Understanding and Supporting Designers to Improve the Engineering Aesthetics of Products

Doctoral Thesis

by

Jitender

(2016MEZ0020)

DEPARTMENT OF
MECHANICAL ENGINEERING

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Certificate

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LAY SUMMARY

Designing items fulfilling consumer desires and preferences is essential in today's fiercely competitive industry. This study focuses on comprehending and quantifying the different aesthetic features of products, which are crucial to consumer response and product success. Product aesthetics are assessed based on factors like functionality, cost, ergonomics, and visual appeal. When purchasing, consumers prioritize product aesthetics, including social relevance, elegance, and utility. The study aims to create resources to assist industrial designers in enhancing the engineering aesthetics of their creations. Several frameworks, methodologies, and methods are used to identify and analyze the crucial aspects of engineering aesthetics. The study starts with defining aesthetics philosophically and understanding it. The researchers lay the groundwork for quantifying and comprehending engineering aesthetics by combining diverse definitions and pinpointing the essential elements of aesthetics in engineering terms. To enlarge the subject, two case studies are done. The first case study focuses on the visual elements affecting people's decision to buy and design cars. The researchers created a system to evaluate the discrepancies between consumer ratings and those offered by designers during the design phase of a new car. The study uses the Pareto Principle, the rank value method, and the Fuzzy Analytic Hierarchy Process (F-AHP). The research examines non-visual elements that affect consumers' cognitive perceptions when making car purchase decisions in the second case study. Visual characteristics like curve lines, grill design, and color influence consumer behaviour. However, non-visual factors like dependability, quality, and ergonomics significantly impact consumers' purchasing decisions. Two rounds of the study are carried out with the participation of potential participants and industry experts. The researchers create a method for comprehending the discrepancies between the rankings given by customers and designers. The rank value method, Pareto principle, and fuzzy-AHP analysis techniques are used. The Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach is used to identify and analyze the non-visual sub-factors to identify the most significant sub-factors.

The third goal of the study incorporates two investigations that seek to comprehend and measure the cognitive components of engineering aesthetics. The first study focuses on the appealing aspect of aesthetics and how it affects people's ability to think visually and cognitively. The study measures how appropriateness in product aesthetics affects consumers. The second study explores the aesthetics of beauty and analyses both qualitatively and statistically each of its components. Cognitive and analytical methods are used to evaluate the aesthetics of products using various design features, photographs, color schemes, and cameras. Quantification techniques include using

Minitab, eye-tracking methods, Likert scales, statistical analysis, and artificial neural networks. The researchers eventually created a GUI tool to help product designers comprehend and measure the beauty of their items using eye-tracking methods. The researchers' ultimate goal is to improve the engineering aesthetics of products by applying software to the output of each element and its component parts. To evaluate the tool's results, a GUI tool is created. Overall, by taking into account engineering aesthetics, presenting methodological methods, and supplying tool support for the quantification and improvement of product aesthetics, this research considerably aids in the development of new goods.

ABSTRACT

In today's extremely competitive market, a key concern in product design is creating new items that satisfy consumer wants and preferences. During the development phase of any product, many aspects or features of products play an active role, such as their "Functionality," "Cost, i.e., economically viable product," "Ergonomics (comfort level)," and "Product Aesthetics." The visual form of any product is a significant contributing factor to customers' reactions and product's success. Products' social significance, elegance, and functionality are frequently assessed entirely based on the aesthetic cues. These evaluations are made in relation to the qualities of products and typically focus on meeting the consumer wants and wishes rather than their necessities. Further, among these three pillars, one of the most important consumer considerations when making purchases continues to be "Product Aesthetics." Several businesses have worked hard in recent years to enhance the appearance of their products to get a competitive edge in this competitive market. This is particularly true of modern consumer goods (e.g., personal computers, digital cameras, smartphones, etc.). Various research suggests that product design and aesthetics play a vital role in the success of any company in the current scenario. Aesthetics impact not only the visual senses of human beings while purchasing or interacting with any product or service, but also, the human cognitive level. Therefore, there is a critical to understand aesthetics in depth.

This research mainly aims to develop support that can help industrial designers improve a product's engineering aesthetics. Before developing the support, it is essential to determine the critical factors related to engineering aesthetics. Further, we create different frameworks and use different techniques and methods for understanding and developing support for industrial designers. In this research, the thesis the first objective is to understand aesthetics and develop a simple definition of aesthetics in philosophical terms. In this work, we first develop a standard philosophical definition of aesthetics from the different sets of authors, blogs, etc. After using these definitions, we identified the core constituents of aesthetics related to aesthetics in engineering terms. That can help identify, understand, and quantify the engineering aesthetics definition. Using this description, we define engineering aesthetics metrics that evaluate human aesthetics, factors influencing

aesthetics, and techniques for improving aesthetics. This study demonstrates that a corporation can choose a particular set of tests and techniques based on how much attention is paid to the critical engineering aesthetics characteristics derived from the common definition. The reason for studying this work is; industrial designers are directly involved in the different stages of product development, from the initial to the final phase. Therefore, there is a need to understand how their cognitive thinking differs from prospective consumers. Thus, after determining the different factors, first, we develop a standard definition in terms of 'engineering aesthetics.' After finding the engineering aesthetics definition and constituents of engineering aesthetics, we divided this work into two sections; first, we tried to identify various factors that influence the aesthetics of engineered products. The second section tries to understand cognitive factors influencing product aesthetics.

In the second objective, we conducted two different case studies. In the first case study, we investigated the visual factors that affect the decision-making of current and prospective buyers and automobile designers' cognitive thinking while purchasing and designing a new product. For that, we developed a method to deem the gaps among the ranks of visual factors assigned by the designers during design and those of the consumers while buying a new car, respectively. This study uses a two-phase methodology; in the first phase, we use two methods, the first rank value method and the second is Pareto Principle. On the other hand, in the second phase, we use the Fuzzy Analytic Hierarchy Process (F-AHP).

In the second case study, we investigated non-visual factors. In the case of a car, visual factors such as the curve line, grill design, and color predominately influence the perspective of the consumer's behaviours. However, other factors, such as reliability, quality, and ergonomics, substantially influence the consumer's purchasing mindset. We investigated the non-visual factors related to the purchase of cars affecting consumers' cognitive perception. The studies are experimentally conducted with industrial experts and prospective participants. Further, the studies are conducted in 2-phases, and an approach is developed for understanding the gaps between the ranks. These ranks are assigned to the non-visual factors given by the consumers and designers, which further relates to their perception gaps. The analysis is performed with the rank value method, Pareto principle, and Fuzzy-AHP. This study is extended to finding their sub-factors. This study aimed to identify the significant non-visual factors of cars that affect the cognitive perception of buyers and estimate their importance relative to each other. A set of non-visual factors and their sub-factors were identified through a literature search and an open-ended survey among car owners. Many of the sub-factors had the same meaning; therefore, these factors were grouped under twenty separate sub-factors. Then, these twenty sub-factors were analyzed by using the Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach to evaluate the most influential sub-factors among the identified sub-factors.

In the third objective, we conducted two different studies to understand and quantify the constituents' factors of engineering aesthetics at a cognitive level.

In the first study, we understand and quantify the attractiveness feature of aesthetics. As we know, attractiveness is totally dependent on time. It is produced by functionality and can vary according to the human being. Further, the product's aesthetic qualities/features always act as a bridge between the buyer and the products at the time of purchase. And these qualities/features generate various kinds of emotions in a human being. Thus, measuring every aesthetic feature is very essential for understanding and quantifying product aesthetics. In this study, we quantify the effect of the appropriateness feature of product aesthetics on human visual and cognitive thinking in this study.

In the second study, we understand and quantify the beauty feature of aesthetics and their constituents qualitatively and quantitatively. During this study, we use the different design elements, images made with the help of various design elements, different color schemes, and Cameras as a product for the assessment of the beauty of any product in cognitive and mathematical terms. For the quantification of the beauty of the product, Minitab, an eye-tracking technique, Likert scale, and statistical tool are used. Ultimately, we use an artificial neural network tool to support product designers' understanding and quantify the product's beauty with the help of eye-tracking techniques.

In the last objective, we abstract the output of each factor and their constituents and apply it using software in engineering aesthetics enhancement of the product. We made a GUI for the assessment of the tool.

Overall, this research work has significantly impacted the development of the new product by considering engineering aesthetics, method, and tool support for the quantification and enhancement of product aesthetics.

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1. Jitender S, Ahuja Parth, and Sarkar Prabir, (2022). A Study of the Non-Visual Factors of Cars Affecting the Consumer's Cognitive Appeal. **JVAD: https://doi.org/10.5614/j.vad.2022.14.1.6.**
2. S Jitender and S Prabir, (2023). Factual analysis of factors influencing consumer cognitive thinking and automobile designing using Fuzzy-AHP. **(Online: Journal of Visual Art and Design).**
3. S Jitender and Sarkar Prabir, (2023). Study the consumer cognitive behaviour for the appropriateness of product aesthetics through eye tracking experiments. **(International Journal on Interactive Design and Manufacturing (IJIDeM): https://doi.org/10.1007/s12008-023-01656-3).**
4. S Jitender and S Prabir, (2022). Study of cognitive behavior of consumers and designers for visual factors of a car using Fuzzy Analytical Hierarchy Process. **(Decision in process: International Journal of Industrial Ergonomics).**
5. S Jitender and S Prabir An artificial neural network tool to support product designers' understanding and quantifying the product's beauty with the help of eye-tracking techniques **(Revision submitted: Expert Systems with Applications).**
6. S Jitender and S Prabir. Engineering Aesthetics generic definitions, tests, factors and methods **(Submitted: Perspectives on Psychological Science).**
7. **Jitender S**, & Prabir Sarkar; Ghulam Ashraf Ul Harmain (2023). A case study on Indian MSMEs for the reduction of the environmental impact of a product through hotspot analysis using Life Cycle Assessment. **(Decision in process: Management of Environmental Quality)**.
8. **Jitender S**, Ajay Y, & Prabir Sarkar (2023): Design and analysis of radial grooved cam with an oscillating follower to control angular position of spindles in a sustainable cotton picker. **Decision in process: International Journal on Interactive Design and Manufacturing (IJIDeM).**

Conference Proceedings

1. **Jitender S**, & Prabir Sarkar (2022). Visual product assessment: using the eye-tracking equipment to study the effect of basic shapes of product on consumer's cognitive thinking, In Proceedings of the 1st (ICAMEMS-22: ***https://doi.org/10.1007/978-981-19-0676-3_12***)", (Scopus proceeding-Online). VIT- University, India.
2. **Jitender S**, & Prabir Sarkar (2017). Understanding the Relationship between Aesthetics and Product Design. In International conference of Engineering Technology Science and Research 16th March 2017). Punjab University, India.
3. **Jitender S**, & Prabir Sarkar (2017). Reduction of Environmental Impact of Products through Hotspot Analysis in Life Cycle Assessment. ICoRD: ***https://doi.org/10.1007/978-981-10-3521-0_13***). IIT Guwahati, India.
4. **Jitender S**, & Prabir Sarkar (2022). Identify and understand the physical characteristics that responsible for the masculine nature of a car. IPDIMS - 2021, ***https://doi.org/10.1007/978-981-19-4606-6_6*** (Scopus proceeding-online), NIT Rourkela India.

CHAPTER 1

1. INTRODUCTION

In today's fiercely competitive business landscape, global corporations are constantly seeking innovative ways to achieve success. While many companies focus on aspects like cost, functionality, sales, and supply chain, some have recognized the pivotal role that exceptional product design plays in their journey to stand out. This story explores the importance of product design through the lens of a few remarkable companies that have made it a cornerstone of their success. Apple, renowned for its iconic products such as laptops, phones, and computers, has consistently set itself apart through its sleek and aesthetically pleasing designs. Ashley Furniture Industries, HNI Corporation, and IKEA, giants in the furniture retail sector, have all embraced modern and captivating furniture designs. Companies like Xerox and Sharp have prioritized user-friendly and innovative designs for their office machines. In the automobile industry, innovators like Tesla and Hyundai have left their mark by focusing on both performance and design. However, it's not just the physical appearance of these products that matters. The story highlights the importance of the entire product experience, from the design of informational booklets to the packaging. Many corporations invest heavily in design and have seen remarkable successes. Yet, it's a journey filled with challenges, and not all designs achieve the distinct character they desire in the market. This is where the burgeoning product design industry comes into play. According to two different marketing research firm like “grand view research” (Grand view research, 2022) and “research markets” (Research And Markets, 2022), the market for product design and development was estimated to be worth USD 9.4 billion in 2022, and from 2023 to 2030, it is expected to increase at a compound annual growth rate (CAGR) of 12.5% USD 24.1 billion by 2030.

Despite this global growth in product design, there's a gap in the Indian market. While international companies invest heavily in design for various products, India faces a noticeable gap, particularly in areas like bicycles, kitchen appliances, office supplies, air conditioners, and automobiles. While international companies invest substantially in design, India has yet to catch up. Effective product design holds the key to various advantages, such as reduced reliance on advertising and increased revenue. A compelling example is found in the music and stereo equipment industry, a fiercely competitive arena. Among the contenders, the British firm KEF has emerged as a standout player, captivating customers with its exceptional designs and cutting-edge audio technology. KEF's success story demonstrates the profound impact of superior product design on consumer preferences and market positioning. Their products, characterized by beautiful textures, rounded edges, and pleasing aesthetics, not only delight the eye but also engage the senses, providing an immersive experience. This focus on outstanding design, coupled with advanced audio capabilities, has set KEF apart from its competitors, earning them a dedicated and loyal customer base. KEF's journey exemplifies how the fusion of performance, beauty, and elegance in product design can wield significant influence, making products more appealing and establishing a distinct market presence (KEF, 2022; KEF R&D, 2022).

Similarly, in the competitive landscape of the automotive industry, where meeting basic consumer needs is a given, companies often focus on functionality and reliability. However, in the contemporary market driven by design and aesthetics, it's the visual and tactile appeal that truly makes a product stand out and influences consumer choices. This narrative delves into the pivotal role of design in shaping consumer preferences, drawing inspiration from automotive icons like the Bugatti Type 57C Atalante, Jaguar E-Type, and Bugatti Chiron (BARRY & HESELTINE, 2021). These legendary vehicles, characterized by the graceful curves of the Bugatti Type 57C Atalante, the timeless charm of the Jaguar E-Type, and the cutting-edge design of the Bugatti Chiron, exemplify the transformative influence of design on consumer perception and preferences. Just as KEF's success was attributed to the fusion of outstanding design with performance, these iconic automobiles showcase how aesthetics can captivate consumers, elevating the significance of design in the automotive sector.

Similarly, in the kitchen furnishings, companies such as Crate & Barrel (2022) exemplify a heightened awareness of the pivotal role design plays in consumer choices. Their curated selection of kitchen furniture undergoes a meticulous evaluation, considering aspects like material quality, finish, form, and color (Dickinson, 2022). Drawing inspiration from design-centric countries like Finland and Italy, where aesthetics are deeply embedded in kitchen furnishing norms, these companies showcase the global influence of design in product offerings. Recent research developments underscore the interdisciplinary attention given to design, with experts in marketing, ergonomics, and neuroscience recognizing its profound impact on consumer perceptions. Studies consistently affirm that a product's visual appeal significantly influences consumer perception and enhances perceived value. In this evolving landscape, where design has transitioned from an afterthought to a central pillar, businesses are increasingly embracing aesthetics as a powerful tool to differentiate themselves and resonate with their target audience (Khalid & Helander, 2006; Colombo et al., 2016; Hu et al., 2022). The synergy between aesthetics and product design has become a critical factor, shaping consumer preferences and contributing to overall success. Design, once considered an afterthought, is now a central pillar in shaping consumer preferences and driving success. Several key factors and variables intricately link aesthetics and product design, forming a symbiotic relationship that greatly impacts the success of a product. These factors include:

Unity and Balance: Form, shape, color, and texture stand as a handful of the visual elements within a product that demand meticulous attention, skillful integration, and a sense of unity. A successful product design seamlessly combines these aspects to create a visually captivating and coherent aesthetic encounter (Moon & Spencer, 1944; Veryzer, Jr. & Hutchinson, 1998; Baskerville et al., 2018).

Consumer Engagement and Perception: The aesthetics of a product play a crucial role in shaping users' perceptions and interactions. A carefully designed product with appealing aesthetics leaves a strong initial impact, drawing users in and piquing their curiosity. This heightened interest encourages users to engage more deeply with the product, resulting in increased satisfaction and a more immersive experience (Bloch, 2011; Candi et al., 2017).

Brand value/image and Emotional Relationship: Aesthetics possess the remarkable capacity to evoke emotions and forge a deep, emotional connection between consumers and products. When products feature aesthetically pleasing designs, they have the potential to elicit positive emotions, fostering a favorable brand image while nurturing consumer trust and loyalty (Khalid & Helander, 2006; Norman, 2002; Simonson & Schmitt, 2014).

Product design stands at the core of crafting prosperous products, and its correlation with product aesthetics is pivotal. The development of functional, visually pleasing, user-centric, and competitive products hinges on robust product design. Aesthetics play a vital role in enhancing the holistic user experience, setting the product apart in the market, bolstering brand recognition, and fostering emotional connections with customers. The interconnection between aesthetics and product design is undeniable. By skillfully melding design and aesthetics, businesses can create products that not only perform admirably but also captivate and delight customers, resulting in a well-rounded offering.

Likewise, there is a growing need to delve deeper into the ways in which design aesthetics influence consumers' cognitive processes and the specific product features, attributes, and their inherent characteristics that come into play. Concurrently, it's essential to understand the primary factors that influence consumer decision-making when it comes to purchasing products. The overarching objective of this study is twofold: firstly, to gain an in-depth understanding of product aesthetics and uncover the core elements of design, aesthetics, and product design; secondly, to comprehend and quantify these fundamental aspects through diverse methods, experiments, and techniques. Subsequently, this knowledge will culminate in the development of tools and methodologies that can aid product and industrial designers in their quest to create new products. To effectively grasp, measure, and analyze product aesthetics design, it is imperative to establish a profound comprehension of both product design and aesthetics. Consequently, this chapter delves into the significance of product design and product aesthetics, examining their direct correlation with consumer purchasing behaviors and the perspectives of product designers. An outline of this work is presented, highlighting its sources of inspiration, objectives, methodology, and the primary contributions it seeks to make in the field.

1.1. Product design

"Product design" is a process that entails identifying existing market opportunities, clearly defining the challenges at hand, devising an appropriate solution, and validating that solution through real consumer engagement (Cheng, 2018). It represents the domain where industrial and product designers skillfully blend consumer needs with business objectives, enabling brands to consistently deliver sought-after products. These products, collectively referred to as the amalgamation of items created for specific purposes and tailored to meet the needs of target audiences, also encompass non-physical services (Cheng, 2018). Industrial and product designers dedicate their efforts to enhancing the overall consumer experience within the products they craft, while simultaneously fortifying their company's position in this fiercely competitive market over the long term. The essence of product design lies in the process of envisioning, crafting, and refining products tailored to solve consumer problems and meet specific demands within the current market. The primary goal of product designers is to grasp, enhance, and tailor the end-user's experience, needs, or knowledge in the solutions they create for both consumers and businesses. Their focus centers on the development of sustainable products that align with enduring business requirements (Bloch, 1995a; Morris, 2009; Sarkar, 2018).

In the intricate process of product design, industrial designers, as highlighted by Walsh (1988) and Morris (2009), play a crucial role in shaping and evaluating abstract concepts, transforming them into tangible realities. This transformative journey spans idea generation, concept development, experimentation, manufacturing, and implementation into tangible and intangible products and services Langeveld (2011). The design phase, often encapsulated in the impactful quote by Speth (2020) *"If you think good design is expensive, you should look at the cost of bad design."* This quote emphasizes that thoughtful design is not a mere luxury but a necessity, with neglect incurring far greater costs. Within the broader realm of product development, the design phase forms one of the triad components alongside manufacturing and marketing (Iqbal & Suzianti, 2021). It assumes a pivotal role in molding the physical attributes of a product to align with consumer requirements, embracing both industrial and engineering design aspects. Industrial design addresses product ergonomics, aesthetics, and user interfaces, while engineering design encompasses electrical, mechanical, and software realms. These collaborative facets ensure that the final product not only meets but surpasses user expectations. Simultaneously, the manufacturing phase oversees the operational aspects, ensuring efficiency and high standards in the production process. In synergy with marketing, which acts as the linchpin, these interconnected phases guide a product from conception to fruition, reflecting the intricate nature of the product development process (Baxter, 1995). This collaboration is illustrated in Figure 1.1.

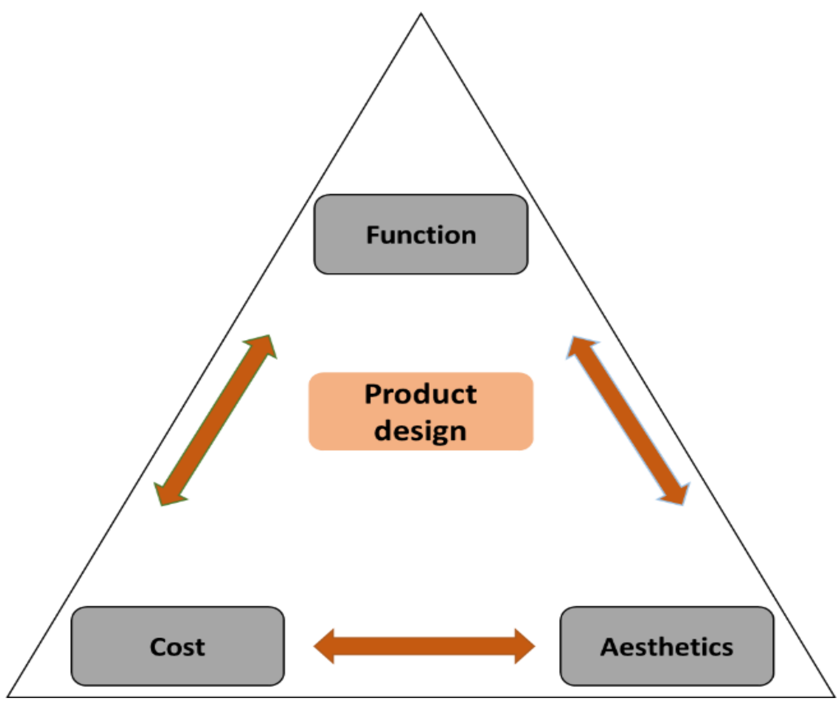


Figure 1.1. Shows the different pillars of product design (Baxter, 1995).

The three pillars of product design are discussed in brief in Table 1.1.

