	1	1
5		Number of connected services	5	5
			20	**20**

Fronx Score: 4/5
I20 Score: 4/5

6.3.1.7. Ease of use

As ease of use is an essential UXD factor that directly impacts user interaction and driving comfort, both the Maruti Suzuki Fronx and Hyundai i20 were assessed across five key parameters. As detailed in Table 38, the Fronx achieved an overall ease of use score of 3.8/5, while the i20 scored slightly higher at 4.0/5. These results contribute to the total UXD scores summarized in Table 42. The evaluation was conducted using the measurement scale outlined in Table 15.

Both vehicles performed equally well in interior icon recognition, voice command accuracy, touchscreen lag, and the number of steering-mounted controls, scoring identical marks for each. The i20 gained a slight advantage in task completion time, scoring 4 compared to the Fronx's 3, indicating quicker and more intuitive interaction with key functions. This marginal lead in task efficiency contributed to the i20's slightly higher overall score. Overall, while both vehicles demonstrate a well-optimized user interface and control layout, the Hyundai i20 offers a marginally more refined ease-of-use experience.

Figure 70: Steering mounted Controls for Fronx and I20 (Source: NexaExperience, n.d, Hyundai, n.d.)

Figure 69: Icons in Fronx and I20 (Source: NexaExperience, n.d, Hyundai, n.d.)

Table 38: Ease of Use Parameters Rating Fronx and I20

Sr No	UXD factor	Parameter	**Fronx**	**I20**
1	Ease of Use	Task completion time	3	4
2		Interior Icon Recognition	5	5
3		Voice command accuracy	3	3
4		Touchscreen lag	3	3
5		Number of Steering mounted controls	5	5
			19	**20**

Fronx Score: 3.8/5
I20 Score: 4.0/5

6.3.1.8. Accessibility

As accessibility is a key UXD factor influencing inclusivity and ease of entry, both the Maruti Suzuki Fronx and Hyundai i20 were evaluated across five core parameters. As shown in Table 39, the Fronx scored 2.8/5, while the i20 followed closely with a score of 2.6/5. These values contribute to the final overall UXD scores detailed in Table 42. Each accessibility parameter was rated using the measurement scale outlined in Table 16.

The Fronx outperformed the i20 in door opening width, scoring 4 compared to the i20's 3, indicating easier ingress and egress. Both vehicles scored equally on handicap-friendly controls (1), door handle accessibility (3), trunk gate handle accessibility (3), and high-contrast display usability (3), highlighting areas where accessibility remains average and consistent across both models. The slightly better door design in the Fronx contributed to its marginally higher overall accessibility rating. While neither vehicle excels in specialized accessibility features, the Fronx shows a slight edge in practical usability for a broader range of users.

Figure 71: Door Opening Width for Fronx and I20

Figure 72: Door Handle Positioning for Fronx and I20 (Source: NexaExperience, n.d.)

Table 39: Accessibility Parameters Rating Fronx and I20

Sr No	UXD factor	Parameter	Fronx	I20
1	Accessibility	Door opening width (inches/cm).	4	3
2		Handicap-Friendly Controls	1	1
3		Door handle Accessibility	3	3
4		Trunk gate handle Accessibility	3	3
5		High-Contrast Display Usability	3	3
			14	**13**

Fronx Score: 2.8/5
I20 Score: 2.6/5

6.3.1.9. Responsiveness

As responsiveness is a crucial UXD factor that influences driving dynamics and system reactivity, both the Maruti Suzuki Fronx and Hyundai i20 were evaluated across five performance-based parameters. As illustrated in Table 40, the Fronx scored 3.2/5, while the i20 performed slightly better with a score of 3.6/5. These scores contribute to the overall UXD assessment as outlined in Table 42. All parameters were rated using the measurement scale provided in Table 17.

In terms of 0–100 kmph acceleration and screen touch delay, both vehicles scored equally (3), reflecting similar performance in basic acceleration and touchscreen responsiveness. However, the i20 gained an edge in transmission shift performance and adaptive cruise control accuracy, scoring 4 in both compared to the Fronx's 3, indicating smoother gear transitions and better driver-assist calibration. Both vehicles performed equally well in locking/unlocking time delay, scoring 4, which shows prompt system feedback for access control. Overall, while the Fronx offers a balanced performance across all parameters, the i20 stands out slightly in terms of responsiveness due to its refined driving features and advanced assistive techno

Figure 73: Adaptive Cruise Controls for Fronx and I20 (Source: NexaExperience, n.d, Hyundai, n.d.)

Table 40: Responsiveness Parameters Rating Fronx and I20

Sr No	UXD factor	Parameter	Fronx	I20

1	Responsiveness	0–100kmph acceleration (seconds).	3	3
2		Screen Touch Delay	3	3
3		Transmission shift performance	3	4
4		Locking/ Unlocking time delay	4	4
5		Adaptive Cruise Control Accuracy	3	4
			16	**18**

Fronx Score: 3.2/5
I20 Score: 3.6/5

6.3.1.10. Navigation

As navigation is an important UXD factor that directly impacts user convenience and driving efficiency, the Maruti Suzuki Fronx and Hyundai i20 were assessed across five key navigation-related parameters. As reflected in Table 41, both vehicles received an equal navigation score of 3.0/5. These scores contribute to the overall UXD evaluation summarized in Table 42. All parameters were rated using the standardized measurement scale defined in Table 18.