Table 1.1. Three different pillars of product design

Pillars	Short Description
Function	● Product/service must be trustworthy and fit the function for which it was designed ("nobody wants a waterproof jacket that lets the rain in!"). Many manufacturers provide years of warranties to demonstrate their confidence in the durability and reliability of their products. ● "Products should be easy to use and appropriate, ergonomically designed, and easily maintainable." ● If a product can be manufactured (service with superiority) with excellent functionality, it may be used as a unique selling point (USP); for example, "Volvo cars are known for their safety features, and it is his USP."
Economic/ Manufacturin g cost	● A well-manufactured object is highly expected to be economically viable. ● It indicates a product produces high profit. ● If the product is to be viable, it must turn a profit and be able to be produced at a cost lower than the selling price.
Aesthetics	● Products/services should provide sensory stimulation in addition to providing a function (feel, hearing, look, taste and smell, etc.). ● In addition to functionality, the product should provide sensory satisfaction such as feel, look, taste, smell, etc.

Industrial product designers are entrusted with the critical task of managing the three elements delineated in Table 1.1. These elements exert a direct influence on a customer's decision-making process during a purchase. Notably, among these three elements, aesthetics emerges as a highly significant factor that warrants in-depth exploration and attention when compared to the functional and manufacturing aspects of product design (Gilal et al., 2018; Kaulio, 1998; Yoshimura & Yanagi, 2001). This underscores the pivotal role of aesthetics in shaping consumer preferences and perceptions in the competitive landscape of product design. It becomes evident that over the past two decades, product design has emerged as a pivotal focal point, gaining significant prominence in various domains (Berg & Vance, 2017). Notably, this emphasis on product design has consistently piqued the keen interest of companies (Khalid & Helander, 2006; Singh & Sarkar, 2018). While some businesses initially hesitated to adopt this strategy, certain industries willingly invested in high-quality materials to enhance the aesthetic appeal of their products. They soon recognized the consumer's propensity to be drawn towards products that captivated their attention through visual allure. The capacity of aesthetics to profoundly influence consumer purchasing behavior positions it as an indispensable component for any company's success (Eisenman, 2013; Shi et al., 2021). Over time, aesthetics has evolved into a differentiating factor that can either elevate a company to success or potentially lead to its demise, particularly as the costs associated with raw materials and manufacturing techniques have continued to decline. This shift underscores the critical role of aesthetics in the dynamic and competitive landscape of product design.

It is worth noting that even in earlier historical periods, craftsmanship underscored the significance of beauty. Medieval artisans, for instance, crafted intricate religious decorations with elaborate designs, aiming to convey a sense of grandeur and earn favor. Similarly, back in the 1930s, trains captured the imagination of passengers with their shining, sleek locomotives and the opulent ambiance of their passenger cars. These historical instances serve as compelling evidence of the enduring impact of aesthetics on human attention and admiration. Nonetheless, it was during the latter half of the 20th century that leading scholars in marketing research began to unravel the profound, long-term connections between product design, marketing, and innovation. The importance of product design, which had previously been somewhat eclipsed by other cultural factors, notably came to the forefront (Bloch, 1995). As societal attitudes shifted and people became increasingly cognizant of how aesthetics significantly influenced consumer behavior, perceptions and priorities evolved. In today's world, the enduring influence of aesthetics on shaping consumer choices and driving commercial success continues to be manifest. Contemporary businesses invest substantial resources in the design of products that not only fulfill functional needs but also evoke strong emotional responses in consumers. The term "aesthetics" has evolved to encompass the realm of superior product design, recognized as pivotal in retaining and securing the support of customers. This dynamic interplay underscores the pivotal role of aesthetics in product design, where it has transformed from a historical phenomenon into a contemporary imperative for businesses in the pursuit of consumer engagement and loyalty.

It is noteworthy that numerous renowned companies spanning various domains, including Alessi, BMW, Delmonte, and Apple, have embraced product design as a cornerstone of their success. Product design serves as a solid bedrock for their business strategies, allowing them to consistently innovate by seamlessly integrating both the functionality and visual aesthetics of their products. Kotler and Rath (1984), underscored the considerable potential of product design in affording every company a competitive advantage. This recognition extends beyond traditional industries and has made its way into the realm of mass media (television and newspapers). This transition is evident through the plethora of videos, websites, and intricate print media that meticulously analyze the latest designs from events like "New York's Fashion Week" and "Tokyo Auto Show." This trend exemplifies how the domain of design has permeated even the most diverse sectors of the economy, underscoring its universal relevance and the compelling role it plays in shaping contemporary business strategies and consumer preferences.

Over the course of time, several researchers have advanced the notion that investing in the design capabilities of an industry can yield positive outcomes, notably in terms of enhancing the industry's profitability (Hertenstein et al., 2005). A striking example of the impact of product design on profitability can be witnessed in the unparalleled success of a company like "Apple," which achieved record-breaking revenues during a slowdown, primarily attributed to its extraordinary leadership in design in 2008 (Michaels, 2010). As a result of this growing recognition, there has been a substantial surge in design research in recent years. This surge is accompanied by a well-balanced stream of relevant journals, articles, conferences, special issues, congresses, design-focused groups, and inspiring blogs. Despite this surge in attention in the present era, design research still remains a subject of relatively modest activity when compared to its profound importance in brand building, consumer decision-making, and overall business success. This discrepancy may arise because researchers in the field of marketing are often less familiar with engineering and aesthetic aspects that are tightly interwoven with design.

In this section, we offer a brief overview of product design, product aesthetics, and their connection to consumer behavior within both academic and industry domains. Moreover, this study places a primary focus on product aesthetics, exploring the attributes, factors, tools, quantification techniques, and methodologies that can contribute to the enhancement of product aesthetics. Recognizing the distinct properties of product aesthetics is crucial. While "product design" is a broad term encompassing a product's kinesthetic, functional, and aesthetic aspects (Hekkert, 2006; Noble and Kumar, 2010; Norman, 2002), "aesthetic attributes" are intimately related to the composition of various design elements (Coates, 2003). In this section, we will delve more deeply into aesthetics, importance of aesthetics, and their intricate relationship with product design in a concise manner.

1.1.1. Aesthetics

The term "Aesthetics" finds its roots in an ancient concept, originating from the Greek word "aisthesis," interpreted as the understanding through sensory perception (Y. Saito, 1998). In the 18th century, the concept began to be employed in the manner it is used today, emphasizing sensory experiences and pleasure (Hekkert, 2006; Kostellow, 2002; Mciver & Gaut, 2002). However, the term aesthetics has traversed various domains, including poetry, art criticism, feminism, paintings, and the sculptures of the Greeks. Yet, the task of defining and arriving at a simple, universal definition of aesthetics remains challenging ((Bloch, 1995; Saito, 1998; Kostellow, 2002; Pirinen, 2020). Different authors have noted that a "standard description of aesthetics" is not only challenging but may be even more so than is typically acknowledged by aesthetic researchers (Mciver & Gaut, 2002; Walton, 2007). Aesthetics has been defined in numerous ways, with philosophers, physiologists, artists, poets, and others offering various definitions and perspectives. Some studies have explored the theoretical aspects of the term "aesthetic," while others have worked on enhancing product aesthetics through direct interactions with consumers and designers (Nagamachi, 1995; Jindo & Hirasago, 1997; Yadav et al., 2013; Singh & Sarkar, 2022).

Furthermore, there have been relatively few studies that revolve around the quantification of aesthetics. Quantifying aesthetics in terms of numerical values presents a significant challenge. Thus, in the domain of product aesthetics, selecting an appropriate technique for evaluating and quantifying these measures or factors often proves to be a formidable task (Khalid & Helander, 2006a; Yan et al., 2008). Establishing a connection between "what the tool or test is measuring" and "what needs to be measured" provides a means to assess the suitability of a method, measure, or factor. This can be achieved by considering a concise definition of aesthetics. Some studies employ various methods and techniques to enhance the aesthetics of product design, identifying specific features or variables that influence aesthetic factors (Bloch, 1995a; Hekkert, 2006; Mciver & Gaut, 2002; Sarkar, 2018; J. Singh & Sarkar, 2022; Walton, 2007; Yadav, Jain, Shukla, et al., 2013a).

1.1.2. Importance of aesthetics

Aesthetics play a pivotal role in motivating individuals to explore new products, guiding their choices, and impacting their overall experiences. It extends beyond mere visual appeal; aesthetics reveal the function, content, and usage of products. Aesthetics have the power to evoke feelings of pride, inspire loyalty, and bring delight (Hekkert, 2006; Hekkert & Leder, 2008).

Importance of aesthetics: The importance of aesthetics is deeply rooted in our unique human capacity for creativity and our ability to appreciate the beauty and deeper meanings found in art. Art has long been regarded as a tool for conveying abstract ideas and bringing significance to them (Guyer, 2008; Mithen, 2003). Aesthetics delves into the fundamental reasons driving the evolution of art throughout history, aiming to understand the intrinsic human desire to perceive the world in fresh and distinctive ways. Beyond just surface-level beauty, aesthetics explores the profound effects of art on the human mind and well-being. It seeks to determine whether art effectively satisfies intellectual needs or potentially hinders the quality of human life. Aesthetics strives to unravel how art enhances and enriches our lives by exploring the intricate connection between art and the human experience. Art serves as a means to convey emotions from one individual's mind to another, allowing people to explore, interpret, and communicate their experiences, emotions, and ideas (Menninghaus et al., 2019; Noy & Noy-Sharav, 2013). In the past, consumers primarily sought functionality and usability when making purchasing decisions. However, the landscape has evolved in today's environment. As consumer expectations have risen, so has the scope of design. Consumers now demand more from their products, looking beyond mere functionality. They seek items that provide pleasure and sensory stimulation, prioritizing aesthetics. The adage "Don't judge a book by its cover" serves as a prime example; in reality, individuals often make snap judgments based on visual cues, and the stronger the visual presentation, the higher the perceived quality of the content (Kostellow, 2002; Kranzbühler et al., 2018). This aspect, referred to as aesthetic-usability, influences how we perceive and interact with products and objects. Even if it may not be entirely accurate, people tend to perceive and find things easier to use when they consider them visually appealing. This effect is especially pronounced when usability, utility, and beauty coexist. Superior aesthetics grant products a distinct advantage in attracting and retaining customers (Sutcliffe & Hart, 2017; Srivastava et al., 2022).

Design for aesthetic pleasure: It's essential to create products that seamlessly blend aesthetics with functionality. But the question arises: how do we discern what to design when aesthetics are subjective and linked to users' perceptions? The answer can be found in the target market for the product or experience. Achieving a thorough understanding of the product is crucial in determining what is aesthetically pleasing. When designers create products intended for real consumers or users, simplicity is often the wisest approach (Hekkert, 2006). In our pursuit of making our ideas aesthetically pleasing, it is imperative to consider three key factors of enjoyment, as depicted in Figure 1.2. These factors serve as valuable guidelines in the design process, ensuring that the resulting products not only look good but also fulfill the users' needs and preferences.

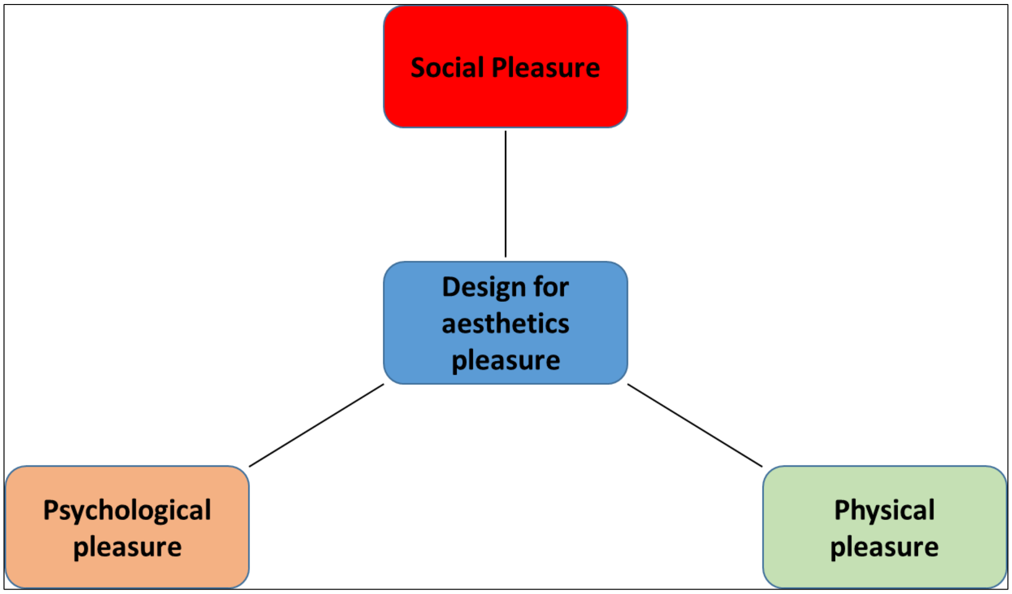


Figure 1.2. Three key enjoyment factors of aesthetic pleasure

There are three main enjoyment factors that can be considered during designing of any product.

Table 1.2. Shows the short description of key factors aesthetic pleasure

Key factors	Description
Psychological pleasure	● The joy/pleasure of finishing a work or experiencing safety and control. The usability of the product is closely tied to this situation. But it might also be connected to the aesthetics of the product design. ● For example, a car that looks sturdy and stable provides greater psychological comfort than one whose door seems like it might break. ● The same is true for digital products, where the consumer feels in charge and is confident that the task can be finished. Making everything appear stable and straightforward. ● Guiding the consumer with excellent motion and composition. The employment of aesthetics greatly contributes to the users' sense of security and control.
Psychical pleasure	● A majority of pleasure comes from touch, smell, and taste. Consider developing a pen, a virtual reality headset, a computer device, or even a hand-held product. ● Making sure the design is ergonomic, doesn't overstimulate, and comfortable to the user's senses is important. Think about how sensitive your user's senses are and what the typical norm is. Make sure the taste and smell are neutral or evoke pleasant memories.
Social pleasure	● Interaction with AI or other humans that brings them pleasure (still not that common). This setting can range from a home assistant device and virtual reality experiences to a room or building that will host social activities. ● We must ensure that the design optimally facilitates social interaction. Employee communication while waiting for the coffee to be ready may be as simple as the coffee machine's aesthetic sound.

1.2. Research motivation

In response to the product's perspective, a harmonious blend of mechanical and industrial design, seamlessly intertwined to fulfill both form and function. Certainly, it's important to recognize the combined effect and collaboration between core engineering designers and core industrial/product designers throughout the entire product development journey. Their parallel efforts from raw material selection to pilot product development, aesthetics, cost, function, testing, and distribution play a vital role in shaping the product's lifecycle and overall success. This integrated approach fosters innovation and ensures that the end product excels in all aspects. In this research, it's crucial to clarify that we don't aim to create divisions among product/industrial designers; instead, we bring both professionals, including engineering designers and product/industrial designers, together on a collaborative platform. This collaboration allows us to employ various multi-criteria decision-making techniques and statistical methods to gain insights into their thought processes and how they may differ from the perspectives of potential consumers. Regarding the definitions of aesthetics, it's essential to underscore that we are not seeking to separate these concepts. Rather, we are distinguishing between aesthetics from a philosophical standpoint and design/engineering aesthetics. Engineering aesthetics, in many ways, encompasses elements of philosophical aesthetics or a more common definition of aesthetics. Philosophical aesthetics often lack quantitative measures, making it challenging to quantify. However, during the development of engineering aesthetics definitions, which share similarities with philosophical aesthetics, we've identified quantitative measures and variables related to the aesthetic quality of products from diverse fields, including design, psychology, consumer behavior, and science. These quantitative elements, combined with the philosophical aesthetics perspective, contribute to the development of a new definition, which we refer to as engineering aesthetics definition. This approach allows us to bridge the gap between the qualitative and quantitative aspects of aesthetics and create a more comprehensive understanding of the concept.

"Engineering aesthetics" refers to the application of aesthetic principles and considerations in the field of engineering. It involves the integration of design and aesthetic elements into the engineering process to enhance the visual appeal, user experience, and overall aesthetic quality of products or systems. In essence, engineering aesthetics seeks to combine functionality and practicality with artistic and design-oriented approaches to create products that not only perform well but also satisfy aesthetic preferences and contribute to a positive user experience. As seen in the previous section, aesthetics stands out as one of the essential elements among the various components of product design (Baxter, 1995). It's widely acknowledged, as noted by multiple authors from diverse fields (Eckstein et al., 2017; Kostellow, 2002; M. Kumar & Garg, 2010a; Perks et al., 2005; Promjun & Sahachaisaeree, 2012; Ranscombe et al., 2012a), that the market success of a product can be significantly influenced by its aesthetic appeal. The quality of aesthetics is a primary determinant of consumer satisfaction in their purchase decisions (Fynes & De Búrca, 2005; Ranscombe et al., 2012a). Ulrich (2006) contends that consumers can make snap judgments about a product's desirability in a matter of seconds based on their initial visual reaction to it. Norman (2004), emphasizes that a product's pleasing appearance is the foremost factor in shaping favorable perceptions of the product. Schindler & Holbrook (2003), assert that most consumers heavily rely on a product's appearance when making their final purchasing decisions. Furthermore, Veryzer (1993) posits that a product's aesthetics play a pivotal role in defining its identity. Bloch (1995a) suggests that aesthetics can enhance consumers' perceptions of a product's quality. Verma and Wood (2001) highlight the strong interaction between aesthetics and function, with many people believing that beautiful and appealing items perform better (D. Norman, 2002; Tractinsky et al., 2000). Lin (2013) supports the idea that products with a strong emphasis on aesthetics can still achieve success and popularity. Norman (2004) underscores how aesthetics can fundamentally alter the way a product is perceived. Tuch (2012a) demonstrates how enhancing a product's appearance can augment its functionality. In light of this collective body of evidence, it is widely accepted that aesthetics plays a significant role in elevating the quality of product design and contributing to the product's success. This reaffirms the importance of aesthetics as an integral aspect of the design process.

The interpretation of product aesthetics has consistently presented a challenging task due to its multifaceted nature (Chen & Chuang, 2008). Many authors have highlighted that product designers often interpret their designs based on their emotional or personal perspectives, which may differ from the consumers' perceptions (Chuang et al., 2001a; You et al., 2006). This discrepancy arises because customers assess a product according to their own subjective understanding of the object's image (Hsiao & Liu, 2002), even though industrial designers craft an object by incorporating design elements and physical characteristics, influenced by various factors (Matsubara & Nagamachi, 1997). Furthermore, the key principle for achieving optimal aesthetic quality from a product designer's viewpoint remains elusive both in practical and theoretical terms (Hsu et al., 2000a). Two primary reasons contribute to this ambiguity: firstly, product designers employ a variety of methods to enhance their design features and influence consumers, while consumers often find it challenging or are hesitant to disclose their own design process due to its inherent subjectivity (Coates, 2003; Lawson, 2010; Tovey, 1997). Secondly, design researchers often interpret aesthetic elements differently than artists (Crilly et al., 2004a), leading to a lack of an objective approach capable of quantifying effective aesthetic traits. Thus, identifying the crucial components in aesthetic evaluation is imperative to address this issue. There are several major factors or variables that contribute to the assessment of product aesthetics, including design principles (Lai et al., 2005a; Luthans et al., 2007), the perception of function (Hsiao & Liu, 2002), visual characteristics, product personality (Brunel & Kumar, 2007; Khalid & Helander, 2006a), as well as cultural attributes, individual characteristics, and situational elements (Crilly et al., 2004a; Schindler & Holbrook, 2003; Veryzer Jr, 1993). The description of these various factors in terms of visual and non-visual factors, design elements, variable, and cognitive levels is presented in chapters 5, 6, 7, 8, and 9.

Building upon the foundation of prior research and the motivations discussed in the preceding sections, the overarching goal of this research is articulated below: to comprehensively understand the various factors that influence product aesthetics and subsequently employ these factors to aid and guide designers in enhancing the engineering aesthetics of a product. This research aims to bridge the gap between the subjective nature of aesthetics and the objective methodologies required to improve the design process.

1.3. Main aim of this research work

Based on the background and motivation established in the previous sections, the overall aim of this research is formulated below. To understand the aesthetics in engineering as well as in philosophical perspective and then found various factors in terms of visual, non-visual and cognitive levels to provide a support for the designers to improve the engineering aesthetics of a products.

1.4. Thesis layout

The thesis is organized into eight chapters, as shown in Figure 1.3.

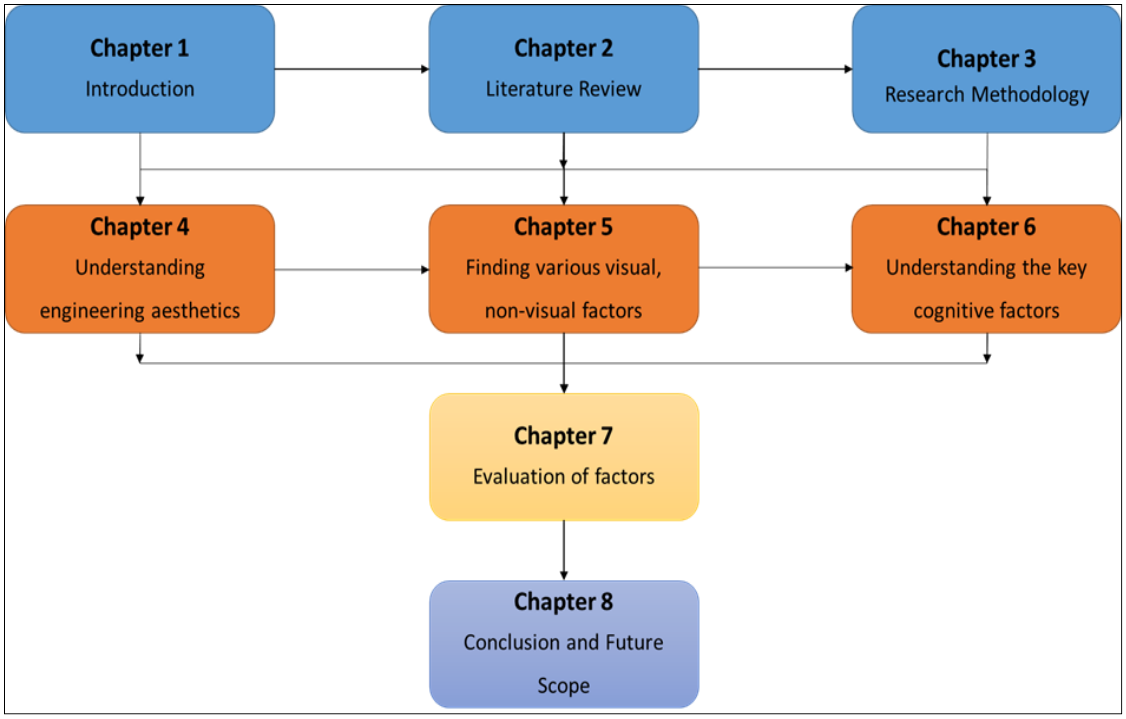


Figure 1.3. Layout of the thesis

This research aims to develop a methodology capable of quantification and enhancement of the qualities of aesthetics by focusing on three main areas: art, science, and psychology.

Chapter 1: Introduction

This chapter lays the foundation stone for the thesis by discussing background, an introduction of the main topics, inspiration to conduct this research study, complete objective, arrangement of the thesis and important contributions.

Chapter 2: Literature Review

This chapter consists of an organized assessment of the previous on product aesthetics. Also, the current research going in the aesthetics area is discussed and key research gaps are found. Research objectives are framed on the basis of identified key research gaps.

Chapter 3: Research Methodology

In this chapter, an overall stepwise methodology used for achieving the proposed objectives is described.

Chapter 4: What is engineering aesthetics? (Understanding of engineering aesthetics a workable definition of engineering aesthetics).

In this chapter, our first main aim is to scrutinize a comprehensive group of descriptions/definitions of aesthetics given by different practitioners and researchers and create their structures into a general or common definition of aesthetics that can be utilized by various establishments/societies. The effort then spreads this definition to create aesthetics. Examine an extensive collection of aesthetic tests or measures, classify them, and associate (make a connection between) them with the meaning/definition of aesthetic. Examine factors affecting aesthetics, group them, and make a connection between them with the meaning/definition of aesthetic; Analysis a complete group of aesthetic enhancing approaches/methods existing in previous works and make a connection between (transmit) them with the meaning of aesthetic. Develop a broad knowledge of aesthetics by establishing links among the methods, measures, definitions, and factors of aesthetics. In this research study, firstly, we analyze the many definitions or brief meanings of aesthetics and sum them up into a common or general definition of aesthetics. Afterward, we group aesthetic valuation experiments (verbs, adverbs, adjective, noun, etc.,), affecting factors and improving approaches in the form of their likeness, and make a connection between (transmit) these with the meaning of aesthetic.

During this work, we searched various fields such as art, history, environment, psychology, phycology, engineering, mathematics (Fibonacci series), and cognition. Further, it will help us in next chapters 5 and 6, where we will understand and study the various factors, and find out different measurement techniques to resolve the research problem.

Chapter 5: Finding out the various visual and non-visual factors of an engineered product (car) that attract people (Understanding influences of aesthetics).

In this chapter, we were discussing various visual and non-visual factors which affect consumer purchase decisions. During this study, we used designers, prospective consumers, experts, and different methods to solve this problem. In the next chapter, we found out key factors related to aesthetics.

Chapter 6: Understanding and studying the key cognitive factors that influence the product aesthetics.

In this chapter, we thoroughly did a factual analysis and study related to the key contributing factors which impact the product aesthetics and affect the perception of consumers and designers. In this study, we conduct various open-ended, closed-ended, laboratory experiments with a large population of users, experienced industrial product designers, use various techniques, approach, and sophisticated equipment to generate an optimum methodology which can support designers to generate an aesthetically improved product.

Chapter 7: Evaluation

This chapter describes the use of various quantification techniques and approaches to assist product designers in improving product aesthetics during the product development phase. The usefulness of the proposed techniques for assessing product aesthetics is evaluated in terms of product aesthetics with the assistance of experienced designers.

Chapter 8: Conclusion and Future Scope

This chapter delivers the conclusions from this research study and suggests the directions for further research work in future.

1.5. Chapter Summary

Product design is an essential part of the product development process, and product aesthetics is the key factor in product design. Product aesthetics affects prospective consumer behaviour, and product development as well as industry success. In previous research, more focus is on the usability and functionality part of the product, but very little on the enchantment of product aesthetics. Some work was conducted on assessing product aesthetics using various qualitative techniques. In this study, we are taking the help of an experimental approach, open-ended surveys, closed-ended surveys, and different decision-making techniques to explore the various assessment criteria of aesthetics and try to enhance the product aesthetics, which can support the designers during the designing of new products.

In Chapter 2, the literature is reviewed to analyze the state of the art of knowledge in the product design and aesthetics domain to find out the research gaps that need to be filled by making specific research objectives.

CHAPTER 2

LITERATURE REVIEW

In this chapter, we discuss previous research and academic understanding associated with product design, aesthetics, and the enchantment of product aesthetics, how consumer desires were related to or different from the industrial product designers' perceptions, and how till will play an essential role during purchasing and designing of a new product. At the same time, we review various techniques, methods, concepts, and practices considered to date or incorporated while designing a new product. As a result of the literature review, the research gap consistent with the study will be found.

2.1. Review Methodology

By identifying keywords, using databases, bibliometric analysis, and network analyses, one can undertake a systematic literature review. The chosen articles are then critically examined to determine research gaps. The review methodology is presented in Figure 2.1.

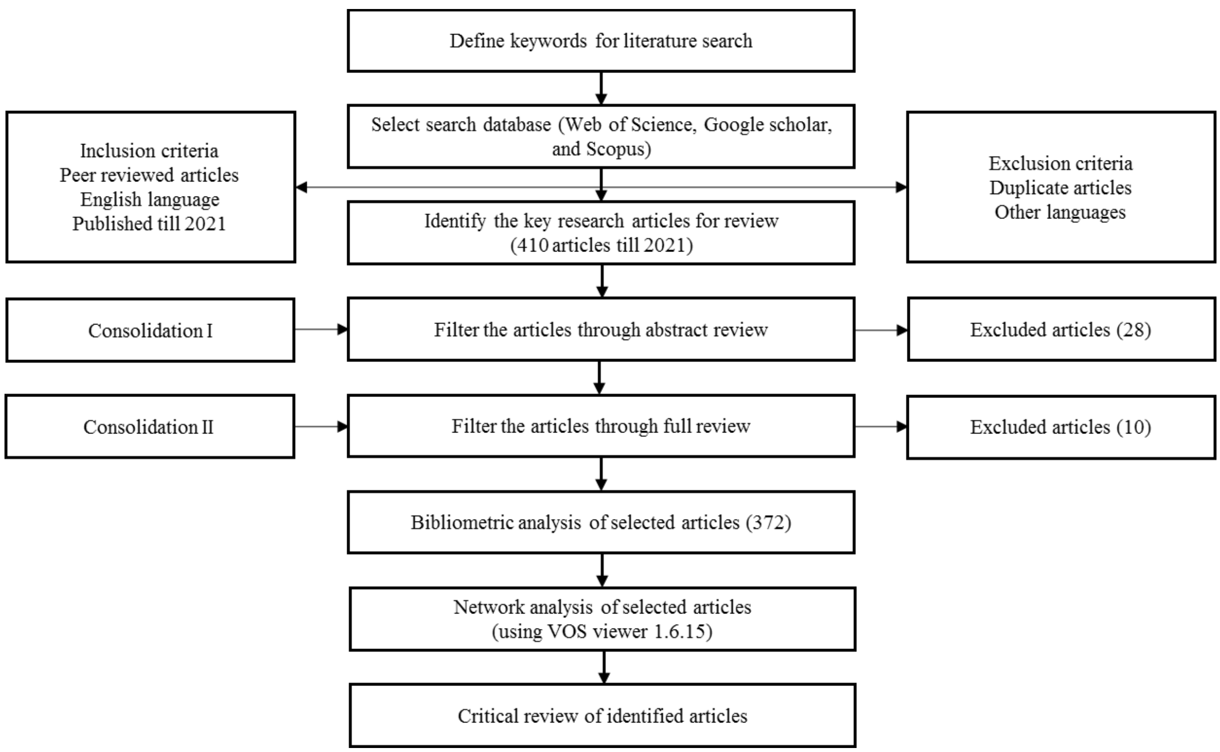


Figure 2.1. The review methodology

2.1.1. Defining keywords

The set of keywords (i.e., search strings) used for searching the articles in the Web of Science database, Scopus, and Google Scholar are: (("product aesthetics design" or "product-design" or "aesthetics" or "aesthetics design" or " product-aesthetics") and ("technique" or "method" or "tool" or “support” or “assessment” or "consumers" or "designers” or “experiments" or “equipment” or “factors” or “variables” or “attributes”)). The pieces must only have been published in journals and had to be in the English language.

2.1.2. Initial search results

Initially, the majority of publishers only use English for academic research, the first search was made for articles written in this language. The search did not include any works that were published in other languages apart from English. Through the initial search, 472 items are initially selected. The search was continued till the end of year 2019. These research articles belong to the wide-ranging research domains, such as, ‘Product Design,’ ‘Industrial Engineering’, ‘Consumer Behaviour’, ‘Product Aesthetics’, ‘Eye-Tracking’, and ‘Human computer Interaction, and Eye-Tracking.’

2.1.3. Refining the search results

According to Sangwa and Sangwan (2018), abstract reading is carried for refining the publications based on the pertinent study area. After reading the abstract of articles, 28 publications are excluded which do not focus either on the product aspects, aesthetics, or a combination of eye-tracking and product aesthetics design aspects. 10 articles were also excluded after a thorough study of each one since they were deemed unrelated to the field of product aesthetics design. As a result, 372 articles have been finalized for a thorough study to determine the research gaps in the pertinent field of study.

2.2. Bibliometric analysis

The affiliation, authorship, citations, publication source (journal), and nation of the chosen literature are examined using bibliometric analysis. A.csv file containing information on the reference research papers, their citations, and their references information is moved from the “Web of Science database, Scopus, and Google Scholar database", VOSviewer, and the “Microsoft Excel software” programme is then used to filter and analyze the data.

2.2.1. Initial data analysis

Figure 2.2 illustrates how research articles have changed throughout time. It demonstrates how the study of product design and aesthetics, which is ongoing, began to attract attention in the beginning of 2010 and has been progressing gradually ever since.

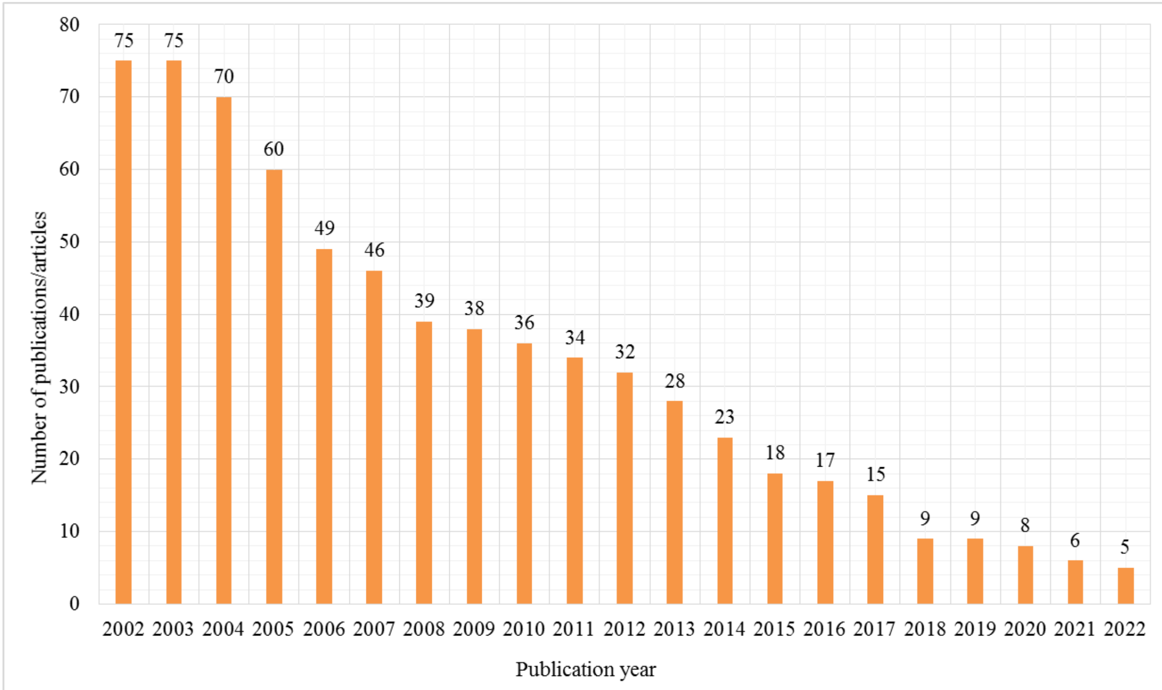


Figure 2.2. Shows that list of publication per year

It is clear that there is a huge increase in the rate at which articles are published. It can be attributed to the worldwide concern over product design and its acceptability for the success of any product and their company in this highly competitive market. Table 2.1 displays the publishing of these articles, which were published in various journals. These journals are chosen based on the requirement that they have at least five papers published in the pertinent study area.

Table 2.1. List of articles published in journal

Serial Number	Publication Titles	#Articles
1	Design journal	18
2	International journal of design	14
3	Journal of product innovation management	12
4	Design studies	11
5	Psychology marketing	11
6	Psychology of aesthetics creativity and the arts	11
7	Behaviour information technology	10
8	International journal of industrial ergonomics	10
9	Journal of product and brand management	10
10	Sustainability	9

2.2.2. Author statistics

Figure 2.3 includes a list of the top 10 authors that are currently writing and publishing articles in the area of product aesthetic design. As can be seen, “Jiao RJ” has published the second-highest number of articles (10), followed by “Wang Y” with 11 (highest number of articles).

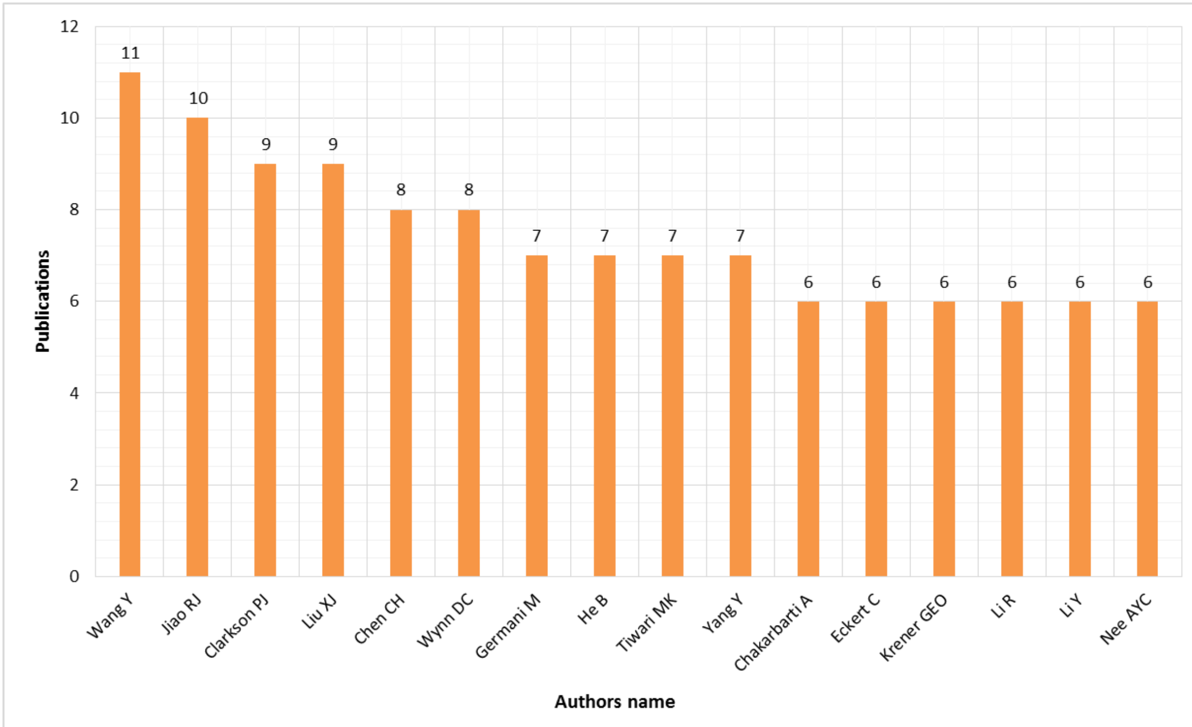


Figure 2.3. Includes a list of the top 10 authors

Also, the top universities which are contributing to the research in product design are shown in Figure 2.4. "Delft University of Technology" stands out to be the leading institute for publishing the articles (16), followed by "The Hong Kong Polytechnic University' with 14 articles.

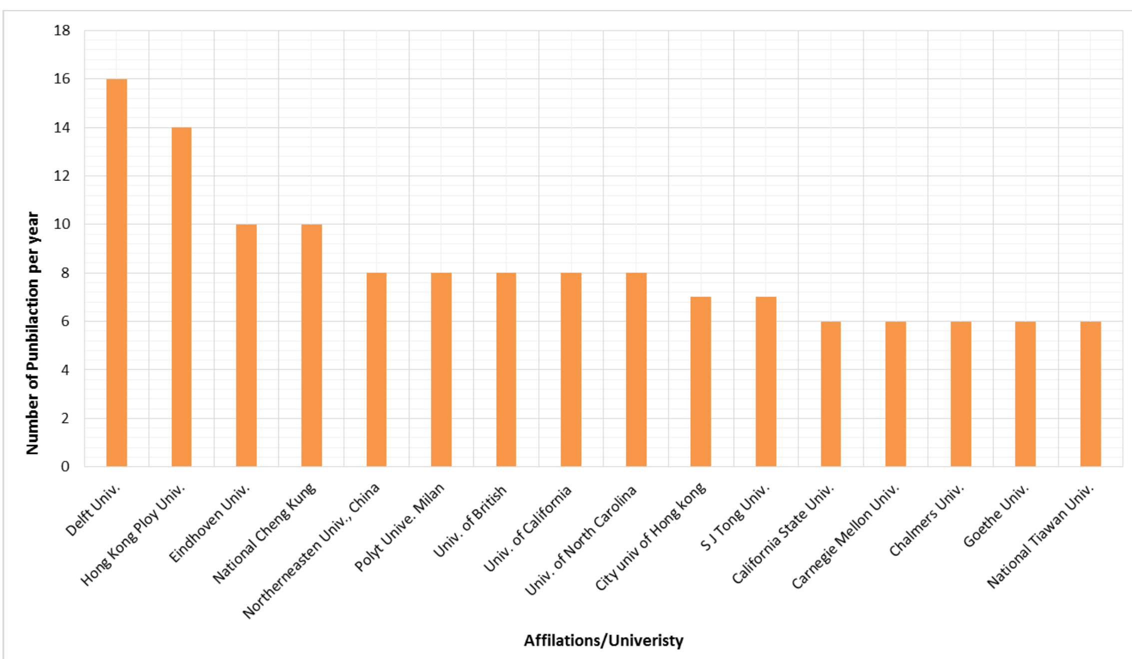


Figure 2.4. Top universities in research in the product design area

2.2.3. Country statistics

The country-wise publication of the articles is shown in Figure 2.5. It is clear from this figure that China and the USA are the two most contributing countries, with each having 30 articles published. However, the other countries, such as the United Kingdom and France, are not far behind with 29 and 28 published articles, respectively. It is interesting to see that India is placed at 16th position with 8 published articles in the relevant field.

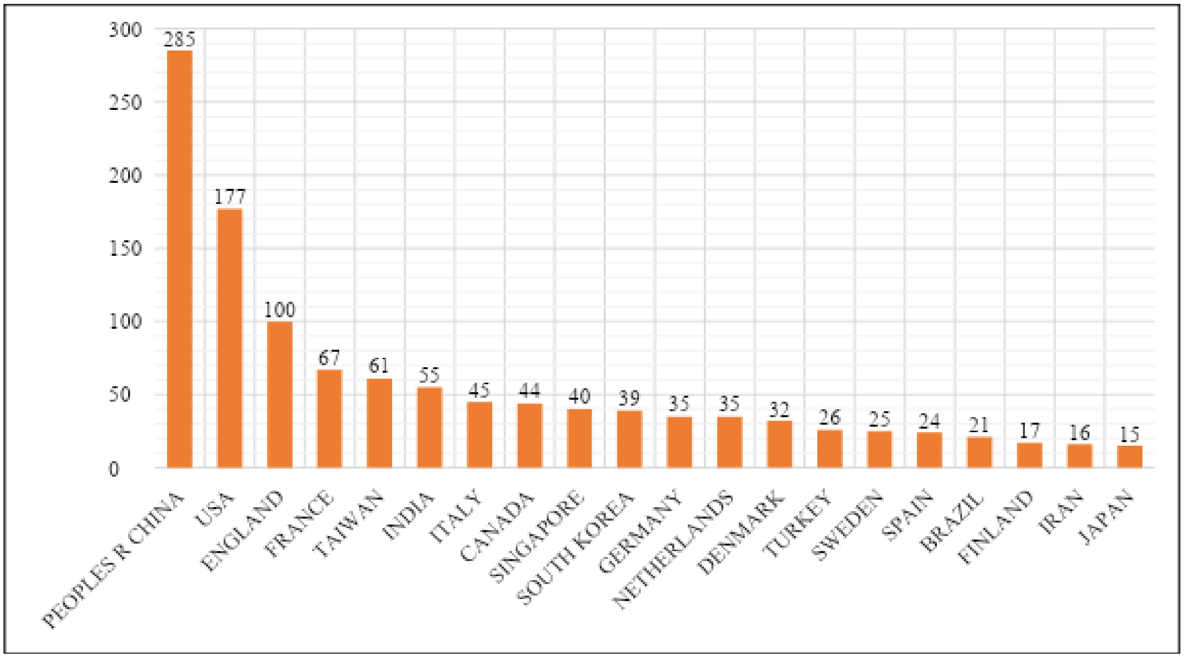


Figure 2.5. Shows that country-wise publication of the articles

2.3. Network analysis

This section presents the graphical investigation of citations and co-citations of the reference papers using network analysis. Network analysis is conducted to identify the highly influencing and linked authors, universities, countries, and publication sources of the relevant research by citation and co-citation analyses of the published literature. VOSviewer 1.6.15 software is used for this analysis. VOSviewer 1.6.15 uses a .csv data file as input which is generated from the Web of Science database, Scopus, and Google Scholar database. VOSviewer is preferred over Gephi, Pajek, and HistCite and other network analysis software because this software is user-friendly and useful for a moderately large number of items (Waltman et al., 2010).