Both vehicles performed equally well in map zoom and pan response, scoring 4, indicating smooth and responsive in-system navigation controls. However, map update frequency for both vehicles was rated low at 1, highlighting a common area for improvement in real-time map data refresh capabilities. The Fronx showed a slight advantage in traffic update delay, scoring 4 compared to the i20's 3, suggesting more timely information on route conditions. Screen refresh rate was consistent in both vehicles, scoring 3, ensuring adequate display performance. In voice guidance clarity, the i20 scored slightly higher (4 vs. Fronx's 3), offering clearer audio instructions. Overall, both vehicles offer balanced navigation experiences, with individual strengths in traffic updates (Fronx) and voice clarity (i20).

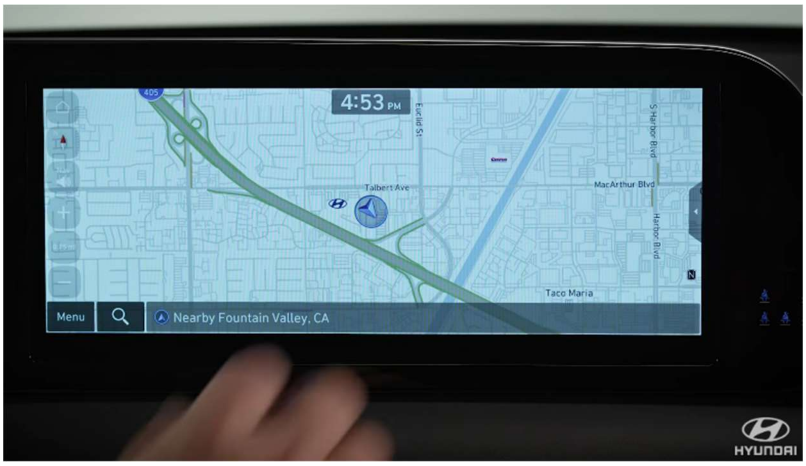


Figure 74: Map Navigation for I20 (HyundaiUSA, 2023)

Table 41: Navigation Parameters Rating Fronx and I20

Sr No	UXD factor	Parameter	Fronx	I20
1	Navigation	Map Zoom & Pan response	4	4
2		Map update frequency	1	1
3		Traffic update delay	4	3
4		Screen refresh rate (Hz for displays).	3	3
5		Voice guidance clarity	3	4
			15	**15**

Fronx Score: 3/5
I20 Score: 3/5

Table 42: Framework Parameter Assessment Using the Likert Scale for Fronx and I20

Category	Maruti Suzuki Fronx	Hyundai I20
Safety	2.6	3
Functionality	3.6	2.8
Ergonomics	3.8	3.6
Aesthetics	4.2	4.4
Sustainability	3.2	3.4
Connectivity	4	4
Ease of Use	3.8	4
Accessibility	2.8	2.6
Responsiveness	3.2	3.6
Navigation	3	3
Total	34.2	34.4

Overall Total Score:

- **Maruti Suzuki Fronx: 3.42**
- **Hyundai I20: 3.44**

Based on the evaluation across ten User Experience Design (UXD) factors, the Maruti Suzuki Fronx received a total score of 34.2 out of 50, while the Hyundai i20 scored slightly higher with 34.4 out of 50.

In the **Safety** category, the Fronx scored 2.6, while the i20 performed slightly better with a score of 3.0. Under **Functionality**, Fronx led with 3.6 compared to i20's 2.8. For **Ergonomics**, both vehicles performed well, with Fronx scoring 3.8 and i20 slightly behind at 3.6. In terms of **Aesthetics**, both vehicles scored highly, with the i20 slightly ahead at 4.4, while Fronx earned 4.2. Under **Sustainability**, i20 maintained a slight edge with a score of 3.4, compared to Fronx's 3.2. Both vehicles matched in **Connectivity**, each receiving 4.0. When it comes to **Ease of Use**, i20 led with 4.0, while Fronx closely followed with 3.8. For **Accessibility**, Fronx scored 2.8, narrowly outperforming the i20's 2.6. In the **Responsiveness** category, i20 again scored higher at 3.6, while Fronx scored 3.2. Lastly, both vehicles were equal in **Navigation**, scoring 3.0 each.

Overall, the Hyundai i20 had a marginal advantage over the Maruti Suzuki Fronx in total UXD score.