2.3.1. Citation analysis

The number of citations received by a journal for a specific research topic shows its significance for that research area. A list of journals that received at least 250 or more citations in the area of product aesthetics design is presented in Table 2.2. It is clearly evident from Table 2.2 that 'Design studies' has the maximum number of citations (1006) followed by 'Journal of consumer research' with 857 citations. Although, the journal 'International journal of design' is placed at 2nd spot for published articles but receives 3rd position for citations.

Table 2.2. Journals with citations on product aesthetics design

Source	Citations
Design studies	1006
Journal of consumer research	857
International journal of design	748
Journal of consumer psychology	722
Journal of innovation and management	510
Journal of marketing research	486
Applied ergonomics	446
Journal of marketing	400
Psychology & marketing	366
Ergonomics	290

A list of countries having at least 500 or more citations on product aesthetics design is presented in Figure 2.6.

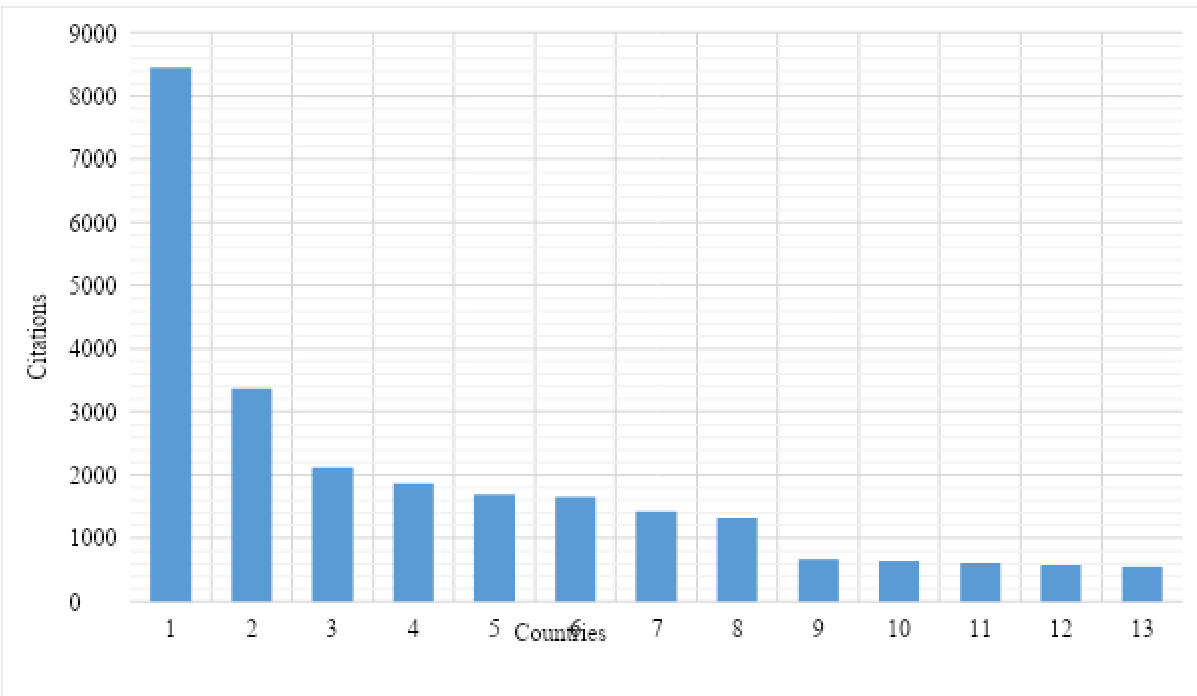


Figure 2.6. List of countries having at least 500 or more citations on product design

It shows that "USA" is placed at 1st rank with the most number of citations of 8454 followed by "England" which has 3367 citations. It is surprising to see that "Germany" and "China" are the top two countries with 1800 published articles but are ranked at 3rd and 10th places, respectively, for citations.

2.3.2. Co-citation analysis

This analysis identifies highly influencing authors and articles in the selected field of research and also investigates the connection among authors/articles using their co-citations. The map represents authors/articles with circles and their connections with the curved lines. The size of the circle shows the number of co-citations made by authors/papers. The thickness of the curved lines represents the strength of the co-citation among them. Figure 2.7 shows a co-citation map of the authors who are highly cited by the other authors working in the same research area.

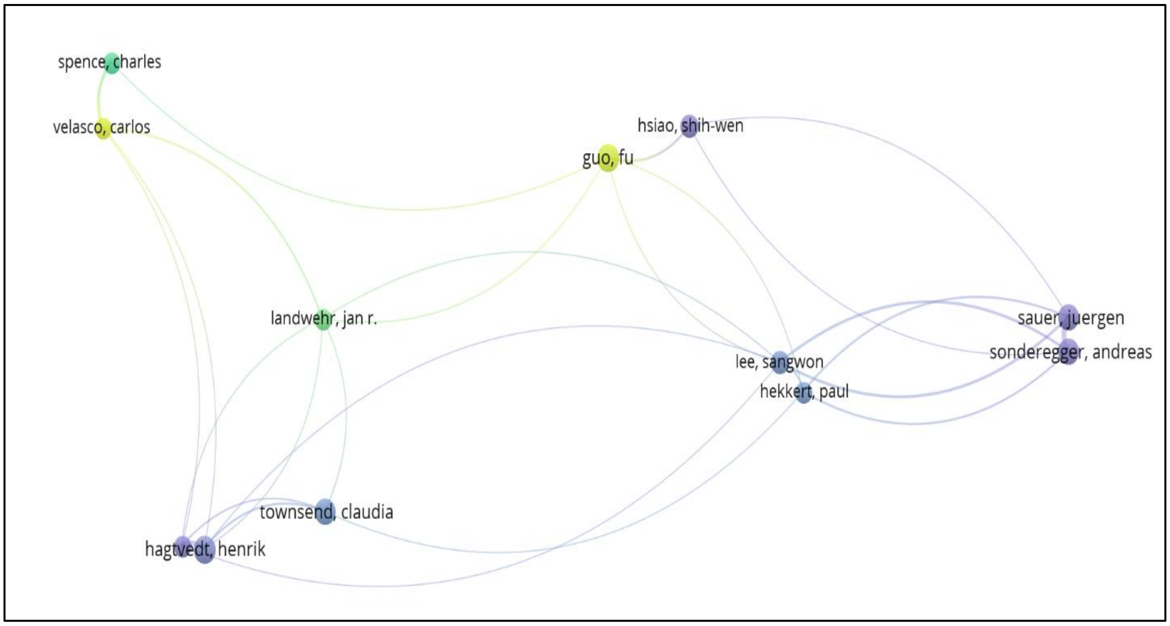


Figure 2.7. Co-citation map of authors

It can be observed that 'Henrik Hagtvedt' achieves the biggest size of the circle, which indicates that 'Henrik Hagtvedt' is the highest co-cited author. Other highly co-cited authors are 'Paul Hekkert,' and 'Andreas Sonderegger'. The line joining the authors 'Shih-wen Hsiao' is very thick, which shows a high co-citation strength between these three authors. This strength represents their co-authorship in research articles as well as the co-citations of their individual articles (not co-authored). Figure 2.7 signifies that the authors who are present in this figure have played a key role in the development of research on ecodesign.

2.4. Critical review of literature

In this section first we understand the basic concept of product design, aesthetics, essential qualities of aesthetics, followed by design elements, human cognitive psychological theories, color theory, Gestalt theory, and then we discussed various previous research works related to the assessment of product aesthetics. In this phase, we discuss some previous important research studies on product design, aesthetics, human cognition, and color theory. And, then we identify the vital research gap and formulation of the research question.

2.4.1. Product design and their current status

“Product design” defines the process of creating, imagining, and repeating products that resolve user’s issues or meet particular needs in a specific market is referred to as product design. Understanding the real consumer need, the individual for whom the product is built, is essential for successful product design. Industrial designers put their effort into resolving the real problems for human beings by using their knowledge and sympathy for their potential customer’s behaviorial requirements, desires, frustrations, and habits. Product design, when executed ideally, is seamless to the point where its presence goes unnoticed. Consumers are able to use the product effortlessly and in line with their desires because the design process takes into account their needs and anticipates their usage. Good product design practices remain relevant throughout the entire lifespan of a product. It plays a critical role in creating the initial product offering and shaping the overall consumer experience, starting from user research prior to the ideation phase and continuing through “concept development, prototyping, and usability testing.” The process of improving the consumer experience and assuring the addition of additional functionality and abilities in a smooth, non-disruptive way and searching are continuing roles played by product design. Brand uniformity and development remain an essential obligation of product design till the end phase of the product. Additionally, it goes well beyond what consumers perceive from their screens. Consumers eventually perceive and interact with the interface design due to essential back-end elements called process design and system design.

Product design is a development of the closely related field of industrial design. Industrial design is a profession that involves creating items that are utilized on a daily basis by millions of people across the world. Industrial designers pay attention to a product's functionality, manufacturing process, experience, and the value it offers users in addition to its aesthetic. Before the advent of mass production, artisans created most things by hand. As a result, there were more expensive and scarcer products for sale. Later, industrialization made it possible for companies to produce goods in large quantities at low cost (Hekkert & Leder, 2008; D. Norman, 2002). Manufacturing companies engaged the aid of industrial product designers to produce practical and aesthetically beautiful items to help sell their goods to the millions of humans who could now afford them. Product design is a division of industrial design that has grown into its own category over time, and it is because modern industrial design is associated with tangible goods like furniture, automobiles, phones, home appliances, etc. Contrarily, any product, including digital or virtual ones like software apps, can be referred to as having a product design. Additionally, it goes well beyond what consumers perceive from their screens. Consumers eventually perceive and interact with the interface design as a result of essential back-end elements called process design and system design. Product design supports industries to gain an additional competitive benefit and make a point of diversity. Precisely, the competitive reasons in the design domain are believed to be product aesthetics (Bloch, 1995a; D. Norman, 2002; Guyer, 2008; Sarkar, 2018).

Nowadays, examining how and why aesthetic designs affect consumer's decision-making has been a popular research topic in light of this growing managerial importance (Cox & Cox, 2002a; Hoegg et al., 2010; Landwehr et al., 2011). Product perception, user preference, and experience can strongly influence product design (Bloch, 1995a; Crilly et al., 2004a; Creusen & Schoormans, 2005a). As product designers are accountable for forming products to generate specific reactions (Crilly et al., 2009a), various research has been done to determine the effects of different product features. Specifically, several research finds that unity (Veryzer, Jr. & Hutchinson, 1998a; Post et al., 2013) affects customers' aesthetic inclination. It has been shown that visual complexity influences how consumers judge environmental friendliness (J. Lee et al., 2015) and product usability (Creusen & Schoormans, 2005a). Consumers' preferences for aesthetics (M. Kumar & Garg, 2010b) and how well they judge a product's performance (Mugge et al., 2018) are both influenced by harmony. Previous research work has also examined the various product personality attributes that can be expressed by product designs (P. M. A. Desmet et al., 2008; Mugge et al., 2009) and the effects of these attributes on customers' thinking of "product performance" quality (Mugge, 2011). Additionally, various toolkits have been developed to support the product designers, such as for a selection of materials (Rognoli et al., 2015; van Kesteren et al., 2008) and for styling activities (Barnes & Lillford, 2009; Camargo & Henson, 2015).

2.4.2. Aesthetics concept

Visual aesthetics talk about a significance (Kieran, 1997) which can be subjectively interpreted (Crilly et al., 2009a) can be objectively calculated (Crilly et al., 2004a) or as a volunteer consumer reaction (Ulrich, 2006) as an external actuality (Khalid & Helander, 2006b). The objective phase is more intuitive (Crilly et al., 2004a), while the subjective phase of aesthetic is associated with the emotional characteristics of consumers or users (Khalid & Helander, 2006b; D. Norman, 2004). Whereas the human eye is getting information (Arnheim, 1969; Etcoff, 2000), it is an examined by the human brain (de Pontual et al., 2009) and then relates the information (Hekkert et al., 2003) with data (Coates, 2003) involves of users' or human's experiences (Hung & Chen, 2012) and understanding (Rojas & Kang, 2001), and with 'concinnity' "(concinnity means harmony in the arrangement of the different parts of something)" (Crilly et al., 2004a) it is centered around on pleasant principles (Hekkert, 2006). Thus, two kinds of reactions are created: cognitive (for example, remembering, reasoning, or thinking) and affective (emotional actions or feelings, or activities controlled by emotions) (Crilly et al., 2004a). Balance among these two opposite characteristics generates a favorable opinion of the aesthetic (Coates, 2003). Specifically, the physical look of a product is perceived as pleasurable when it is capable of pleasing a customer/user in logical as well as sentimental sides of aesthetics (Bloch, 1995a; Jacobsen et al., 2006), which are connected to the design principles (Kostellow, 2002) human factors (Jordan, 1998a) and as a part of product concinnity (Crilly et al., 2004a), and product characteristics (Shank & Langmeyer, 1994; van Breemen & Sudijono, 1999) usability (Sonderegger et al., 2012; Tuch, Roth, et al., 2012b) and as a part of product functionality (Verma & Wood, 2001). Cognitive features generates 'beauty' (Coates, 2003; Crilly et al., 2004a), and Behavioural features of aesthetics creates 'attractiveness' (P. Desmet, 2003; D. Norman, 2002) as the key integral elements of aesthetics (Khalighy et al., 2014).

2.4.3. Role of aesthetic

According to Baxter (1995), aesthetics is one of the three essential components in product design, along with manufacturing cost and function. According to Clark (2000), Hanna (2010), and Ranscombe et al. (2012), aesthetics has received significant attention as a determining factor (Kieran, 1997) for determining the success of a product in the current market (Rafaeli & Vilnai-Yavetz, 2003; Perks et al., 2005). In other meanings, quality of aesthetic is a main factor in increasing the consumer/user contentment (Yamamoto & Lambert, 1994; Fynes & De Búrca, 2005; Swift, 2010; Ranscombe et al., 2012b). As Lee (2018), highlights the character of beauty in the success of a product. Further, Norman (2004), demonstrates that the attractive look of any product is the main intention for bringing out the positive impersonation of the product. Similarly, Ulrich (2006) expresses aesthetics as an initial reaction to any product that can persuade a customer/user to buy or not buy the product in just a few seconds. Robert (1995), in their study, described that for recognition of any product, the aesthetics of a product is one of the crucial factors. Similarly, Bloch (1995a) states that aesthetics can enhance consumers' opinions of product features. Further, Verma and Wood (2001)**,** mentioned that aesthetics also almost work together with function; therefore, some other authors also believed that attractive and beautiful products work in a better way (Tractinsky et al., 2000; D. Norman, 2002). Schindler & Holbrook (2003), believe that aesthetics is one of the prime factors influencing consumers' final purchase decisions. Lai (2005a) explains that a product with aesthetics can be famous and successful even if it does not have good qualities, technology, and function. Perception of a product is completely changed with the help of aesthetics (D. Norman, 2004). It can also help in improving manufacturing and functional quality. Tuch & other authors (2012), described in what way improvement of the aesthetic will result in enhancement of the functionality. Thus, it is usually assumed that aesthetics has an integral part in improving the success of products and the quality of product design. Bloch et al. (2003) distinguished that a product includes a large variety of characteristics, containing "production efficiency, ergonomics, production efficiency, recyclability, strength, and ease delivery, along with aesthetics". According to Simonson & Schmitt (2014), the effective use of aesthetics might potentially foster a favourable perception of the brand and its organisation. In addition to adding value, this strategy satisfies customer aesthetic preferences. Furthermore, the importance of aesthetics in the realm of product design is generally acknowledged. Notably, research by Veryzer, Jr. & Hutchinson (1998) found that in the field of product design and aesthetics, unity (i.e., the coherence of design elements) and prototypicality (i.e., how well an object represents a category) have a positive influence on aesthetic evaluations. Aesthetics comprises one's cognitive reactions to particular objects and shapes and is considered an integral feature of product design (Heitmann et al., 2020; M. Kumar & Garg, 2010b; Veryzer, Jr. & Hutchinson, 1998a). In the meantime, visual aesthetics refers to customers' insights of the product's beauty and the physical feeling of satisfaction that it suggested (Bhandari et al., 2019; Moshagen & Thielsch, 2010). From a non-practical perspective (Baskerville et al., 2018), visual aesthetics is objective (against subjective) and replicates a comprehensive gratitude (against the influence of precise design aspects). Although the critical method to aesthetics (Hassenzahl, 2008) supports the general confidence that complete beauty be present, fresh research work accept that "beauty lies in the eye of the beholder", and as a result, aesthetics consider as subjective (Baskerville et al., 2018; M. Kumar & Garg, 2010b). Therefore, a design can be highly aesthetic to one person but not to others, as visual aesthetics is based on psychological mechanisms reflecting individual and detailed features (M. Kumar & Garg, 2010b). Therefore there is a need to discuss the importance of beauty.

2.4.4. Beauty

What is beauty? And, what creates for an appealing painting, beautiful face, delightful scenery, or pleasing design? This enquiry has been discussed from more than two century's and has been already stated a large number of responses (Robert W., 1995; Tatarkiewicz, 1970). Aesthetics is differently explained as beauty in look (Lavie & Tractinsky, 2004), a process (Osborne & Langer, 1984), an experience (Ramachandran & Blakeslee, 1999), a property of objects (Porteous, 2013), an attitude (Cupchik, 1993), a judgment or a response (Hassenzahl, 2004a, 2004b), and visual appeal (Lindgaard & Dudek, 2003). In philosophy, 'beauty' is an old subject. Early academicians from philosophy field, suggested that "beauty is an objective" property of any products, although some time academicians proposed that it is more of a personal/subjective experience activated by product/objects (Hassenzahl, 2004b; Hekkert, 2006; Porteous, 2013). Many academic philosophers, seeing back as a minimum to Plato, "saw beauty as a property of an object that produces a delightful experience in any appropriate perceiver" (Tatarkiewicz, 1970). Among the concede features are proportion and balance (Arnheim, 1974; Birkhoff, 1933; Gombrich, 1995), contrast (Gombrich, 1979, 1995; Solso, 1997), symmetry (Arnheim, 1974; Birkhoff, 1933; Gombrich, 1995; Humphrey, 1997). On the other hand according to Tatarkiewicz (1970) anything is beautiful which our senses. In view of most modern philosophical, "a sense/judgement of beauty arises from arrangements in the means various persons and objects communicate (Merleau-Ponty, 1964; Kaelin et al., 1986). In the perspective of philosophical attention to the world's direction, "beauty is identified with its quality of orderliness, i.e., keep things, objects or something else in well-planned order, well organized, proper or symmetric pattern, and pleasantness. The term aesthetics describes the overall pleasure that a human being recognizes/collects through the sensory objects' characteristics (Y. Liu et al., 2017) and the observation of object beauty (Hoegg et al., 2010). According to Hassenzahl (2008), the judgmental viewpoint to aesthetics encourages the general acceptance that complete beauty exists, present day studies concur that "beauty lies in the eye of the beholder", and hence, "aesthetics can be subjective" (M. Kumar & Garg, 2010b; Baskerville et al., 2018). A study of aesthetics within the business environment involves a strange reactance. Appreciation of art and the perception (five different types, i.e., touch, smell, taste, sound, and vision) of beauty appears at difficulties with the essential goals of profit-making and efficiency (Baskerville et al., 2018; Hekkert, 2006).

In 1790, Immanuel Kant described the relationship between beauty, taste, and aesthetic knowledge (Guyer, 2008). Robert Solomon also describes the perception of Kants by observing that aesthetic understanding involves a frequent movement among the imagination and cognition with individuals "enlivening one another " (Solomon, 2002). In western world, art is more involved in the visual domain and as of this, the perception of aesthetics has been more used as synonymous for the "visual beauty" (Guyer, 2008). Amidst the involvement of professionals from diverse backgrounds in the fields of graphic design and computer science interface, the fundamental distinction between the two forms has remained ambiguous. Some individuals attempt to establish a framework by identifying and defining the key characteristics of beauty, which may include elements like regularity, balance, proportion, and rhythm (Ngo & Byrne, 2001). In general, studies in aesthetics can be categorized into two approaches: those that investigate how objective and perceptual characteristics of products contribute to beauty (bottom-up), and those that explore how the subjective meaning of objects influences beauty (top-down) (Hassenzahl, 2004b). Several philosophers, tracing back at least to the time of the Sophists, have proposed that any product, whether tangible or intangible, can be considered beautiful if it pleases the senses in some way (Tatarkiewicz, 1970). From this viewpoint, "beauty is a purpose of idiosyncratic characteristics of the eyewitness and all attempts to recognize the laws of beauty are fruitless". This subjectivist perspective, cogitate in words like "beauty is in the eye of the beholder", motivates the social constructivist weights on the traditionally changing and culturally relative nature of beauty (Kubovy, 2000).

2.4.5. Beauty and Aesthetic Pleasure

Philosopher Santayana (1896) defined beauty by using three features: positive, objectified, and intrinsic (basic/natural nature), and according to them, beauty is the feeling of satisfaction observed as the attribute of a thing. This definition defines "beauty as a value", and this means it is not the ability to "understand a relation" or a "matter of fact". This definition is similar to the "Thomas of Aquinas" definition i.e. "what provides a feeling of satisfaction or being happy at sight" suggesting instant joy without in-between reasoning (Scott, 2012). Lastly, "beauty is objectified." For instance, the feeling of having a chilled soft drink on a summer day is mutually intrinsic and value positive, on the other hand, this instant enjoyment or feeling of satisfaction or being happy lies purely in a constructive feeling of the body and is a very small thing to ensure with aesthetic gratitude of the product. In comparison, human beings look at wall painting in an art gallery not just to give pleasure to their body, nonetheless to enjoy the beauty of wall painting. Therefore human beings feel beauty as something which beholds in the product. For that reason, "beauty is not an "objective," but an "objectified" assets" (Audi, 1995). Beauty is defined in terms of objective features of any stimuli, for example symmetry, quantity of information, contrast, clarity, and figure (Santayana, 1896; Kostellow, 2002; Hekkert, 2006; Scott, 2012).

Philosophers of aesthetics have extensively measured contrast as an "objective" factor of beauty (Gombrich, 1995; Solso, 1997). Though fluency is commonly a relationship between two quantitative with objective characteristics, flow is the prognostic variable when both are juxtaposed. Thus, identical patterns are rated more favorably when presented with vertical rather than horizontal symmetry (Palmer, 1991), reliable with the opinion that vertical balance facilitates processing (Royer, 1981). Likewise, high contrast improves fondness for designs shown concisely, but not for patterns displayed for a long time (Reber & Schwarz, 2001). Furthermore, objectively the same stimuli are assessed more constructively once their processing is aided along the priming process (Reber et al., 1998; Musch & Klauer, 2003). In conclusion, we recommended that their effect on processing flow conciliates the impact of objective characteristics. Beauty describes the link/correlation among the design elements' competence is physically perceived as lovely (Kostellow, 2002). Beauty is "absolute" (Coates, 2003), "timeless" (Etcoff, 2000), "independent of function" (D. Norman, 2004), "rational" (Khalid & Helander, 2006b), and "absolute" (Coates, 2003).