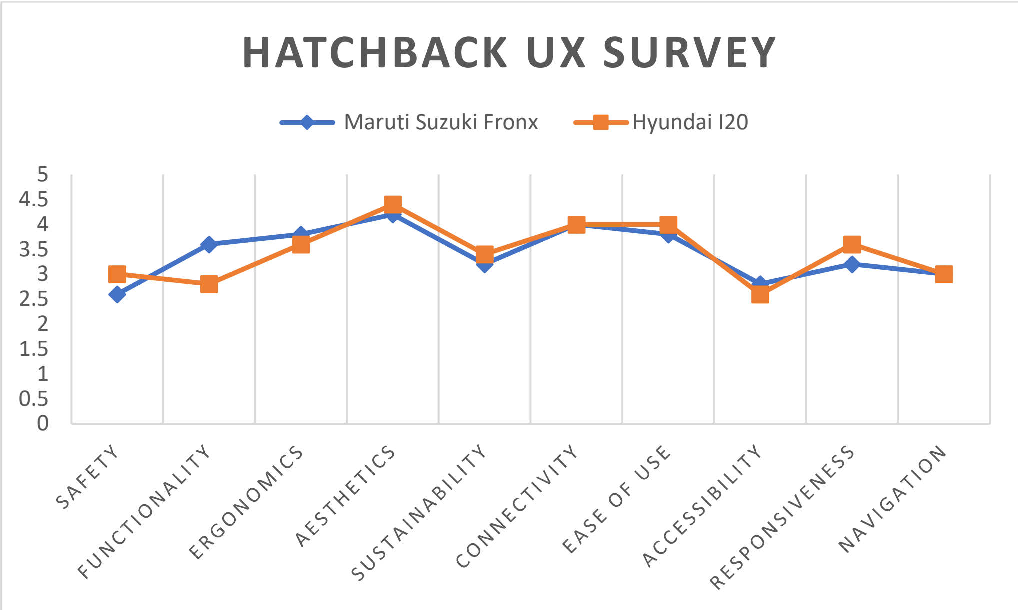


Figure 75: Line graph after Framework Parameter assessment (Fronx & I20)

Score aggregation clearly identify the vehicle with the higher total score as the preliminary winner is Hyundai I20.

- The **Hyundai I20** scores higher overall, particularly in **Safety**, and **Responsiveness**.
- The **Maruti Suzuki Fronx** performs well in **Functionality** and **Ergonomics**.
- Both vehicles are competitive, with the I20 having a slight edge due to its superior safety.

6.3.2 User Experience Survey

Table 43: Maruti Suzuki Fronx User Experience Survey Result

User	Safety	Functionality	Ergonomics	Aesthetics	Sustainability	Connectivity	Ease of Use	Accessibility	Responsiveness	Navigation	Total Score
1	3	3	4	5	3	4	4	4	3	4	37
2	2	4	4	4	2	4	4	5	4	3	36
3	3	3	5	4	4	3	4	4	4	4	38
4	2	4	3	3	3	3	3	5	3	3	32
5	3	3	5	3	4	4	4	4	4	4	38
6	2	5	4	5	3	3	2	2	3	3	32
7	3	4	4	4	3	2	3	4	3	4	34
8	3	4	4	5	3	4	4	2	2	4	35
9	2	3	5	4	3	2	2	2	4	3	30
10	2	4	5	5	2	4	4	4	4	4	38

Total 350 points and Mean 35.0

Table 44: Hyundai I20 User Experience Survey Result

User	Safety	Functionality	Ergonomics	Aesthetics	Sustainability	Connectivity	Ease of Use	Accessibility	Responsiveness	Navigation	Total Score
1	4	3	4	5	3	4	4	3	3	3	36
2	3	3	3	3	3	3	3	3	3	3	30
3	4	4	4	5	3	4	4	3	3	4	38
4	3	3	4	3	4	3	4	3	4	3	34
5	4	4	3	5	3	4	4	3	3	4	37
6	3	3	3	3	3	3	3	3	3	3	30
7	3	3	4	5	3	3	5	4	4	4	38
8	4	4	3	5	2	4	3	3	4	4	36
9	3	3	4	3	3	3	5	3	4	3	34
10	3	4	4	5	4	4	5	4	4	4	41

Total 354 points and Mean 35.4

Below figure AA shows the comparison line graph of Maruti Suzuki Fronx with mean 35.0 and Hyundai I20 with mean 35.4 It clearly shows that Hyundai I20 is a clear winner in the user experience survey with clear margin of 0.40

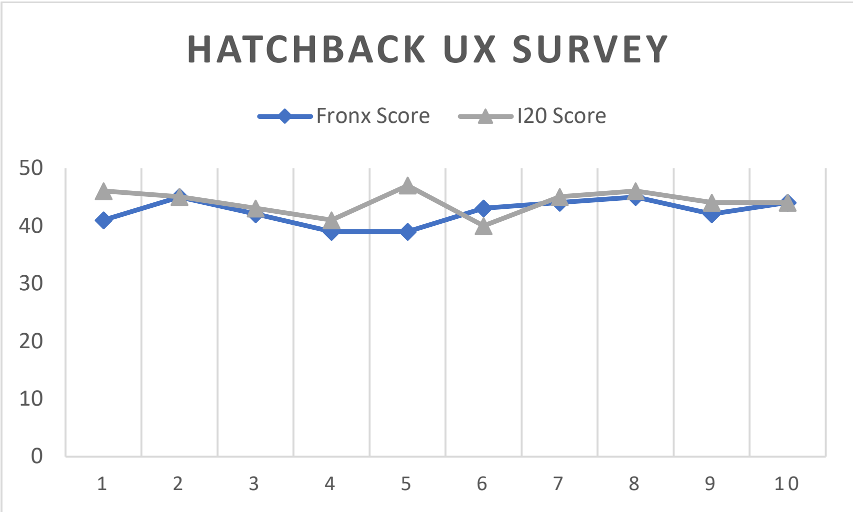


Figure 76:Comparison line graph after user experience survey (Fronx & I20)

As chart and score shows that Hyundai i20 is a clear winner during user experience survey and framework parameter validation. This clearly show that by using our framework any product can enhance their user experience.

The analysis of Compact SUVs (Maruti Suzuki Brezza vs. Tata Nexon) and Hatchbacks (Maruti Suzuki Fronx vs. Hyundai i20) through User Experience Driven Automobile Design (UX-DAD) demonstrates its effectiveness in assessing user experience (UX) design. The Likert scale evaluation and user experience surveys aligned closely, confirming the framework's reliability in measuring UXD factors. Tata Nexon and Hyundai i20 emerged as winners in their respective segments due to superior safety, responsiveness, and overall UX factors. This confirmation establishes that UX-DAD will be able to assess and optimize UX in auto design to facilitate user-focused product development by automakers.

CHAPTER 7:

RESULTS AND DISCUSSIONS

This chapter presents the findings derived from a comprehensive research study that employed a mixed-method approach to investigate user experience (UX) in the context of automobile design. The methodology integrated expert interviews, quantitative surveys, and a Delphi technique to ensure a systematic validation of UX factors relevant to the automobile domain. Experts from various stages of the automobile design process contributed in-depth insights, while the survey responses helped quantify the importance and perception of specific UX factors among key stakeholders. The Delphi method played a crucial role in achieving consensus and refining the list of UX parameters based on expert validation. To further assess the practicality and effectiveness of the proposed framework, the User Experience Driven Automobile Design (UX-DAD) framework was tested using case studies of compact SUVs and hatchbacks. These vehicle segments were chosen due to their popularity and diverse user expectations. The outcomes of these case studies served to illustrate how the UX-DAD model performs when applied to real-world scenarios, offering measurable insights into its utility. The chapter discusses these findings in alignment with the overarching research objectives, highlighting the influence of UXD factors- such as safety, ergonomics, aesthetics, and functionality- on enhancing the user-centered design of automobiles.

7.1. OVERVIEW OF RESEARCH FINDINGS

The research sought to:

- Determine essential UX factors in Automobile design.
- Create a framework for assessing these factors.
- Examining the reliability of the framework using industry expert feedback and real-world case studies.

To achieve these objectives, data was collected from literature and validated by using the Delphi method, Likert-scale evaluations, expert surveys, and user experience assessments across different car segments.

The Delphi Method, used in two stages, for finding a finalising UXD factors and also helped refine UXD parameters through expert consensus, ensuring the selected parameters were relevant, measurable, and industry-specific. Subsequently, two case studies were conducted to validate the framework, comparing the Maruti Suzuki Brezza vs. Tata Nexon (Compact SUVs) and Maruti Suzuki Fronx vs. Hyundai i20 (Hatchbacks).

7.2. QUANTITATIVE AND QUALITATIVE ANALYSIS

7.2.1 Identification of UXD Factors

- A thorough literature review and expert interviews were conducted to shortlist 97 UX-related parameters influencing automobile design.
- Using Gestalt principles, these were grouped into 11 primary UXD factors (Safety, Functionality, Ergonomics, Aesthetics, Sustainability, Connectivity, Ease of Use, Accessibility, Responsiveness, and Navigation).
- A structured Delphi method was used to finalize UXD factors by engaging Automobile design experts. The experts rated each factor based on industry relevance. After two rounds of evaluation, the top 10 UXD factors were finalized:
  - Safety
  - Functionality
  - Ergonomics
  - Aesthetics
  - Sustainability
  - Connectivity
  - Ease of Use
  - Accessibility
  - Responsiveness
  - Navigation

These factors were later used for framework development and also used in real-world case studies to assess their influence on vehicle usability.

A structured online survey was distributed among Automobile designers to assess UXD factor prioritization. Safety, Functionality, Ease of use and Accessibility emerged as the most crucial factors with 100%. Ergonomic, Aesthetics, Connectivity and Responsiveness were identified as emerging concerns in modern car design with 90% vote. Sustainability and Navigation came last with 80%. Figure 29 graph prioritization of UXD Factors by automobile designers.