2.4.6. Beauty

In western countries, art is more involved in the visual domain, and the perception of aesthetics has been used as synonymous with "visual beauty" (Guyer, 2008). Santayana (1896) defines beauty by using three features value positive, objectified, and intrinsic (essential/innate nature) are not as many technical words; Beauty is the feeling of satisfaction observed as the attribute of a thing. This definition defines "beauty as a value," and this means it is not the ability to "understand a relation" or a "matter of fact". The main ability of beauty is basically created from some key factor which makes human eyes capable of distinguishing physical design elements. This factor is called 'contrast' which is collected of proportion and pureness. According to Coates (2003), Contrast is produced because of dissimilarity among various design elements which is a source of visual acknowledgment. The reason for the difference is the collection of qualitative and quantitative factors: in what way the elements are different and by what means different elements. A recurring theme in aesthetics is the balance of order and complexity. For example, it is this balance referred to in Coleridge's notion of beauty as "unity in variety." The biggest question is what we mean by beauty? What creates an appealing painting, beautiful face, charming scenery, or pleasing design? For the last twenty-five centuries, this question has been discussed among all the researchers from different domains, industrial peoples, consumers, etc., and a vast variety of answers has been coming out (Tatarkiewicz, 1970; Audi, 2015). Several philosophers, such as Plato, say beauty is an asset of a product that makes a delightful exposure to any appropriate observer (Tatarkiewicz, 1970). This objectivist opinion encouraged numerous emotional efforts to recognize the key providers of beauty. Among the recognized structures were regularity (Birkhoff, 1933; Arnheim, 1974; Gombrich, 1995; Humphrey, 1997), proportion and balance (Birkhoff, 1933; Arnheim, 1974; Gombrich, 1995; Pittard et al., 2007), complexity and informational content (Garner, 2014; Hogan, 1978; Tuch et al., 2010; Washburn, 2022), along with clarity and contrast (Gombrich, 1995; Hughes, 2022; Uriely, 1997). In the 16th century, the objectivist opinion related to beauty mattered a lot that artists presented design books and provided a subscription to pictorial elements that artists possibly will mimeograph and merge with everyone to compose beauty (Gombrich, 1995). Tatarkiewicz concluded from other philosophers' research that whichever object pleases your senses is considered as beautiful (Tatarkiewicz, 1970). From this viewpoint, beauty is a meaning of idiosyncratic assets of the observer and all best endeavor to recognize the rules of beauty are useless. This subjectivist opinion shown in words like "beauty is in the eye of the beholder" underlies the public constructivist importance on beauty's factually changing and traditionally comparative nature (Reber et al., 2004).

According to modern philosophical researchers and analysist a logic of beauty appears from various shapes/outline/designs/arrangements in such a way consumers and products narrate (Merleau-Ponty, 1964). Merleau (1964), discussed that energizes social practices (such as cooperation, competition, and conflict) from consumers or human-being interaction and look to categorize those forms/patterns/outlines. As discussed later, "To put it simply, how our feelings and thoughts react to a thing's features determines whether we find it beautiful. Our perception of beauty is linked to the thoughts and feelings it arouses, and this connection can endure over time." Santayana (1896) defined beauty in three features: "beauty is intrinsic, value positive, and objectified". From intrinsic and value positive, authors signified that beauty delivers happiness/delightful, not considering any line of thought related to estimated usefulness. It is identical to "Thomas of Aquinas' ' definition related to beauty: "immediate joy without intermediate reasoning" (Rader, 1966). Similarly, Reber (2004), an art historian states that human being either "like or appreciates any product at first sight or not at all." Therefore, we can consider beauty as an objectified quality. For instance, the experience of taking a hot coffee or drink in a winter day is equally intrinsic and value positive, however this immediate happiness/satisfaction remain completely in a "positive perception of the body" and "has slight to do with aesthetic appreciation of the product/body." On the other hand, a person who is looking at a painted canvas is not to satisfy their own body desires, however to appreciate/enjoy the painted canvas. Therefore beauty lies in the object as experienced by a human being. Hence, it is an "objectified" property as compared to an objective property (Audi, 2015).

In this study, this philosophical thought is considered and describes beauty as an enjoyable subjective practice in the direction of a product and not conciliated by intervening thinking. It approximately matches the description of aesthetic understanding considered in observed or pragmatic aesthetics (Martindale & Moore, 1988). Martindale (1988) also explains the relationship between aesthetics and the positive effects of stimuli. In their study, they attempt to decipher how design elements, color, and category influence consumers' aesthetic responses. Rarely any research scholars during psychology and aesthetics study are asked to review/judge "beauty" per se. Alternatively, maximum work has concentrated on decisions like pleasantness, figural heavens, preference, and liking. Some of them are surprised that these highly modest findings express the grand kingdom of beauty. Many academic scholars, by investigating or considering these simple findings, can find out the root of the simple method/fundamental of the aesthetic experience. Hence, there are motives to have faith in findings that liking, beauty, and preference are closely associated.

Human being value/admire beauty: Over a sequence of investigation, Diefenbach and Hassenzahl (2011) confirmed that human beings convey a solid inclination for beauty when choosing products; nonetheless, they are hesitant to devote themselves to such objects and tend toward those that look to be useful, above all. According to authors (Diefenbach & Hassenzahl, 2011), adoring beauty is adamantly defended due to its "soft" quality and subjective nature. In this study, we discussed the sense of beauty, which is quantifiable with the help of different design elements. Before discussing beauty, we first must define what we think about "design aesthetics." "Aesthetics is an ancient concept rooted in the Greek word aesthesis, which may be translated as an understanding through sensory perception." From Plato to Aquinas, Aquinas to Kant, and beyond, beauty has usually been observed as a typical example of aesthetic quality. Therefore, relatively naturally following "Socrates'" approach in "The Meno", "we are tempted to simplify from our analysis of the nature and value of beauty, a particular aesthetic value, to an account of aesthetic value generally" (Kieran, 1997). "We can derive pleasure from various things presented to us, even if they are not conventionally considered beautiful, such as the humorous and the sorrowful, which we still desire to categorize as aesthetic." Therefore, a general characterization is required to grasp the essence of aesthetic value. The typical way is to consider a similar clarification method, where beauty was considered the essential example of aesthetic value to develop a common account of aesthetic quality. The classic explanation provided by Beardsley finds out in aesthetic value, in standard which changes from the good-looking to the tragic or comic, in the complexity, proper unity, and potency of a product's suitable for the occasion and cognitive characteristics (Kieran, 1997).

Determinants of Beauty: In the above literature, we study related cognitive psychology, experimental aesthetics, and social psychology bearing different factors that impact beauty. For that, an "objective" topographies of stimuli is considered or discussed for instance "symmetry", "quantity of information", "clarity", and "figure ground contrast".

Objective Topographies of Stimuli - Quantity of Information: The idea that the amount of information plays a significant role in beauty has a long history within the field of aesthetics (Arnheim, 1974; Gombrich, 1995). Gestalt theory is the main or basic criteria to start the research in psychology or in product design domain. Some early academic researchers concentrated on stimulus arrangement and stated that suggested "goodness" of the stimuli determined by the relation among the psychological mechanisms and stimulus arrangement (e.g., (Koffka, 1935). Consequently, study in the Gestalt practice has greatly active towards the quantity of information characterized in a stimulus, persistent with the existing assumption that "beauty" live-in in the product (Hochberg & McAlister, 1953; Attneave, 1954).

2.4.7. Aesthetics and its aspects in product design

According to Baxter (1995), the design process of product function, aesthetics of a product, and manufacturing process of a product produce the three most crucial pillars of the product design triangle. These three features interact with one another in which enhancing the functionality and manufacturing quality will leads in aesthetic improvement (Cawthon, 2007; Sauer & Sonderegger, 2009; S. Lee & Koubek, 2010; Sauer & Sonderegger, 2011; Seva et al., 2011). Aesthetics include non-visual and visual aspects (Veryzer Jr, 1993; MacDonald, 2001; Bloch et al., 2003). In this work, we mainly consist of 'visual' features of aesthetics.

2.4.8. Visual aesthetics

Aesthetic value (Kieran, 1997) that can be objectively assessed as an outer actuality (Crilly et al., 2004a; Khalid & Helander, 2006b), and it can also evaluate in a subjective way (Crilly et al., 2009b). In the above section, we discussed about beauty's subjective and objective aspects in product design. According to Crilly (2009b), a tangible product can be described by its dimensions, geometry, textures, colors, materials, detailing, and graphics. Features, for instance, the style, persona, and perceived novelty of the object, are not taken as the features of the object as they are not objective characteristics of the product design. The style, persona, and perceived novelty of the object, are shown as parts of the customers' cognitive reaction to the object/product. The psychological response, states that the decisions that the customers or user makes about the object built on the data received by the perception. These judgments contain an assessment of the object's apparent abilities. In existing literature, several different approaches are taken to describe a response to a particular design. Different techniques such as "Questionnaire-based techniques using different scales to measure symbolic association and aesthetic impression (Farina, 2001; Jordan, 1998; Mahlke, 2007), and cognitive models like signs and metaphors is utilized for the presentation of the product's capabilities for targeted semantic interpretation (Baxter, 1995; You & Chen, 2007)" is used to define the object design. These three qualities such as symbolic association, aesthetic impression, and semantic interpretation are cognitively motivated equally by the insight of pre-existing knowledge and physical stimuli. People observe products and perceive them as physically appealing, visually captivating, attractive, and displaying elegance (H.-C. Chang et al., 2007a; Hekkert & Leder, 2008; J. Singh & Sarkar, 2022, 2019). Many times the process of perceiving the product is often enjoyable; this type of optimistic aesthetic feeling often started interest among art theorists, philosophers, and design researchers for many years. Even though a lot of research has been going on beauty for many years, still there is no common statement that tells, what beauty is or what are the constituents of beautiful products. Baxter (1995) states that the intrinsic attractiveness of physical shape/form is "that most intangible and elusive quality". In spite of that, various aesthetic theories and principles offer a proper core foundation. Most early researchers in the domain of beauty believed the viewpoint that eye-catching features exist within the product itself. The subjective face of aesthetics is associated with the emotional characteristics of customers (D. Norman, 2004; Khalid & Helander, 2006b), and the objective face of aesthetics is relatively highly natural (Crilly et al., 2004a). At the same time, the human being collect information through their eyes (Arnheim, 1969; Etcoff, 2000). They analyzed this information through their minds and relate it to the consumer understanding and "concinnity" ("concinnity means harmony in the arrangement of the different parts of something") (Crilly et al., 2004a; Hekkert, 2006; Hung & Chen, 2012). Their knowledge, which is established on pleasurable principles. As of this, two kind of reactions emerge: Affective and cognitive. Striking a harmony in the middle of these diverging components results to an effective evaluation of aesthetics (Coates, 2003; Crilly et al., 2004a). Further, the physical look of any object is perceived as pleasurable object when the object is capable of pleasing a human from both an emotional perspective and rational perspective aesthetic standpoint. Most of the earliest beauty researchers believed that an object's attractive qualities were inherent. The stimuli under consideration were regarded as possessing an objective property of beauty. There was a belief that certain angles, ratios, shapes, and colors were naturally beautiful. This method implies that every object will have a perfect shape that, once obtained, will typically be viewed favorably by all (Coates, 2003; Cupchik & Laszlo, 1995). The reflection of product objective qualities spins about the "degree of contrast" that a design displays in association to its own background and elements, which is identified by means of the combination and interplay of different design elements (Kostellow, 2002). As an example, when products display a significant variation in color in comparison to their adjacent environment and integrate a wide-ranging array of lines, shapes, and textures they will exhibit a significant degree of contrast. This relationship to design principles is interconnected with the sensory experience of a well-structured design, encompassing factors such as functionality, usability, human factors, and product features (Jordan, 1998a; Verma & Wood, 2001; Crilly et al., 2004a; Jacobsen et al., 2006; Crilly et al., 2009b). Behavioural phase of aesthetics produces cognitive phase generates "beauty" (Coates, 2003;

Crilly et al., 2004a) and “attractiveness” (D. Norman, 2002; P. Desmet, 2003)**,** as the key essential features of product aesthetics (Khalid & Helander, 2006b).

2.4.9. Potentials of attractiveness

Attractiveness: Attractiveness is an indicator of aesthetic assessment, and it is an expressive response to any object or product with aesthetic importance that is supposed to be carefully associated with an eyewitness's hedonic feelings (Marin et al., 2016; Martindale et al., 2018; Rahal & Fiedler, 2019). “Metaphors are frequently used in greeting cards, posters, and ads (McQuarrie & Mick, 1996; van Mulken et al., 2010; Gao et al., 2017). Because of their intrinsic perceptual incongruence, metaphors can arouse emotional and aesthetic responses (Tendahl & Gibbs, 2008)” Metaphors connect many thoughts or ideas by moving beyond literal language. Metaphors add depth and complexity to communication by clicking one picture with another, frequently using figurative language. This depth of significance captures the audience's imagination and elicits strong feelings. The impacts of metaphors were especially explored within a female-to-male complementary paradigm in study (Gao et al., 2017). The research's conclusions showed that metaphors were superior to the usage of precise and literal words in terms of their stunning appeal and attractiveness. Metaphors have a unique power to draw people in and make an impression that sticks. They provide a novel and inventive viewpoint that enables a more complex and moving expression of ideas.

In addition, it underlined that women illustrated a stronger tendency towards unique metaphors as compare to the traditional ones (Baskerville et al., 2018). This description reveals the significant function of metaphors, fostering attraction, and capturing attention particularly among female who are moved from unconventional to innovative expressions. The perception, judgment of art and beauty, and appreciation is the region of aesthetics. The realm of aesthetics is the perception, appreciation, and judgment of beauty and art. Aesthetic object has potentials “in accordance with principles of taste or artistic beauty; intended or giving to provide pleasure through beauty; of pleasing appearance” (Baskerville et al., 2018).

Perception of function (appropriateness): Aesthetics is concerned with the functionality and concinnity of the product. Further beauty is linked to the concinnity and the attractiveness is related with functionality (Yadav, Jain, Shukla, et al., 2013a). On the other hand, attractiveness or unattractiveness is the perception that is developed through the product's aesthetic impression. In the early 21th century, Coates (2003) described their own theory related to the perception of product attractiveness. He positively describes aesthetics with concinnity and information factors. Concinnity is associated with logic and order (for example, in a proper way), which possibly supports the customer in understanding the product (Crilly et al., 2004, 2009). In addition, Coates (2003) also defines aesthetics as a combination of objective and subjective qualities. Objective qualities may be perceived as the quantity of “contrast” that a formation/design provides in opposition to within itself and its background. This depends on how specific design components are put together. For instance, objects that use a diversity of lines, shapes, and textures and are a starkly different color from the context in which they are observed will demonstrate great contrast. The innovation deemed in the design may be regarded as subjective information. This is mainly based on how far the product deviates from forms that the consumer is currently accustomed to. For instance, products that use shapes and lines drastically different from those typically seen attract curiosity because of their uniqueness. The two factors may consider the objective quality of product aesthetics; the first one is the amount of “Contrast” present by design (product) in contradiction to its background or surrounding itself, and the second is the “Order” perceived in the design. Subjective quality is concerned with the consumer's familiarity with the product and to what extent the design of the product makes sense to the consumers. This is determined by the customer’s personal, cultural and visual experiences that assist them in understanding the product. The consumer's personal interaction, cultural, and visual, plays an essential part in reaching a decision. Through their comprehensive knowledge of the product, customers engage themselves in a development of their personal creation. If the information is greater than concinnity, in that case, the product could be confusing, ugly, and meaningless. On the other hand, if the information is less than concinnity, the product will be boring and dull. That balance is required among shapes, forms, and functionality to create the attractive product. Beauty is produced from logical or rational physical appearance relations (Kostellow, 2002; Khalighy et al., 2012) in that a proper sense of balance among these relationships produces a most favorable pleasantness. The standard of beauty is primarily generated from the key element which makes human beings capable of distinguishing visual elements. To describe powerful and measurable essential features of aesthetics it is necessary to initiate with the very basic level. By imagining/visualizing a completely spotless or fresh or new painting board, the very first feature or thing that attracts any human being is a visual element of design elements and it is known as “contrast”.

2.4.10. Contrast

Kostellow (2002) defines the relationship between beauty and the different design elements. They also described how a product could be visually delightful using these elements. The visually delightful is one of the critical characteristics that come to designers' perception when designing any new product. Since visual aesthetic is a physical/visual appearance, it is directly associated with “what is seen” by a human being. The reason that the eye can recognise an object is because of the difference between the properties of the object and the properties of the background (Kostellow, 2002). For example, in current situations, what things or object makes you capable of understanding or recognizing the script on this manuscript or chapter is due to the difference in the colour or proportion of the words/text. According to Coates (2003), this is named as ‘contrast’. Contrast is associated with the visual properties of the product, and it is not only restricted to the product’s context, but it can also include other domains such as surgery, painting, and many more. In other words, contrast is produced by variation among the visual/physical properties of the design element and the background of the product. For instance, the variation among the length and the height of a product produces a contrast (Elam, 2001). Furthermore, the sum of these variations intensifies the contrast (Coates, 2003; Crilly et al., 2004a). Consequently, contrast is made by the quantity and the quality of the variations produced by the “elements” and the “composition of the gestalt”. Higher the variation in elements and composition, higher the contrast, or lower the variation means lower the contrast (Khalighy et al., 2014).

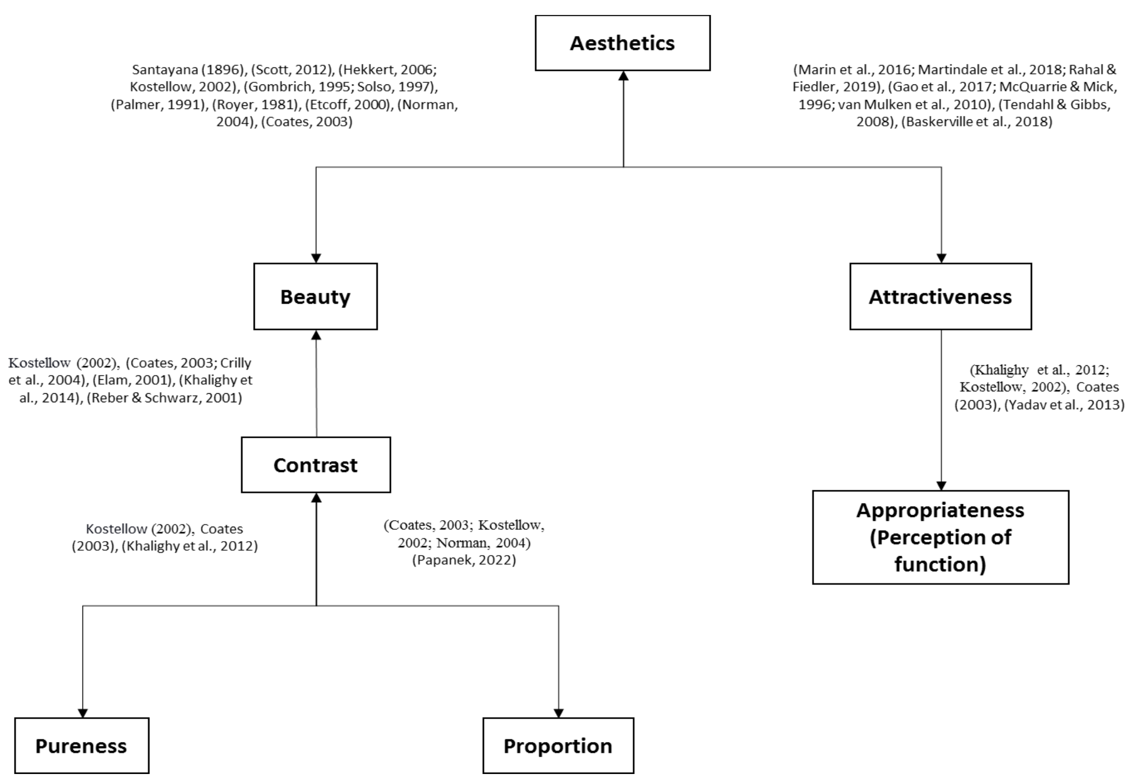
2.4.11. Pureness

Kostellow (2002) describes in their work that pureness is a measurable quantity of contrast. Coates (2003) also defines in their study that the design elements fascinate the human being, for example; lower the pureness means higher the (curiosity) power of the fixing the mind (grabber) and vice versa (Khalighy et al., 2012). Similarly, the quantity of visual/physical elements rises, another factor which is known as "pureness". This factor is expressible in quantity, an essential characteristic of the term "beauty".

2.4.12. Proportion

There is another factor called "proportion," which is defined based on both similarity and dissimilarity when the visual elements interact with everyone. The term "proportion" is a qualitative portion of "contrast" (Kostellow, 2002). Since, it depends more on the consumers/user's observation and real-time case studies. Proportion is described on the basis of the visual similarity among the properties of the design elements, for example, size, nature, place, and colour (Papanek, 2022). In other words, proportion determines the stability generated by the visual weights of the gestalt composition (Coates, 2003). Thus, lower the likeness means lower proportion, and higher the likeness means higher the proportion. "A design not only has to be structural, it has to appear to be structural. You have to recognize structure like you recognize a hot stove." "Always imagine these things one hundred times as large, and you'll see that the proportions make a huge difference." And these three (proportion, pureness, contrast) factors are the main constituent that combinely represents "beauty" (Kostellow, 2002; Coates, 2003; D. Norman, 2004).