Figure 77: Bar graph showing average ratings of each UXD factor

7.2.2 Graphical Representation of UX-DAD FRAMEWORK

- A flow-based diagram was developed to visualize how UXD factors interconnect with the Automobile design lifecycle.
- Below in figure 77, is the finalized User Experience- Driven Automobile Design (UX-DAD)

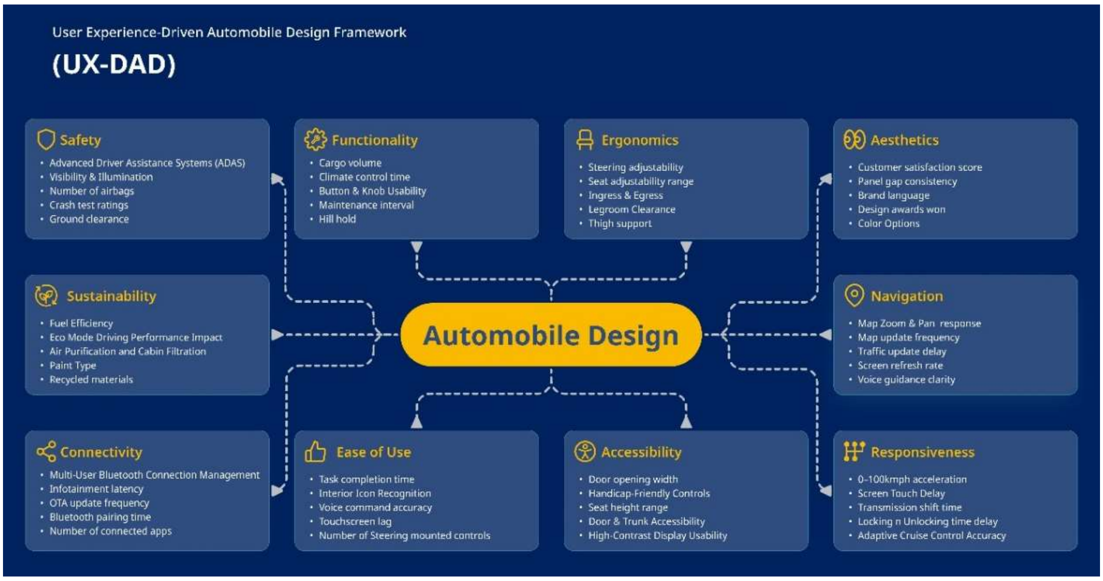


Figure 78: Finalized User Experience- Driven Automobile Design (UX-DAD) framework.

7.2.3 Parameter Definition and Finalization

- Each UXD factor was associated with measurable parameters (e.g., Crash Test Ratings for Safety, Touchscreen Lag for Ease of Use).
- A Delphi Stage 2 method with 10 design professionals (from Research, Styling, 3D Modelling, CMF, etc.) further refined the parameters. Table below show the Finalized UXD parameters:

Table 45: Show the Finalized UXD parameters:

Sr No	UXD Factors	Final parameters after expert validation
1	**Safety**	Advanced Driver Assistance Systems (ADAS) Visibility & Illumination Number of airbags Crash test ratings Ground Clearance
2	**Functionality**	Cargo volume Climate control time Button & Knob Usability

		Maintenance interval Hill Hold
3	**Ergonomics**	Steering adjustability Seat adjustability range Ingress & Egress Legroom Clearance Thigh support
4	**Aesthetics**	Customer satisfaction score Panel gap consistency Brand language Design awards won Colour option
5	**Sustainability**	Fuel Efficiency Eco Mode Driving Performance Impact Air Purification and Cabin Filtration Paint Type Recycled materials
6	**Connectivity**	Multi-User Bluetooth Connection Management Infotainment latency OTA update frequency Bluetooth pairing time Number of connected apps
7	**Ease of Use**	Task completion time Dashboard Icon Recognition Voice command accuracy Touchscreen lag Number of Steering mounted controls
8	**Accessibility**	Door opening width Handicap-Friendly Controls Seat height range Door & Trunk Accessibility High-Contrast Display Usability
9	**Responsiveness**	0–100kmph acceleration Screen Touch Delay Transmission shift time Locking n Unlocking time delay Adaptive Cruise Control Accuracy

10	**Navigation**	Map Zoom & Pan Response Map update frequency Traffic update delay Screen refresh rate Voice guidance clarity

- The final UX-DAD framework consisted of 10 UXD factors and 50+ measurable parameters.

7.2.4 Quantification of UXD Factors

- A Likert-scale method (1-5 rating) was adopted to quantify each parameter.
- A scoring system was defined for case study evaluations, allowing for direct UX comparisons between vehicles.

7.3. CASE STUDY ANALYSIS: UX-DAD FRAMEWORK

To empirically validate the UX-DAD framework, two case studies were conducted comparing framework-derived usability scores with actual user experience survey results. The studies focused on Hatchbacks (Maruti Suzuki Brezza vs. Tata Nexon) and Compact SUVs (Maruti Suzuki Fronx vs. Hyundai I20).