Flow chart:



In this section, we discuss various studies that have been done in previous years related to product design and product aesthetics, and various techniques, methods, approaches, and their drawbacks. At the same time, we also discuss some critical studies related to product aesthetics that will be linked to consumer behaviour, and designers. And how these studies help in measurement as well as enhancement of aesthetics. Further, we will discuss some meaningful findings from things from these studies and also discuss the drawbacks. In the end, we review critical concepts related to product design, aesthetics, their essential variables and factors, and relations of aesthetics with art and engineering to find out the best possible approach for the measurement of product aesthetics. Numerous efforts have been considered for the development of a goal-oriented methodology to calculate the abilities of aesthetics (Khalighy et al., 2012). Previous studies are separated into two different sections: first, work that has tried to examine theoretical ideas of aesthetics, and at the same time, they also investigate various characteristics of product physical look perception and psychological effects, for instance, affective and cognitive (Bloch, 1995a), concinnity and information (Coates, 2003), attributes and characters (Shank & Langmeyer, 1994), objectivity and subjectivity (Khalid & Helander, 2006b), emotional and functional (Noble & Kumar, 2008), complication and straightforwardness (Cox & Cox, 2002a; D. Norman, 2004), identification and acknowledgment (Crilly et al., 2009a), neuro-aesthetic (Galanter, 2010), the influence of age, education, and sex on aesthetic likability (Schindler & Holbrook, 2003), aesthetic grace (Vyncke, 2002), aesthetic conversion (Ulrich, 2006), manufactured product aesthetic (Y. Liu, 2003). Then, the subsequent research studies were directed to suggest and make concrete aesthetic representations proficient in measuring with scientific experiments, for example, by using known statistical tools and the different engineering approaches, for instance "product-form design model based on GE algorithms" (Hsiao et al., 2010), "quantifying shape descriptors" (Zuniga et al., 2014), "incorporating the Kano model into robust design method" (Hsiao et al., 2008), "use of shape preference information in product design" (Kelly & Papalambros, 2007), "aesthetic measurement" (Hsiao et al., 2008), "user-oriented design by using Kansei Engineering" (Lai et al., 2006), "improving feeling quality of a product by applying Taguchi" (Li & Zhu, 2019), "applying semantic methods" (Karlsson et al., 2003), and "measuring consumer perceptions" (Petiot & Yannou, 2004a). In addition to the preceding factors, other factors (visual and non-visual factors) significantly impact how designers and customers view a new product during the design and purchase processes. These elements may influence how they perceive the product's appeal, usability, and overall appeal. Additionally, it shows that there is still a cognitive perception gap—a difference between how consumers and designers think and perceive the world. This implies that designers and consumers may have different understandings or perspectives when it comes to assessing and appreciating a product's attributes. Different opinions and preferences may result from this cognitive thinking gap, which may impact the product's design and marketing tactics to effectively bridge the gap and serve the needs of both parties. In the next part, a detailed discussion is given to understand all the methods which were used by different academics.

2.5. Critical assessment

Even though some researchers use unidirectional methodologies (Lavie & Tractinsky, 2004; Rashid et al., 2004; Schenkman & Jönsson, 2000), other researcher uses bidirectional standards for their planned approaches (Bottani & Rizzi, 2008; Chen & Chuang, 2008; Krish, 2011). Unidirectional approach usually moves around consumer-based inputs techniques (Nagamachi, 1995a; Yun et al., 2003; Zhang, 2002) for example Kansei engineering (Nagamachi, 1995a). Kansei technique helps product designers and researchers to translate prospective consumer's feelings and emotions into product form (Hsiao & Chen, 1997; Matsubara & Nagamachi, 1997; Yun et al., 2003) and by this, they can also find out relationships among the product designers and elements of design (Perona & Saccani, 2004; Salvador & Forza, 2004). A centralized method is projected to understand better the connection between the product criteria and consumer satisfaction and to acquire the best possible design characteristic arrangement of the "multiple-criteria" optimization. Some "multidimensional techniques" are constructed using 2-Dimensional models, for example, the Kano model (Kano et al., 1984). In some studies, researchers try to integrate diverse models and create more than 2-Dimensional model in their projected techniques (Chen & Chuang, 2008). A combination of the "Kano model and the Grey-based Taguchi Method (GTM)" (Chen & Chuang, 2008); others use cluster analysis and Fuzzy analytical hierarchy process (FAHP), and generative design method and multi-criteria decision making technique (Bottani & Rizzi, 2008). In this section, we discussed previous research works to develop methods to assess/measure the products' aesthetics. At the same time, we also discuss various methods and techniques that are useful in measuring product aesthetics.

2.6. Literature Summarization

In Chapters 1 and 2, we explored aesthetics and its components, factors, and its relationship with various fields such as engineering, philosophy, science, arts, etc. Previous studies primarily concentrated on discussing aesthetics on a theoretical basis. However, over time, certain researchers have put their efforts for the development of concepts and theories regarding aesthetics in different fields. But, most of the previous research work emphasizes on improving statistical analysis and engineering techniques instead of fundamental effective traits, as seen from the applicable methodologies and methods of prior study. The applied stimuli's variables are quite few, and the investigations' foundation is heavily based on subjective interpretations. In the results of every study, we found that the majority of the outcomes are far from optimized designs, and some of them even offer inferior quality to the original conception. Although "art" is the key basis of product aesthetics.

"Previous studies have provided limited indications of understanding of aesthetics in terms of statistical analysis and engineering point of view. Moreover, in the initial stage of aesthetics research, researchers from the field of arts, science, psychology, and others, have primarily focused only on the theoretical aspects." After that, researchers move towards the theoretical discussions of consumer preferences and behavior towards product aesthetics." Thus, "the assessment and improvement of product aesthetics have been subject to limited research and exploration. However, there is a scarcity of empirical studies that explore the relationship between aesthetics and various fields such as arts, science, psychology, and others." Therefore, there is an urgent need to analytical approach for the understanding and assessment of product aesthetics.

The analytic method carries the most of the load in the all of these different techniques, approaches, methods, and the significance of the input data is largely disregarded. The cause is that engineering approaches individually cannot deliver a complete explanation to the problem. In the above sections, we already mentioned that aesthetics is multifaceted, except for engineering and science methods; establishing a design methodology is also required for studying other areas such as psychology and art. In this thesis, we propose the development of a novel methodology and tool aimed at enhancing the process of product design and development. This methodology and tool are specifically designed to integrate aesthetics into the product development process. In this thesis, we have adopted the design research methodology developed by Blessing and Chakrabarti (2009) as the foundational framework for our main research methodology section and for each research study within our work.

2.7. Research gaps

Researchers have identified that the research on aesthetics has been growing steadily at the academic level, but, in comparison to this, the implementation of aesthetics in industries has been still minimal, especially in developing countries, and still most industries are focusing on the functionality of a product (Hoegg et al., 2010). On the other hand, researchers have tried to reveal the factors contributing to the restricted inclusion of aesthetics in industries. However, there is still a pressing requirement to exhaustively know and measure the elements that affect aesthetic product aesthetic design, and this information should be included in the existing literature (Crilly et al., 2004a, 2009b). As we have gone through many research publications and various search engines, very less research is done in the area of tool development for aesthetic assessment. Although the reason behind the lack of tools could be more precise, some authors mentioned that aesthetics is majorly studied in a theoretical manner and only a few academic researchers use scale and statistical technique to measure it (Boks & Stevels, 2007; Rossi et al., 2016). Most of the work or research in aesthetics is done in philosophical and theoretical ways. Also, often the design researchers work in isolation within the universities or research institutes. Leading to very few researchers working in collaboration with the industry. Thus, there is a huge gap between academic design researchers and industry people. Additionally, it appears that, designers in industry mainly rely on their past experience, instincts, and intuition. On the other hand, there is a basic necessity to create a stronger interrelation within academic industrial design researchers and industrial designers themselves. The evaluation and practical use of aesthetics would be made easier and more effective support to this link. In previous times, design researchers primarily focused on the functional aspects of a product. However, as time has passed, the importance of aesthetics has gained more importance. Because of this, there is a rising need to handle these topics both mathematically and theoretically, ensuring comprehensive understanding and exploration. In addition to that, there is an urgent need to provide the support for the designers for the assessment of product aesthetics (Khalid & Helander, 2006; Helander et al., 2013). Based on the above discussion, some key research gaps along with certain recommendations for the understanding and support, are highlighted below.

There were few studies that aimed to understand the term aesthetic in a theoretical way. Further, different studies have been done to improve the product aesthetics by directly interacting with consumers and designers

(Beardsley, 1981; Jindo and Hirasago, 1997; Nagamachi, 1995; Singh and Sarkar, 2022; Yadav et al., 2013). There were very few aesthetic measures, and it is also very difficult to quantify them in terms of number. It is frequently challenging to select a suitable technique for evaluating/quantifying these measures or factors (Khalid and Helander, 2006; Yan et al., 2008). A simple way to identify which method, measures, or factors are suitable is to associate “what the tool or test is measuring” with “what necessity to be measured.” “What necessity to be measured” could be found in a simple description of aesthetics? Similarly, various methods or techniques are used to improve the aesthetics of the products, and there are also various features or variables that affect the aesthetic factors/measures (Bloch, 1995; Hekkert, 2006; Mciver and Gaut, 2002; Sarkar, 2018; Singh and Sarkar, 2022; Walton, 2007; Yadav et al., 2013). Our aim to assemble these experts on a cooperative platform to maximize the synergistic effect of their knowledge and experience.

The intrinsically qualitative nature of philosophical aesthetics, lacking in quantitative measures, is one of the difficulties we face when studying/working with aesthetics. However we went deeper into aesthetics by studying different field of literature related to aesthetics and design such as product innovation & consumer behaviour, psychological, art, science, poetry, architecture, cosmetic surgery, and engineering-associated aesthetics.

Through a comprehensive examination of the existing literature, we have identified a philosophical aesthetics definition, which notably negligible quantitative factors. In contrast, the various domains related to product design and innovation approach the subject by considering many elements, variables, and factors theoretically. These aspects are amenable to quantification, and we have leveraged appropriate methodologies and experiments, encompassing both open-ended and closed experiments, to address this gap. These quantifiable components are essential because they can improve the understanding of aesthetics by offering a more organized and quantifiable framework. By integrating psychological aesthetics insights with these quantitative measures, we have developed what we refer to as the engineering aesthetics definition. This novel method offers a thorough grasp of this complex idea by bridging the gap between aesthetics' qualitative and quantitative aspects.

Therefore, the understanding of the consumer desire in the initial stage of the product development is the main requirement product design (Khalid & Helander, 2006c; G. Norman, 2010a). Bloch (1995) also defined that the form of any product produces emotional responses in human mind. The blend of cognitive perception and emotional feelings eventually convey the behavioral reactions of human beings (Cox & Cox, 2002b). Thus, these responses can be utilized to study the consumer's emotional desire, ultimately guiding the development of a new product under the umbrella of product aesthetics. “Consequently, we can delve into this constraint to reveal the gap in cognitive thinking between designers and consumers when it comes to product development and the purchasing of new products.” Hence, comprehensive research and depth analysis are required to an extensive understanding and analysis of the visual and non-visual factors that influence consumers and designers during product development. Additionally, in this research work, we studies the cognitive effects of these factors on consumers as well as designers and aims to assess those using quantitative terms. In addition to that, the cognitive features of product aesthetics and their basic design elements always play an important role during product development stage and consumer cognitive feeling at the time of purchase of new product (Coates, 2003; Crilly et al., 2009b). Therefore, there is a need to study, understand, and quantify the basic elements that are related and affect product aesthetics and at the same time, a need for tools that can support product designers for assessment of product aesthetics.

2.8. Research question and objectives

2.8.1. Research questions

On the basis of the research gaps, the main research question is identified as:

"How to develop a support system that can help industrial designers understand and improve the aesthetics of a product?"

Before developing an aesthetics support, it is important to understand the factors that influence and relate to product aesthetics. Also, the requirements of designers from aesthetics support should be understood clearly. As a result, the following sub-questions should also be addressed:

1. *"What is engineering aesthetics (Understanding of engineering aesthetics a workable definition of engineering aesthetics)?"*

2. *"What are the factors of an engineered product (car) that attract people? (Both visual and non-visual factors are identified)?"*

3. *"How can we identify and quantify the essential cognitive factors that influence product aesthetics design (How cognitive factors influence design aesthetics?)?"*

4. *"What kind of support should be required for designers to improve product aesthetics (suitable support for industrial designers)?"*

2.8.2. Research objectives

Based on the research gaps and the research questions, the following research objectives are formulated to be undertaken in this study.

- Understanding of aesthetics and engineering aesthetics: Create a definition of engineering aesthetics by using different methods.
- To identify various factors that influence the aesthetics of engineered products (both visual and non-visual factors are to be identified).
- To identify and quantify the cognitive factors that influence design aesthetics (analyze cognitive factors).
- A comprehensive understanding is required: Can we develop a method to develop aesthetically improved products? (To support designers to improve product aesthetics, suitable support for industrial designers).

2.9. Chapter summary

This chapter presents the bibliometric and network analyses of the literature to understand the spread of academic research related to product aesthetics design. This analysis helps to understand the current scenario of the research on product aesthetics design geographically as well as to identify those who are the key contributors to the research on product aesthetics design. This chapter also reviews the literature to understand the current status of product aesthetics design adoption in industries as well as academically. Research gaps and the research questions are identified through a critical review of the literature. Based on the research gaps and the research questions, four research objectives are formulated to be undertaken in this study.

CHAPTER 3

Methodology

The challenges in product design and aesthetics design have been discussed in Chapter 2. In line with the challenges observed in the literature research for product design and aesthetics design, we have developed the objectives for this research.

The main aim of this thesis is to **understanding and supporting designers to improve the engineering aesthetics of a product**. Understanding the Engineering Aesthetics generic definitions, tests, factors and methods (Objective 1). Study of cognitive behavior of consumers and designers for visual factors of a car using Fuzzy Analytical Hierarchy Process and, factual analysis of factors influencing consumer cognitive thinking and automobile designing using Fuzzy-AHP. Further, a Study of the Non-Visual Factors of Cars Affecting the Consumer's Cognitive Appeal (Objective 2). Understand and Quantify the Consumers' Cognitive Behavior for the Appropriateness Features of Product Aesthetics through the Eye-Tracking Technique and similarly, we also explore, an artificial neural network tool software to support product designers' understanding and quantifying the beauty of 2-D product with the help of eye tracking techniques gas been generated (Objective 3). Refer to Table 3.1. In this chapter, we discuss the methodology which is used to conduct this research. This chapter is divided into two sections. The first section explains the research methodology and the second section explains the research method applied during this study to attain the formulated goals.

3.1. Research Methodology

The literature contains a number of research procedures that offer thorough explanations for carrying out research (Bordens & Abbott, 2011). Visocky & Visocky (2017) book "A Designer's Research Manual" gives guidance to designers on how to conduct qualitative and quantitative research as well as summative and formative research design. In addition, "Understanding Engineering Design - Context, Theory and Practice" by "Richard Birmingham" (1997) offers guidelines for surveys of the advancement of design theories. Some other books, such as "Design Methods" by Chris Jones (1987), are divided into two sections: the first one defines the creation of a design process, and the second provides a collection of 35 methods that can be applied at various stages of the design process. The current study, however, focuses on problem comprehension, support development, and evaluation and is closely linked to a specific research methodology known as "Design Research Methodology (DRM)" proposed by "Blessing & Chakrabarti" (2009a). Hence, "Design Research Methodology" has been adopted in this research work. It presents a rigorous procedure for conducting a design study. Many researchers have adopted this methodology to conduct their investigations. There has been some recent DRM-based research undertaken by Koch et al. (2016), Ramos-Mejía et al. (2019), Bertoni et al. (2020), and Eisenmann et al. (2021). Figure 3.1 depicts the four steps that make up the design research methodology.

In order to develop a practical and worthwhile research goal, the researchers try to find some sign or at the very least indications, that support their hypotheses. They mostly achieve this by looking up elements that affect product success in the literature.

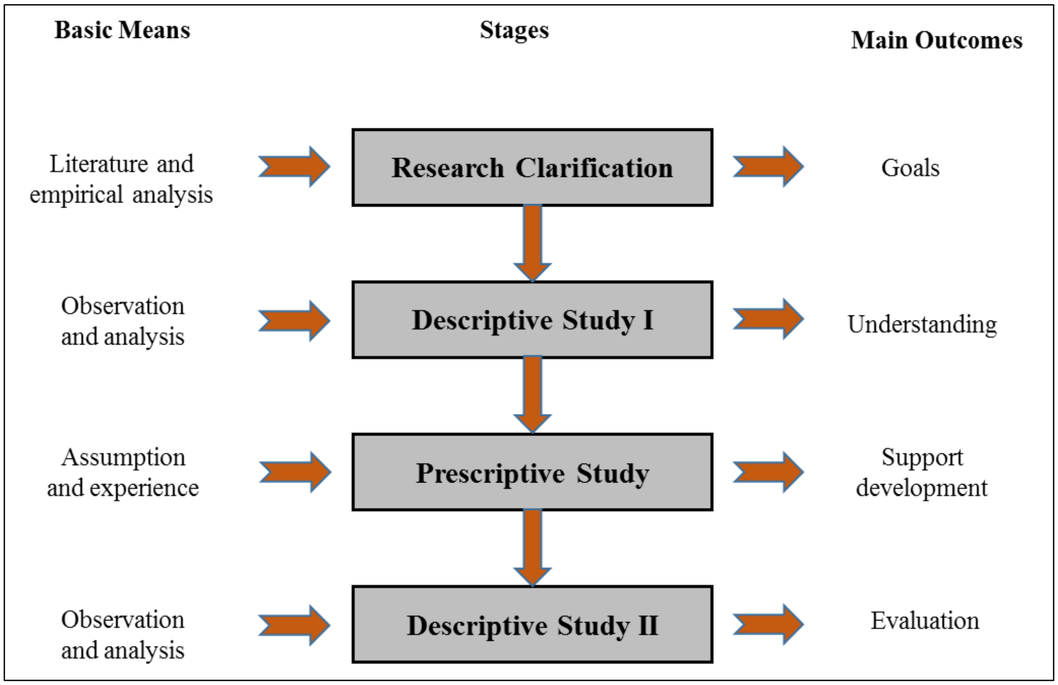


Figure 3.1. Framework of Design Research Methodology {Blessing & Chakrabarti (2009a)}

In the *"Descriptive Study I phase",* "the researchers, now having a clear goal and focus, review the literature for identifying the various aesthetic definitions and formulate the engineering aesthetics definitions, find out more influencing factors to elaborate the initial description of the existing situation, in emotional as well as in product aesthetics term. The main purpose is to make the description detailed enough to determine which factor(s) should be addressed to improve task clarification as effectively and efficiently as possible. However, they do not find enough evidence in literature to clearly determine these crucial factors, and decide to observe and interview potential products buyers and industrial designers at work to obtain a better understanding of the existing situation. Next, we studied various factors related to product aesthetics qualitatively and quantitatively, before moving on to the next stage and start developing support to address these factors".

In the *"Prescriptive Study (PS) Phase",* "the researchers use their enhanced understanding of the existing situation to correct and elaborate on their initial description of the desired situation. This description represents their vision on how addressing one or more factors in the existing situation would lead to the realisation of the desired, improved situation. They develop various possible scenarios by varying critical constituents/features of product aesthetics. The researchers decide to focus on improving the quality of the problem definition as the most promising constituents/features of product aesthetics to address. Their argument is that this study should provide the prominent support to the designers by improving the aesthetics of any product (by providing use of eyetracking equipment and AI tool), reduce the number of modifications, which in turn should reduce design time, which eventually should shorten time-to-market and increase product success through increased profit. They now have enough confidence to start the systematic development of a support to improve the quality of problem definition. They use their understanding of the various interconnected influencing factors obtained in the DS-I stage; the well-developed description of the desired situation; as well as their experience in developing design support" (Blessing & Chakrabarti, 2009).

The researchers proceed to the *"Descriptive Study II"* phase to "study the influence of the support and its capability to realize the desired situation. They undertake two empirical studies to gain an understanding of the actual use of the support. The first study is used to evaluate the applicability of the support. The main question is whether the support can be used to encourage the high-quality problem definition. The second study is used to evaluate the usefulness, *i.e.*, the success of the support, based on the criteria developed earlier".

The research conducted in this thesis is spread across all the stages of the Design Research Methodology (DRM), i.e., research clarification (preparation of research objectives), descriptive Study-I (understanding the present state of research), prescriptive study (development of support) and descriptive study – II (use and assessment of the support). Research objectives 1, 2, and 3 are related to descriptive Study-I, whereas research objectives 4, and 5 are associated with both prescriptive study and descriptive study – II.

In the first objective, we intend to understand aesthetics from both philosophical and engineering perspectives. This requires comprehensive understanding and knowledge of various definitions of aesthetics. Various approaches will be discussed and employed to "formulate the generic definition of aesthetics". For the development of definitions for both philosophical and engineering aesthetics, a deep understanding of fundamental factors, features, and attributes related to aesthetics through different domains such as science, art, pottery, engineering, etc. This objective helps us to understand the depth and breadth of the product aesthetics design and aesthetics field.

In the second objective, we compile a list of different variables or factors influencing apart of factors or attributes that are linked with product aesthetics. In this study, we found different visual and non-visual factors related to an engineered product through which consumers and designers related to each other. In order to fully comprehend and analyse the visual and non-visual variables that influence customers and designers during product creation, thorough research and depth analysis are therefore necessary. Additionally, we examine the cognitive consequences of these elements on both consumers and designers in this research effort with the intention of quantifying those effects. For that, we have conducted a case study in which we considered the car as a product. During this study, we determine what factors (visual and non-visual) cognitively affect the consumers' and designers' decision-making while purchasing as well as designing. In this study, we understand and analyze how these factors relate to design principles, color theory, and decision-making techniques as suggested in Descriptive Study-I of Design Research Methodology (DRM).

In the third objective of the thesis, we took essential factors and attributes from the first objective. These factors and attributes are found during the formulation of the generic engineering aesthetics definition. In first objective, these elements are thoroughly discussed and used for the formulation of definition. But, in this objective, we deeply understood and quantified every factors and attributes pertaining to product aesthetics, as suggested in Descriptive Study – II of the Design Research Methodology (DRM).

In the next (fourth) objective, our main is to evaluating the methodology and steps which we found in last previous three objectives. We want to determine to what extent these techniques, procedures, and tools can help academic design researchers as well as industrial designers in enhancing the aesthetics of products. We seek the assistance of an industrial designer during the evaluation process to evaluate our procedures, steps, and equipment. This assessment tries to ascertain how well they correspond with the requirements and difficulties industrial designers face in actual situations. The study conducted as suggested in Prescriptive Study – III of the Design Research Methodology (DRM).

3.2. Research Approach

The research approach applied in this study is presented in Figure 3.2.

The different tasks of the research approach are mentioned briefly as follows:

- A systematic review was conducted to understand the current state of the research in the relevant field and to identify the challenges and gaps in the research conducted till date.