7.3.1 Case Study 1: Hatchbacks – Maruti Suzuki Brezza vs. Tata Nexon

7.3.1.1 UX-DAD Framework Evaluation

- **Overall Average Scores:**
  Maruti Suzuki Brezza = 33.8
  Tata Nexon = 35.6

- **Difference Calculation:**
  Difference = 35.6 – 33.8 = 1.80

- **Percentage Difference:**
  Percentage Difference = (1.80 / 33.8) × 100 = 5.33%

Interpretation:

According to the UX-DAD framework, the **Tata Nexon is 5.33%** better than the Maruti Suzuki Brezza based on the overall usability scores.

7.3.1.2 User Experience Survey Evaluation

The vehicles were evaluated based on Likert-scale ratings assigned to UX factors, followed by user surveys shown in table 46.

Table 46: UXD Factor Comparison Using Likert-Scale (Compact SUVs)

UXD Factor	Maruti Suzuki Brezza	Tata Nexon
Safety	3.2	4.0
Functionality	3.2	3.0
Ergonomics	3.4	3.6
Aesthetics	4.0	4.2
Sustainability	3.2	3.8
Connectivity	4.0	4.0
Ease of Use	3.8	4.0
Accessibility	2.8	2.6
Responsiveness	3.2	3.4
Navigation	3.0	3.0
Total Score	**33.8**	**35.6**

Findings:

- Tata Nexon outperformed Maruti Brezza in safety, aesthetics, and sustainability.
- Brezza scored better in accessibility, making it more convenient for varied user groups.
- Both vehicles performed equally in connectivity and navigation.

Comparison:

The close alignment between the UX-DAD framework (5.33%) and the survey results (5.57%) confirms the framework's reliability, with only a minimal deviation of 0.24 percentage points.

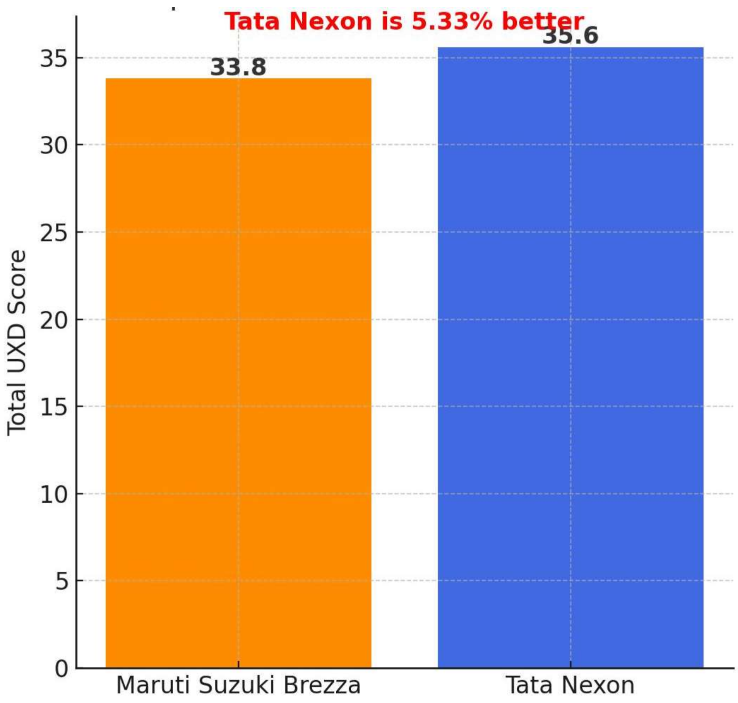


Figure 79: UXD Score Comparison – Maruti Suzuki Brezza vs. Tata Nexon

7.3.2 Case Study 2: Compact SUVs – Maruti Suzuki Fronx vs. Hyundai I20

7.3.2.1 UX-DAD Framework Evaluation

- **Overall Average Scores:**
  Maruti Suzuki Fronx = 34.2
  Hyundai I20 = 34.4

- **Difference Calculation:**
  Difference = 34.4 – 34.2 = 0.20

- **Percentage Difference:**
  Percentage Difference = (0.20 / 34.2) × 100 = 0.58%

Interpretation:

Based on the UX-DAD framework, the **Hyundai I20 is 0.58%** better than the Maruti Suzuki Fronx.

7.3.2.2 User Experience Survey Evaluation

The vehicles were evaluated based on Likert-scale ratings assigned to UX factors, followed by user surveys.

Table 47: UXD Factor Comparison Using Likert-Scale (Hatchback)

UXD Factor	Maruti Suzuki Fronx	Hyundai i20
Safety	2.6	3.0
Functionality	3.6	2.8
Ergonomics	3.8	3.6
Aesthetics	4.2	4.4
Sustainability	3.2	3.4
Connectivity	4.0	4.0
Ease of Use	3.8	4.0
Accessibility	2.8	2.6
Responsiveness	3.2	3.6
Navigation	3.0	3.0
Total Score	**34.2**	**34.4**

Findings:

- Hyundai i20 outperformed Maruti Fronx in safety and responsiveness.
- Maruti Fronx scored higher in ergonomics and functionality, making it more comfortable.
- Both vehicles were similar in connectivity and navigation performance.

Comparison:

The UX-DAD framework's output (0.58%) is very close to the survey result (1.1%), with a deviation of just 0.52 percentage points.

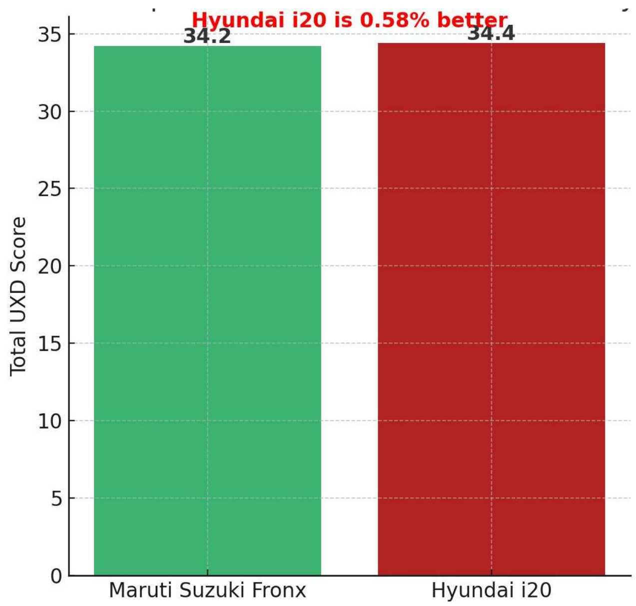


Figure 80: UXD Score Comparison – Maruti Suzuki Fronx vs. Hyundai I20

7.4. DISCUSSION

7.4.1 Validating the UX-DAD Framework

The coincidence of the case study results—with small percentage differences (0.24% for Hatchbacks and 0.52% for Compact SUVs)—indicates that the UX-DAD framework is a sound, data-driven assessment of automobile usability. The results confirm the framework as a credible instrument reflecting real user perceptions, thus making it useful in informing design enhancements.

7.4.2 Theoretical and Practical Implications

- **Holistic Integration:** The results validate the imperative to fold a complete combination of UX considerations—stretching from safety and functionality to beauty and connectivity—into the car design process.
- **Design Optimization:** The agreement between framework scores and survey data indicates that vehicle designers can proceed with confidence utilizing the UX-DAD framework as a diagnostic aid to evaluate and improve usability in the design life cycle.
- **Industry Adoption:** With its reliability, the system can be used as a strategic roadmap for design teams, promoting cross-disciplinary collaboration and allowing iterative refinements that align with actual-world user expectations.

7.4.3 Discussion on AI-Based Visual Validation

The integration of AI-generated visualizations in this study allowed for a unique form of qualitative validation of the UX-DAD framework. The AI images demonstrated how each UX factor cluster influenced perceived vehicle design — for instance, how safety and functionality led to compact, robust forms, whereas aesthetics and comfort emphasized smooth surfaces and open interiors. This visual validation supports the framework's ability to guide future automobile design directions by providing designers with perceptual cues linked to UX principles. The AI tool functioned as a visual synthesizer, translating abstract UX data into intuitive, human-readable forms.

Below Figure (80-89) Shows the automobile segment renders generated with the help of UX DAD framework with the help of AI Tool (ChatGPT, Gemini). Chat GPT is from Open AI and is widely used for quick brainstorming and discussion. List of Segments are

- Compact SUV
- Luxury Sedan
- Mini (Less 3400 mm)
- Hatchback

7.4.3.1 Compact SUV

Figure 81: Compact SUV Interior View

Figure 82:Compact SUV Front Quarter View

7.4.3.2 Luxury Sedan

Figure 83:Luxury Sedan Front Quarter View

Figure 84: Luxury Sedan Interior View

Figure 85:Luxury Sedan Rear Quarter View

7.4.3.3 Mini (Less Than 3400mm)

Figure 86:Mini (Less than 3400mm) Rear Quarter View

Figure 87:Mini (Less than 3400mm) Front Quarter View

Figure 88:Mini (Less than 3400mm) Interior View

7.4.3.4 Hatchback

Figure 89: Hatchback Rear Quarter View

Figure 90:Hatchback Front Quarter View

Figure 91:Hatchback Interior View

CHAPTER 8:

CONCLUSIONS AND FUTURE SCOPE OF THE STUDY

This chapter concludes the research on the development of the User Experience Driven Automobile Design (UX-DAD) framework, focusing on user experience in automobile design. The research is able to address a number of major goals, such as the identification of the factors that drive user experience in automobile design, the creation of an overall framework that includes these UXD factors, and analysing the framework across various car segments. Through a systematic methodology, literature and expert confirmation, by setting a user-focused approach to vehicle design, this study contributes significantly to the Automobile design sector. The research findings are tabulated below mirroring each of the research objectives. In sum, this study points out the crucial importance of user experience design (UXD) considerations in automobile design, laying emphasis on the harmonious incorporation of functionality, aesthetic appeal, and technological innovation.