Figure 3.2. Research approach

- Research objectives were formulated on the basis of identified research gaps.
- Data was collected from the experts and designers through questionnaires and then analyzed to retrieve the information in terms of their perspective for product aesthetics design.
- This information laid the foundation for developing the product aesthetics design support for designers.
- The evaluation of the developed support was carried out through designers' experiments to verify its applicability.
- In the end, the conclusion of the proposed study is presented along with the directions to take this research forward.
- Another support is presented in the form of a tool that helps the designers for analysis of beauty of products.

This is overall research design and is a compilation of the research accomplished in this thesis. The objective wise research design has been discussed in the distinct chapters.

The first is to study is to develop aesthetic definitions in terms of philosophical as well as engineering aspects. The methodology of this study is based on a framework that consists of two phases. A deep literature search has been done to identify the different set of aesthetics definitions in philosophical and engineering point of view, followed by an analysis part of speech and cluster analysis methodology has been done in this work. During this objective, we use Oxford and Cambridge Dictionary and clustering techniques to understand and form engineering aesthetics definitions. All two phases of the methodology are described in detail as follows: A generic definition of engineering aesthetics developed and can be utilized to recognize suitable aesthetics methods and tests for enhancing or testing aesthetics.

The key goals of this research study, thus, are to: Scrutinize a comprehensive group of descriptions/definitions of aesthetics, given by different practitioners and researchers, and create their structures into a general or common definition of aesthetics which can be utilized by various establishments/societies. The effort then spreads this definition to create aesthetics. Examine an extensive collection of aesthetics tests or measures, classify them and associate (make a connection between) them with the meaning/definition of aesthetic. Examine factors affecting aesthetic, group them and make a connection between them with the meaning/definition of aesthetic. Analysis a complete group of aesthetic enhancing approaches/methods existing in previous works and make a connection between (transmit) them with the meaning of aesthetic. Develop a broad knowledge of aesthetic by establishing links among the, methods, measures, definition, and factors of aesthetic.

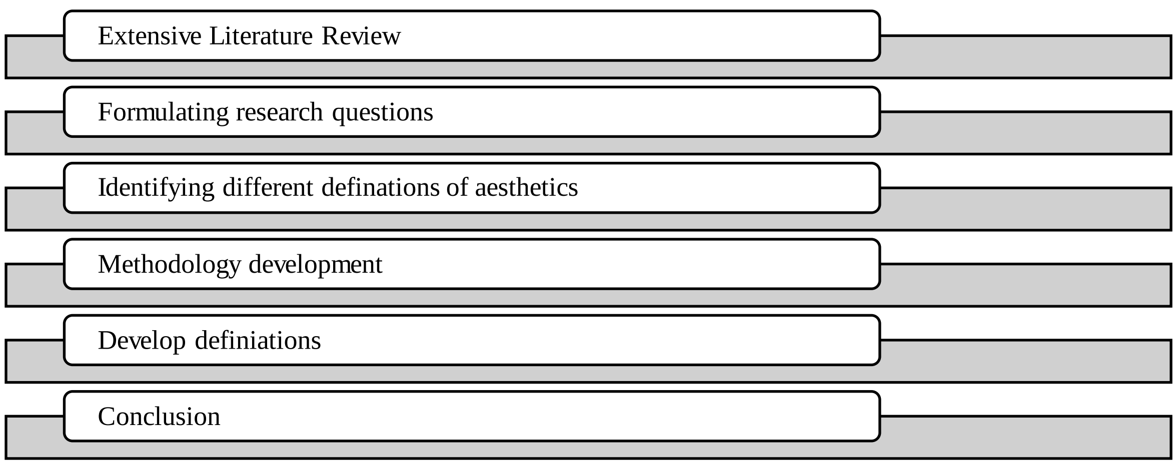


Figure 3.3. Research design of objective 1

For addressing this challenge, the following research design is adopted. Refers to Figure 3.3.

In the second objective, we investigated the top visual and non-visual factors which affected the perception of both the potential customers and the industrial designers for a car considered as a product. The mapping of the consumer's cognitive perception is done just before or after purchasing a new car. In addition, the cognitive feelings of industrial experts for the new product is examined. During this study, a two-phase methodology is applied for prioritizing the top visual and non-visual factors among consumers and designers related to the perception of cars. In the first phase (Phase I), we use literature and an open-ended survey for determining the visual and non-visual factors. A mathematical technique is then used to identify the top visual and non-visual factors that affect the likeness and purchase behaviour of consumers at the time of purchasing a car. In the next phase (Phase II), we use the F-AHP to determine a comparative understanding of the factors from consumers and designers points of view.

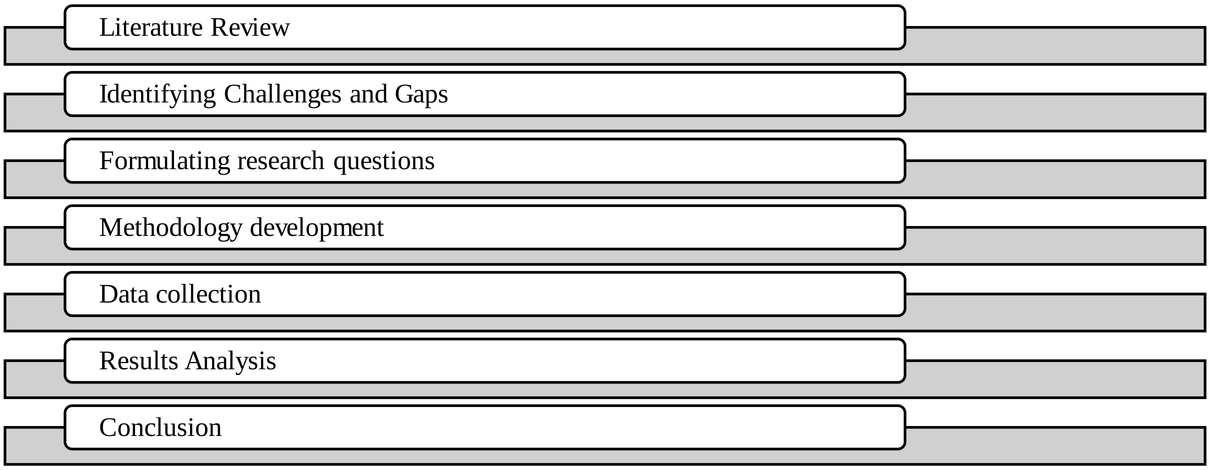


Figure 3.4. Research design for objective 2

In the third objective, we took essential factors and attributes from the first objective. These factors and attributes are from the literature search to formulate a generic definition of engineering aesthetics. In the first objective, these elements are thoroughly discussed and used for the formulation of the definition. However, in the third objective, we deeply understand with the help of different case studies and quantify every factor and attribute pertaining to product aesthetics, as suggested in Descriptive Study – II of the Design Research Methodology (DRM). This objective is performed in two studies. In first study, we understand and analysis the attractiveness factors with the help of perception of function features. First study gathers and analyses information in two phases. Both semi-structured and structured surveys and experiments are used. Figure 3.5 shows the flowchart that demonstrates the approach used in this study.

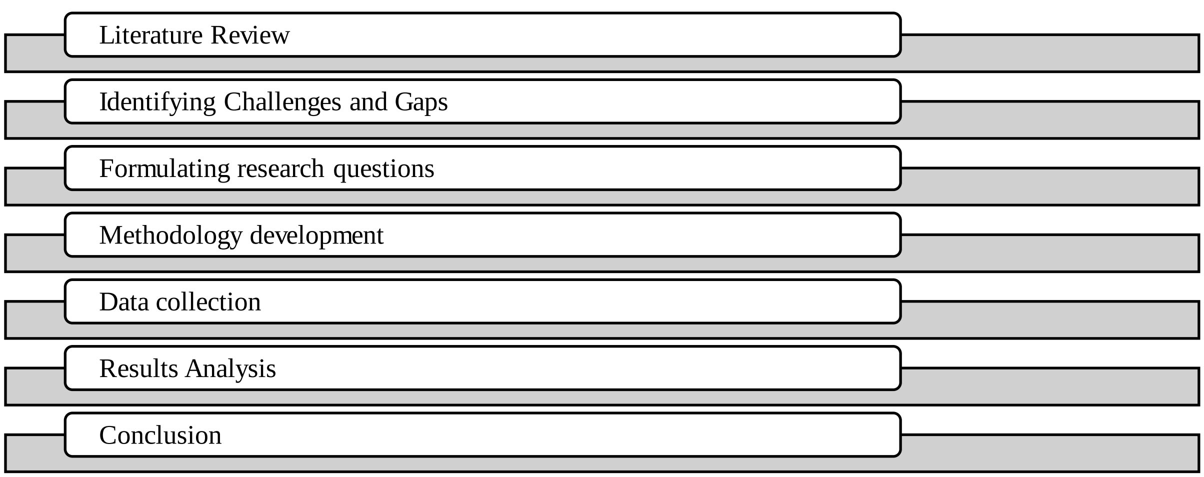


Figure 3.5 Research design for objective 3.

In phase-I, the cognitive ability task is conducted to collect consumers' perceptions related to the appropriateness feature of product aesthetics. In phase-II, the eye-tracking experiment is performed to collect the cognitive perception of customers. Initially, the survey is conducted with different product images. After completing the phase-I study, the frequency match ratio values for each silhouette with respect to the consumer input are calculated. In phase-II, an eye-tracking experiment is conducted with different respondents, apart from the phase-I respondents. Next, an open-ended survey is undertaken to note the consumer behavior of the participants involved in the eye-tracking investigation. In this phase, emotional and sensory responses were analyzed by considering a different group of variables mapped from an eye-tracker experiment performed for more in-depth analysis.

In second study of objective 3, we understand and analysis the beauty factors with help of different features such as contrast, pureness/purity, and proportion/symmetry. Next, we also develop an AI tool to support the industrial designers for improving the aesthetic of products during product development and generate a graphical user interface. First study gathers and analyses information in two phases. Both semi-structured and structured surveys and experiments are used. In first phase, "Pro TX300 eye tracker is used during this study to note down the consumer inputs and in second phase, consumer preference is noted down for the aesthetic preference of product. The experiment was carried out in a closed environment. The windows are covered to prevent eye distraction, only artificial light is used, and all the experiments were conducted during nighttime. A well-defined procedure is required to measure the qualities of product aesthetic design with the intention of sustaining the reliability and robustness of the methodology, which contests the outcome data of the assessing tool/equipment. The fixation count, location, and Total fixation durations for each trial are included in the output data.

The fourth objective is to apply the information, methods, techniques, factors, and features we found in the above three research objectives to evaluate the product aesthetics after and before indulging these information, methods, techniques, factors, and features. During the evaluation process, an industrial designer participates in three different phases.

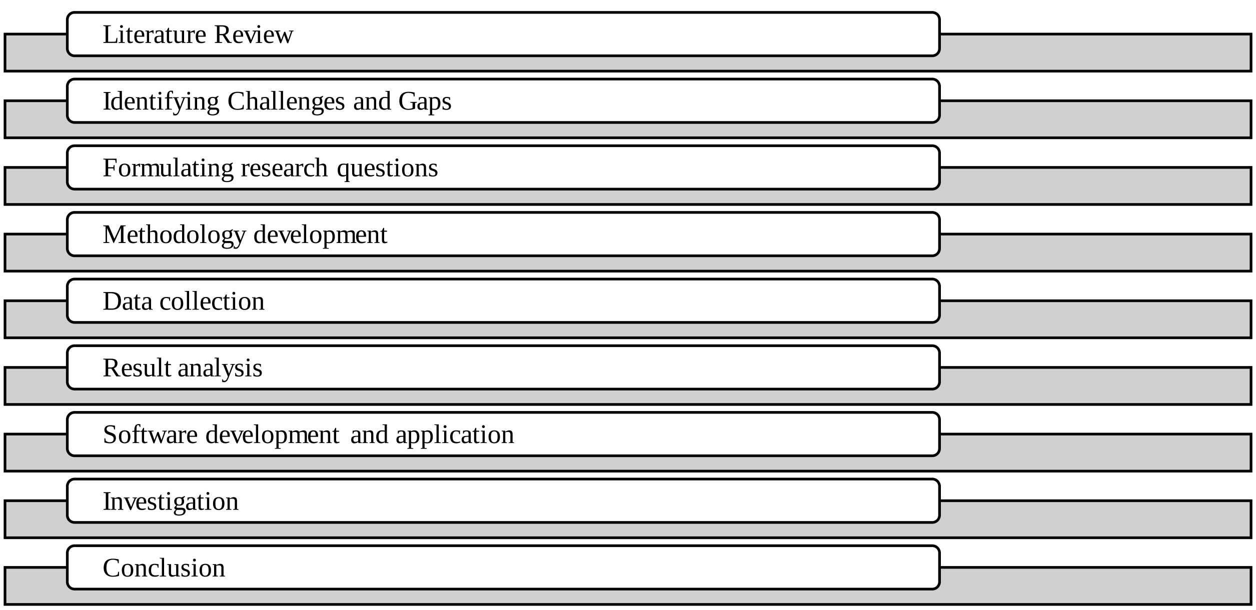


Figure 3.6 Shows the flowchart for objective 2 for the second study.

The fifth objective is to apply the information, methods, techniques, factors, and features we found in the above three research objectives to evaluate the product aesthetics after and before indulging these information, methods, techniques, factors, and features. During the evaluation process, an industrial designer participates in three different phases. In the first phase, a few designers use their own past experience and gut feeling to generate the design of the prescribed product. In the second phase, the information, methods, techniques, factors, and features found in the above three research objectives are provided to generate the design of the prescribed product. In the third phase, we request highly experienced designers to provide their value input in terms of numbers or quantitative form by using different rating scales. Refers to Figure 3.7.

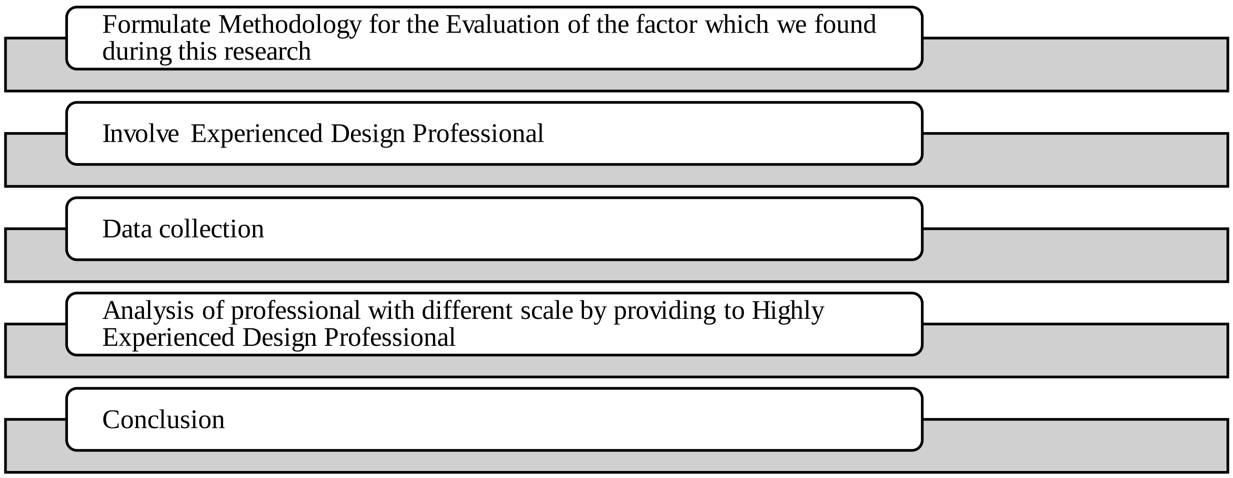


Figure 3.7, Research design for objective 5

3.3. Methodology

This section presents the different instruments for collecting the data and the methods for analyzing these data.

3.3.1. Data Collection

This section provides an insight into the approaches for collecting the data. It mainly includes primary and secondary data collection.

Primary data collection: "Primary data collection" refers to the process of gathering data directly from the source through surveys, interviews, or experiments. A common example of primary data is household surveys. This method allows researchers to personally ensure that the collected data meets the required standards of quality, availability, statistical power, and sampling for a specific research question. With the growing global access to specialized survey tools, survey firms, and field manuals, primary data has become the primary source for empirical research in the field of developing economics.

The tools or techniques used for primary data collection are discussed below.

Questionnaire: In this category, a set of questions are mailed to the respondents. They should read, reply and subsequently return the questionnaire. The questions are arranged in a definite order on the form. A good survey should have the following features:

- Short and simple
- Should follow a logical sequence
- Provide adequate space for answers

- Avoid technical terms
- Should have good physical appearance such as colour, quality of the paper to attract the attention of the respondent

Interview: In this category, the data is collected in terms of oral or verbal responses. It is achieved in two ways as follows:

- Personal Interview – In this method, a person known as an interviewer is required to ask questions face to face to the other person. The personal interview can be structured or unstructured, direct investigation, focused conversation, etc.
- Telephonic Interview – In this method, an interviewer obtains information by contacting people on the telephone to ask the questions or views orally.

Observation or design experiments: This approach is used when the study relates to behavioural science. This method is planned systematically. It is subject to many controls and checks. The different types of observations are:

- Structured and unstructured observation
- Controlled and uncontrolled observation
- Participant, non-participant and disguised observation
- Secondary data collection

Secondary data refers to data that is collected by someone other than the primary user. Common sources of secondary data for social science include censuses, information collected by government departments, organizational records and data that was originally collected for other research purposes. The tools or the sources which are used for collection of secondary data includes magazines, newspapers, books, journals, etc. It may be either published data or unpublished data. Published data are available in various resources including:

- Government publications
- Public records
- Historical and statistical documents
- Business documents
- Technical and trade journals

Unpublished data includes:

- Diaries
- Letters
- Unpublished biographies, etc.

Various techniques used for collecting the data in this research are presented in Table 3.1.

Table 3.1. Techniques/approach used for data collection

Data collection technique	**Source of data**
Questionnaire-based survey	Designers and academicians contacted through e-mail and on call.
Secondary data	Online resources, journals, books, etc.
Discussions and interviews	Interactions with designers through video calls as well as in person meetings

Design experiments	Actual design experiments with novice designer and common people, online and offline survey

3.3.2. Data Analysis

In this section, the specific methods which were used for analysing the data in each research objective are mentioned along with the data collection techniques, as provided in Table 3.2 below.

Table 3.2. Methods used for data analysis

Research objectives	Data collection technique	Method/tool/Machine for data analysis/collection
Objective 1	Online resources, journals, books, etc.	Cluster analysis
Objective 2	Questionnaire (online and offline survey) and discussion	Rank value method, Pareto principle, Survey, and Fuzzy AHP
Objective 3	Design experiments and data retrieval	Online and offline Survey, Eye tracking Equipment tool, and Anova
Objective 4	Design experiments and data retrieval	Online and offline Survey, Eye tracking Equipment tool, Anova, and Artificial neural network
Objective 5	Key Point gathering	Offline Survey and Designer input

3.4. Thesis Flow

The thesis flow begins with the finding, understanding and studying of aesthetics in philosophical and in engineering prospective. In this chapter, the identification of definitions of aesthetics in philosophical and engineering aspects. Chapter 5 describes the understanding and studying of the various engineering factors of an engineered product from consumers' and designers' cognitive perspectives while purchasing and designing an engineered product. Additionally, this chapter presents the understanding of the designers' and consumers' requirements and identifies their priorities using the Prato principle approach, Fuzzy-AHP Technique, and DEMATEL Technique. The identifying follows it, understands the essential features and attributes of engineering product aesthetics, and quantifies them with the help of open-ended survey and eye-tracking equipment. Further, a frequency match ratio and ANOVA technique are employed for quantification. Similarly, we use an artificial neural approach to generate the AI tool for product designers to support them, presented in Chapter 6. An evaluation of the tool is provided in Chapter 7 and Chapter 8, which is followed by the conclusions and future scope of this research provided in Chapter 9.

3.5. Chapter summary

In this chapter, the overall research methodology adopted for the study has been described. We describe the objectives, motivation, and challenges catered by that objective. We present the data collection methods used in this research in detail. Further, objective wise data collection methods are presented with the form in which they have been used. More details for these data collection methods have been provided in the individual chapters. Design Research Methodology (DRM) has been adopted as the methodical approach for carrying out this research. Different stages of DRM are described in detail and the research objectives associated with the various stages are discussed briefly to show their relevance with the different stages of the DRM. Also, various steps of the research approach used for conducting this research are described. After providing the research methodology in this research, we proceed to actual research work, which is accomplished in the successive chapters.

CHAPTER 4

Engineering Aesthetics generic definitions, tests, factors and methods

The importance of product aesthetics design has grown over time and is now essential to competing successfully in the current market. This chapter aims to provide readers with a complete understanding of aesthetics by examining its facets span philosophy, the arts, science, and engineering. A definitive definition of aesthetics from philosophical and engineering perspectives has been established via extensive research in art, philosophy, psychology, and engineering product design. The literature search also identified necessary tests and criteria for product aesthetics design.

4.1. Introduction

Research suggests that product design and aesthetics play a vital role in the success of any company. Aesthetics impacts not only the visual senses of human beings while purchasing or interacting with any product or service, but also influences the human cognition. In this work, we try to find different definitions/statements from different authors or researchers related to aesthetics and build simple common definitions for “engineering aesthetics.” Product design is a wide-ranging word that incorporates a product's kinesthetic, practical, and aesthetic features (D. Norman, 2002; Hekkert, 2006; Noble & Kumar, 2010); aesthetic possessions are linked to the composition of various features of a design (Coates, 2003). The term "Aesthetics" is a very ancient concept and was generated from "The Greek" word "aisthesis" which can be interpreted as comprehension through sensual insight (Y. Saito, 1998). The concept started to be used similarly to how it is used today throughout the 18th century, referring to sensory experiences and the quest for pleasure (Hekkert, 2006; Kostellow, 2002; Mciver & Gaut, 2002). However, the term aesthetics has been discussed in different areas, such as; poetry, art criticism, feminism, paintings, and "sculpture of the Greeks." But, still, we struggle to define and identify the simple and standard definition of aesthetics (Bloch, 1995a; Kostellow, 2002; Pirinen, 2020; Y. Saito, 1998). In this perspective, it is essential to recognize and identify the importance of aesthetic which is an essential part of designing any product.