With the industry advancing towards electric and autonomous mobility, designing cars that place user experience at the centre will become crucial to improve usability, comfort, and engagement. The research emphasizes the extent to which UXD factors drive consumer satisfaction and market success emphasizing the importance of a user-centered approach in automobile development. Facilitating frictionless interaction, accessibility, and efficiency will be critical drivers to transform the future of mobility and propel the automobile sector further.

8.1 SUMMARY OF RESEARCH

This research successfully:

- Identified ten key UXD factors, validated through expert feedback and literature analysis.
- Developed a structured User Experience-Driven Automobile Design Framework (UX-DAD) to evaluate user experience in automobile design.
- Validated the framework through real-world case studies, proving its reliability and industry relevance.

The UX-DAD FRAMEWORK methodology offers a scalable, data-based solution for automobile manufacturers, designers, and UX professionals to maximize vehicle usability, accessibility, and competitiveness in the market. As the Automobile world continues to progress toward autonomous and electric mobility, utilizing this UX-centered methodology will be critical in delivering improved user satisfaction, safety, and integration of technology.

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8.2 IMPLICATIONS FOR PRACTICE

The findings of the study provide manufacturers, user experience designers, and automobile designers with valuable new insights. In order to enhance usability and user satisfaction, the User Experience Driven Automobile Design (UX-DAD) can be effectively integrated into the automobile design and development process, as indicated by the high correlation between the framework and real user experience surveys. Design teams can minimize the cost of costly revisions down the line by applying UX-DAD to make decisions that are informed by data early on in the design phase. In addition, the framework's ability to provide quantifiable usability scores allows different car models to be compared, which can assist manufacturers with market positioning and competitor analysis. Also, by matching product development to customer demands, its systematic technique can promote brand loyalty and consumer interaction.

8.3 FUTURE SCOPE OF THE STUDY

The User Experience Driven Automobile Design (UX-DAD) framework has demonstrated significant potential as a practical tool for evaluating and enhancing vehicle usability and user experience. However, its current scope presents certain limitations that highlight opportunities for further research and development. Addressing these areas can improve the framework's generalizability, adaptability, and long-term relevance across evolving market and technological landscapes.

Firstly, the study's geographic and demographic scope, while inclusive of diverse design professionals, may not fully capture the nuances of user behaviour across different regions and cultures. Driving habits, environmental contexts, and cultural influences significantly shape user perceptions and interactions with automobiles. Hence, future research should expand to include broader demographic profiles and varied geographic contexts to enhance the framework's applicability across global markets. This will support the development of more universally relevant usability design guidelines.

Secondly, the current validation of the UX-DAD model, though positively aligned with user feedback, must be expanded to include a more diverse user base and a wider range of vehicle types and market segments. Incorporating larger sample sizes and exploring multiple automobile classifications will strengthen the framework's credibility and utility as an industry-wide standard. This inclusive approach will enable better insights for designers, manufacturers, and academic researchers.

Thirdly, the fast-paced evolution of automobile technologies—such as AI-based interfaces, autonomous features, voice command systems, and adaptive infotainment—necessitates continual updates to usability parameters. The current study evaluates user experience at a specific point in time; however, as these technologies evolve, so too must the UX-DAD framework. Future research should focus on integrating emerging technologies and their impact on user interaction to keep the framework relevant and forward-compatible.

Additionally, there is a need to embed UXD factors more systematically across each stage of the vehicle design process—namely Research, Styling, 3D Modelling, Clay Modelling, CMF (Colour, Materials, and Finish), and Visualization. By aligning UXD principles with these specific phases, future studies can contribute to a more structured, stage-specific, and iterative usability assessment model. Exploring the role of advanced technologies such as AI, augmented reality (AR), and digital twins in enhancing design stage usability can further refine this approach.

The UX-DAD framework already offers a robust foundation for enhancing automobile user experience, its true potential lies in continuous adaptation. Expanding demographic scope, increasing validation across user groups, incorporating technological advancements, and embedding UXD principles throughout the design lifecycle will help transform UX-DAD into a universally applicable, future-proof methodology. This will not only elevate user satisfaction but also support innovation and user-centricity in future mobility solutions.

Final Remarks:

The UX-DAD framework offers a structured and validated approach to enhancing user experience in automobile design. By focusing on key UXD factors, it supports designers and manufacturers in creating vehicles that better align with user needs and expectations. As automobile technology continues to evolve—with innovations such as AI, autonomous systems, and connected interfaces—the framework must also adapt to remain relevant. Ongoing refinements will ensure that vehicles become increasingly intuitive, user-friendly, and inclusive. This continuous improvement will not only improve comfort and accessibility but also contribute to delivering superior user experiences in future mobility and transportation solutions.

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