4.1.1. Importance of aesthetics in product design

Baxter (1995), highlights that aesthetics plays an important character as a primary element in product design, helping as an sign of the product's promise success in the present market (Perks et al., 2005; Rafaeli & Vilnai-Yavetz, 2003). In other meanings, quality of aesthetic is a main factor in increasing the consumer/user contentment (Fynes & De Búrca, 2005; Ranscombe et al., 2012b; Swift, 2010; Yamamoto & Lambert, 1994). Ulrich (2006) expresses aesthetics as an initial reaction to any product that can persuade a customer/user to buy or not buy the product in just a few seconds. Robert (1995), in their study, described that for recognition of any product, the aesthetics of a product is one of the crucial factors. Similarly, Bloch (1995a) states that aesthetics can enhance consumers' opinions of product features. Further, Verma and Wood (2001), mentioned that aesthetics often work together with function; therefore, some other authors believed that attractive and beautiful products work in a better way (D. Norman, 2002; Tractinsky et al., 2000). Schindler & Holbrook (2003) believe that aesthetics is one of the prime factors influencing consumers' final purchase decisions. Lai (2005a) explains that a product with aesthetics can be famous and successful even if it does not have good qualities, technology, and function. Perception of a product can be completely changed with the help of aesthetics. It can also help in improving manufacturing and functional quality (D. Norman, 2004). Authors Tuch & Presslaber (2012), described in what way improvement of the aesthetic will result in enhancement of the functionality. Thus, it is usually assumed that aesthetics has an integral part in improving the success of products and the quality of product design. Bloch et al. (2003), distinguished that a product includes a large variety of characteristics, containing "production efficiency, ergonomics, production efficiency, recyclability, strength, and ease delivery, along with aesthetics". Author Simonson & Schmitt (2014), explain that effectively incorporating an aesthetics methodology can create a powerful brand character and contribute importance by fulfilling customers' aesthetic desires. It is widely accepted that the discipline of product design is elaborately interlinked with aesthetics.

4.1.2. Need for a comprehensive understanding of aesthetics through its definition

Different authors state that "normal description of aesthetics is challenging and it could be in an even tougher state than is generally acknowledged by aesthetic researchers themselves (Beardsley, 1981; Mciver & Gaut, 2002; Y. Saito, 1998; Walton, 2007). Aesthetics is defined in various ways, and there were many definitions and thoughts given by various philosophers, physiological, artists, and artist. There were few studies that aimed to understand the term aesthetic in a theoretical way. Further, different studies have been done to improve the product aesthetics by directly interacting with consumers and designers (Beardsley, 1981; Jindo & Hirasago, 1997; Nagamachi, 1995a; J. Singh & Sarkar, 2022; Yadav, Jain, Shukla, et al., 2013a). There were very few aesthetic measures, and it is also very difficult to quantify them in terms of number. It is frequently challenging to select a suitable technique for evaluating/quantifying these measures or factors (Khalid & Helander, 2006b; Yan et al., 2008). A simple way to identify which method, measures, or factors are suitable is to associate "what the tool or test is measuring" with "what necessity to be measured." "What necessity to be measured" could be found in a simple description of aesthetics? Similarly, various methods or techniques are used to improve the aesthetics of the products, and there are also various features or variables that affect the aesthetic factors/measures (Bloch, 1995a; Hekkert, 2006; Mciver & Gaut, 2002; Sarkar, 2018; J. Singh & Sarkar, 2022; Walton, 2007; Yadav, Jain, Shukla, et al., 2013a). The main objective of this paper, therefore, is to: find out different definitions of aesthetics and engineering aesthetic definitions. With it, we also found different factors or variables which affect product aesthetics. As a result, various measures and methods are identified to address the aesthetics, but these are very much unclear to find a proper definition of aesthetics. Similar to the aesthetics measures, subjects exist for aesthetics methods and factors too. Aesthetics techniques or methods are often employed to improve aesthetics of every person, and aesthetics features are control/dominant that influence aesthetics. From previous research more than five factors that affect aesthetics and more than four aesthetics improvement methods (Section 10 discusses these in detail). On the other hand, it is challenging for a business corporation to emphasize all these methods and factors concurrently. Therefore, we want an approach to recognize and find out the best possible test, method, and factor for aesthetics. For this, as defined in the previous section, we initially require to describe aesthetics.

4.2. General definitions of aesthetics

According to several authors, several difficulties are involved with traditionally explaining aesthetics. These difficulties can even be more significant than what aesthetic experts commonly accept among themselves (Beardsley, 1981; Mciver & Gaut, 2002; Y. Saito, 1998; Walton, 2007). Aesthetics is defined in various ways, and there were many definitions and thoughts given by various philosophers, physiological, artists, and artists. There were few studies that aimed to understand the term aesthetic in a theoretical way. Further, different studies have been done to improve the product aesthetics by directly interacting with consumers and designers (Beardsley, 1981; Jindo & Hirasago, 1997; Nagamachi, 1995a; J. Singh & Sarkar, 2022; Yadav, Jain, Shukla, et al., 2013a). There were very few aesthetic measures, and it is also very difficult to quantify them in terms of number. It is frequently challenging to select a suitable technique for evaluating/quantifying these measures or factors (Khalid & Helander, 2006b; Yan et al., 2008). A simple way to identify which method, measures, or factors are suitable is to associate "what the tool or test is measuring" with "what necessity to be measured." "What necessity to be measured" could be found in a simple description of aesthetics? Similarly, various methods or techniques are used to improve the aesthetics of the products, and there are also various features or variables that affect the aesthetic factors/measures (Bloch, 1995; Hekkert, 2006; Mciver and Gaut, 2002; Singh and Sarkar, 2022, 2018; Walton, 2007; Yadav et al., 2013). The main objective of this paper, therefore, is to: find out different definitions of aesthetics and engineering aesthetic in terms of philosophy and engineering. With it, we also found different factors or variables which affect product aesthetics. As a result, various measures and methods are identified to address the aesthetics. Aesthetics techniques or methods are frequently used to improve aesthetics of every person, and aesthetics features are control/dominant that influence aesthetics. From previous research more than five factors that affect aesthetics and more than four aesthetics improvement methods (Section 10 discusses these in detail). On the other hand, it is challenging for a business corporation to emphasize all these methods and factors that affects products' aesthetics concurrently. Therefore, we want an approach to recognize and find out the best possible test, method, and factor for aesthetics. For this, as explained in the previous section, we initially require to define aesthetics.

The key goals of this research study, thus, are to:

- Scrutinize a comprehensive group of descriptions/definitions of aesthetics, given by different practitioners and researchers, and create their structures into a general or common definition of aesthetics which can be utilized by various establishments/societies. The effort then spreads this definition to create aesthetics.

- Analyze a wide range of aesthetic tests/measures, categorize them, and establish their connection to the definition of aesthetics. Group them and establish a link between them based on the meaning/definition of aesthetics.
- Analysis a complete group of aesthetic enhancing approaches/methods existing in previous works and make a connection between (transmit) them with the meaning of aesthetic.
- Develop a broad knowledge of aesthetic by establishing links among the, methods, measures, definition, and factors of aesthetic.

4.3. Approaches to cultivate a common or generic descriptions/definitions of aesthetics

In previous research work, there are several thoughts/definitions and methods of aesthetics; though, there does not appear to have a collective common description of aesthetic, and there were some methods that rarely relates to the clear thoughts/definitions of aesthetics (Norman, 2002; Saito, 1998; Walton, 2007). Consequently, as long as various measures of aesthetics are found out, it is ambiguous exactly how sound these results relate to aesthetics. However aesthetics has been used in arts, poetry and other areas for over 20 years, yet, still we are still lacking a common understanding of aesthetics. If something is attractive or beautiful to a user, does it depends on the area? Thus, a common understanding of aesthetics is important to have. Taliaferro (2013), describe that typical definition of aesthetic is quite confusing "i.e., is a branch of philosophy that deals with beauty and art". Mainly the definition of aesthetic is provide a theoretical framework. And, on this definition is quite difficult to understand how and in what way the term is aesthetic is linked with different field. Therefore, there is a need of simple definition and description (measures, tools and methods) with which, we can define aesthetic in easy way. Without getting a definition, measures, tools, and methods it will be difficult for researcher to understand and quantify the product aesthetics design.

4.4. Aim and Methodology

4.4.1. Aim

The main aim of this study is to develop aesthetic definitions in terms of philosophical as well as engineering aspects. The methodology of this study is based on a framework that consists of two phases, as shown in Figure 4.1.

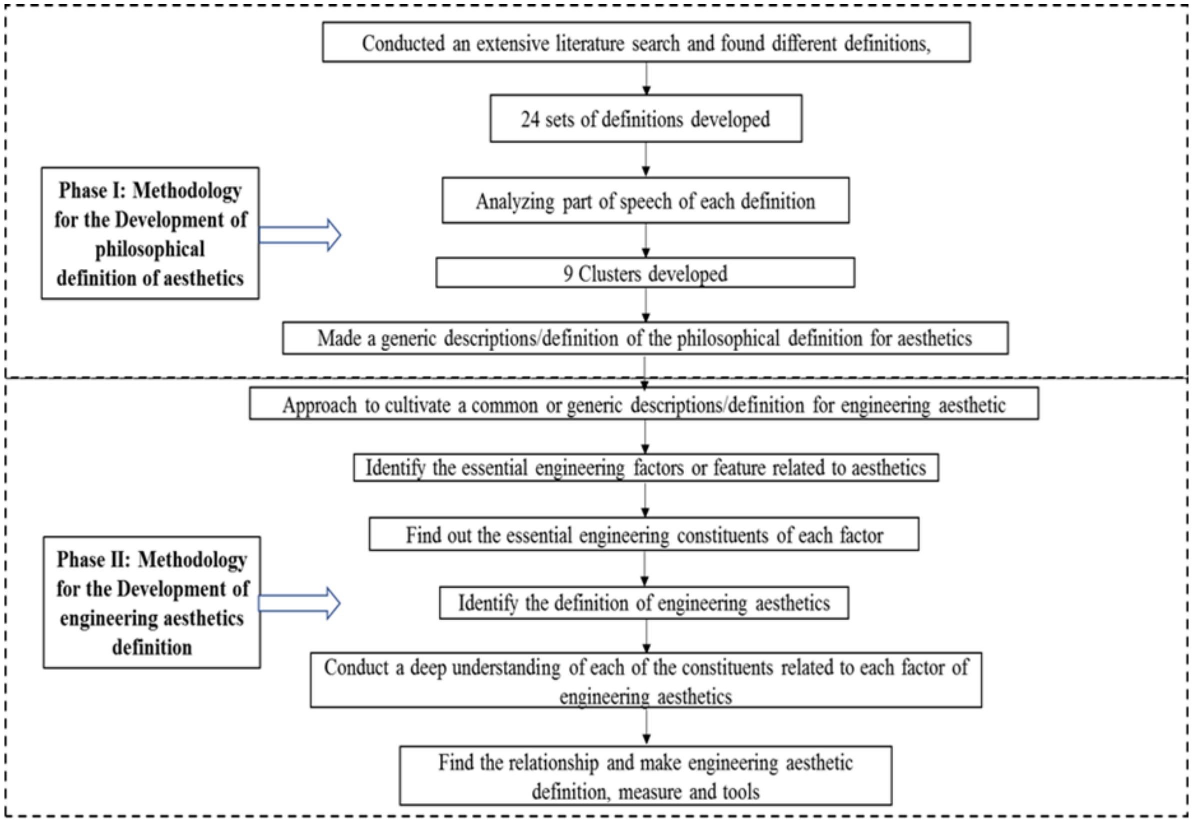


Figure 4.1. Shows the framework of aesthetics definitions

A deep literature search has been done to identify the different set of aesthetics definitions in philosophical and engineering point of view, followed by an analysis part of speech and cluster analysis methodology has been done in this work. A two phase's methodology are described in detail which consists of the followings: basic or generic definition of aesthetics can be utilized to recognize suitable aesthetics methods and tests for enhancing or testing aesthetics. A flow chart has been shown below, which shows the actual path followed by the research to sum-up the study. In flow chart, we can see that the study had been conducted into two phases. In the first phase of this study, we collected different sets of definitions from various sources such as journals, blogs, books, chapters, conference papers, etc. From an extensive literature search, a total of forty-two definitions of aesthetics were found. We discovered during this search that aesthetics is defined by multiple authors, some of whom have published widely and have years of experience in design research, while others have not. It is frequently challenging to locate their research background through Google search. A proposed standard definition of aesthetics should, to the best of the research community's ability, reflect that understanding. This prompted us to limit our attention to definitions whose authors have contributed writings in aesthetics, design, or innovation. We searched each author's research history using Google again, and twenty-four reports that met the aforementioned requirements were ultimately chosen. After that, we conducted an analysis of speech. In doing so, we sought assistance from the Cambridge Dictionary, Oxford Dictionary, and the Google search engine. Subsequently, we developed nine distinct clusters based on different word categories such as nouns, verbs, pronouns, adjectives, and so on. Using these words, we proceeded to formulate a philosophical definition of aesthetics. In the second phase of this investigation, we carried out a comprehensive search to pinpoint the essential and crucial engineering components of aesthetics. We then analyzed and comprehended each element from an engineering standpoint to grasp how they relate. We constructed a definition of engineering aesthetics thanks to this thorough investigation.

4.4.2. Methods to develop a common or generic definition of creativity/ Approaches to cultivate a common or generic descriptions/definition of aesthetics

Development of a "common" definition depends on the generic features of the expression/words "aesthetics" as held among academic scholars. Therefore, study taking place with a determination to gather a complete list of aesthetics definitions from previous work. "Aesthetic" is appropriate for an extensive variety of topics from psychology to literature to management to engineering to medical. Basically, there is barely any region that does not need aesthetic. This is the foremost motivation, why this precise word is been employed by practitioners in all domains of study. A broad examination of the "aesthetics" previous work opened many definitions of this thought. Search has been carried out in Google Scholar/Google and separate journal publishers' websites such as Springer Link, Elsevier, Taylor & Francis, Wiley, Emerald, and Sage Online. During the literature search no constraint was imparted on the publication year or field of a research journal; however, organizational aesthetics was the key focus. Definitions were gathered from published research works in book chapters, conferences, and journals specifically committed websites on aesthetic.

Forty-two definitions of aesthetics were found through this thorough, open-ended search and were studied from various sources. We discovered during this search that aesthetics is defined by multiple authors, some of whom have published widely and have years of experience in design research, while others have neither. It is frequently challenging to locate their research background through Google's search. A proposed standard definition of aesthetics should, to the best of the research community's ability, reflect that understanding. This prompted us to limit our attention to definitions whose authors have done writings that contribute to aesthetics, design, or innovation. We searched each author's research history using Google again, and twenty-four reports that met the requirements above were ultimately chosen. Only these twenty-four definitions (some listed in Appendix 4.1.A) were used for our analysis. The year range for the selected definitions is 1890 to 2020; however, the date was not used as a search criterion.

4.5. Collected definitions

A total of twenty four different definitions are considered for our examination (see Appendix 4.1.A for a few of generic definitions of aesthetics). The collection of the aesthetics definitions id from the year of 1890 to 2020; on the other hand, year was not considered as a norm for literature search. We look two probable meanings for a "general definition" of aesthetics. Firstly, since the "general definition" must replicate the opinions said by the larger number of academic researchers and very senior peoples of industries in the area, we must cultivate a method (approach) that customs, in the "general definition", those thoughts that are most regularly used through existing definitions. Secondly, another significance is an established on the justification that the majority of the above definition might not be express/represent in very good way, the basic relationships between the ideas taken care in the numerous definitions, and thus cannot deliver a mutual demonstration of total of all the definitions. Hence, we develop a new, alternative methods/technique that find out the relationships between the languages/words/nouns/terms/pronouns used in collected definitions. And these are used to develop a meaning of aesthetics. We considered this process “relationship analysis”. The results or outcome of first technique might be provide a valuable understanding for the combined concept of aesthetics definition. Although, the second study is more into finding a commonality among them by linking through the terms/language/words used into the different definitions or thoughts about the aesthetics. The outcome from the above two studies are then analysed and combined to develop a common or generic definition of aesthetics.

Initial assessment of total of twenty four definitions presented three defined characteristics amongst all total of selected definitions:

- Step I: first definitions or thoughts of researcher/senior designers uses an expression/phrase i.e. (“either a verb or a noun”) for preciseness of spirit/core of the definitions or thoughts and it is similar qualifiers, incorporating of verbs or adjectives, to demonstrate something precise regarding the expression/phrase such as ‘beauty,’ ‘patterns,’ or ‘appropriate’.
- Step II: second, from all definitions certain essential qualifiers of aesthetics have been underlined, for example ‘beauty,’ ‘contrast,’ ‘art,’ and ‘psychology’.
- Step III: from total of all definitions which we get through senior designers and academia’s from different culture and backgrounds, aesthetics has been explained by considering one or more of the subsequent means: (i) a outcomes, products, or services with a following features (approximately every definitions consider this), (ii) a group of quantifiable and non- quantifiable quantities/features/abilities/variable/personal traits: example, pure, appropriate, beautiful, symmetric, rhythm, harmony, and attractiveness.

Further, in next section, we talk about in what way these outcomes could be considered in the two techniques/methods to hypothesis the general definition of aesthetics.

4.6. Majority examination

In majority examinations our main focus is to classify the basic resemblance through the definitions. To fulfill this, every definition or thoughts are separated out into verb phrases or primary noun. Similarly in next step, the occurrence of these verb phrases and noun with their entries among all the collected definitions were considered. Further, these phrases and their related entries were carefully analysed and gathered in a set of matching to their likeness/similarity (something but not exactly the same) in meaning. Commonality among all verb phrases and noun were arranged individually (Table 4.1 and also provide some examples). In next step, frequencies rate for every verb and noun (statistical rate of occurrence) were found out for every set of group, the core entries and core phrases were recognized, and these were considered to build the “generic/general aesthetic” definition.

4.7. Analyzing part of speech of each definition

Six major groups of noun phrases are recognized as shown in Table 4.2. Each of these phrases was further subdivided into four groups Part A and Part B (where Noun (Part A), Verb (Part B), Adverb (Part C) and Adjective (Part D), to have additional comprehensive understanding, certainly, the new phrases were long. Expressions with greater quantity of amounts ("shown in brackets in Table 4.1") were prepared part of the generic definition of aesthetic.

Aesthetics states to the some kind of experience sensed by a he or she when dealing with a process, product, their surroundings, or service. To eliminate pronouns like "his" and "her," we substitute the word "human being," which is defined as "something that feels a change or an effect or is impact particular human's cognitive thinking."

"**Table 4.1.** Clustering of definitions showing the highest occurrences (shown in bracket) of the noun phrases"

Definition no.	Noun (Part A)	Verb (Part B)	Adverb (Part C)	Adjective (Part D)
1	a branch of philosophy	Nature of beauty, art, and taste and with the creation and appreciation of beauty.		
2	Visual Beauty			
3	(i) a particular theory or conception of beauty or art, and (ii) a particular taste for or approach to what is pleasing to the senses and especially sight.	Approach, Sight	Especially	Particular, Conception, Pleasing
4	Concept	Understanding through sensory perception.		
5	Phenomena	the pleasure attained from sensory perception,		
6	visual beauty			
7		sensory pleasantness in general,	Things can also be aesthetic or pleasant to listen to, touch, smell, or taste.	
8	philosophy of art, which comprises one of its branches	Nature and value of the arts but also with those responses to natural objects that find expression in the language of the beautiful and the ugly.		
9	Experience, Realm, Criticism, Taste, Contemplation, Fine art, Enjoyment, Charm	Art		Beautiful, Ugly, Sublime, Elegant, Sensuous
10	experience, art, Study, objects, behavior	Art, Approach		Naturalistic,
11		Perception by the senses, perceptive," of things, "perceptible," to perceive (by the senses or by the mind), to feel, "to perceive."		
12	philosophy	the intrinsic value and emotional quality of art and its creation		

13	Of beauty" or "pleasing to the eye".			
14	pleasure we derive from perceiving an object or experience through our sense	experiences that are a pleasure to buy and consume		
15	A branch of philosophy dealing with the nature of beauty, art, and taste and with the creation and appreciation of beauty. Philosophy dealing with the nature of art and beauty.			
16	Theory, Conception, Beauty,	Art		Particular
17	(i) Perception through sensation. Sensory perception, and so preserves the implication of immediacy carried by the term 'taste.' (ii) Pertaining to sense perception; aistheta, perceptible things; aisthenasthai, to perceive; aisthesis, sense perception. Clearly, aesthetics has to do with human perception.			
18	"Related to the enjoyment or study of beauty", or "an aesthetical object or a work of art is one that throws great beauty".			
19	Pleasure, Understanding			
20	sensation	perception of	attractiveness (or unattractiveness) in products	
21	Judge, People, Places, Terms, Beauty, Attractiveness,		Often, Beauty,	Attractiveness
22	Works of art or with the sense of beauty.			
23	Blocks, Sense, Perception, Person,	Make, Feel		Unable
24	Function, response to function	conducive to purposefulness and functionality	semantic attractiveness	

We wanted to find how researchers' defined aesthetics and what are the major constituents used in these definition. Later we aim to find the commonality among these. First we take each of the definition as shown in Appendix 4.1.A, analyze it, find the constituents (Noun, Verb, Adverb, and adjectives) of each is shown in Table 4.1. Apart from these four major parts of speech, there is also conjunction, interjection, and pronouns; however, the numbers of these are ignorable and the authors did not use any major standard terms for these.

4.8. Finding major phrases

Next, we find the major phases that the researchers' used to develop the definition. In table 4.2 we show this analysis.

Table 4.2. Major phrases used in the definitions (with respect to each definition)

Definition no.	Phrase set 1	Phrase set 2	Phrase set 3	Phrase set 4	Phrase set 5	Phrase set 6
1	a branch of philosophy	Nature of beauty, art, and taste and with				

		the creation and appreciation of beauty				
2			Visual Beauty			
3		of beauty or art	Pleasing to the senses and especially sight			
4				Sensory perception		
5				sensory perception,		
6			Visual beauty			
7				sensory pleasantness in general,		
8	Philosophy of art	beautiful and the ugly				
9		Beautiful, Ugly, Sublime, Elegant, Sensuous				
10	Philosophy of art				study of art objects, behavior, and experience	
11				perception by the senses		
12	Philosophy					the intrinsic value and emotional quality of art and its creation
13			pleasing to the eye	pleasing to the eye		
14				experience through our sense		
15	Philosophy	(i) Nature of beauty, art, and taste and with the creation and appreciation of beauty (ii) nature of art and beauty				
16		Beauty or art				
17				(i) perception through sensation, (ii) pertaining to sense perception		
18		(i) study of beauty" (ii) work of art				
19				Pleasure, Understanding		
20		perception of	attractiveness (or unattractiveness) in products			
21		Beauty	Attractiveness			

22		art or with the sense of beauty				
23				Sense, Perception		
24	purposefulness and functionality		semantic attractiveness			

4.9. Cluster analysis

In Table 4.3, cluster analysis has been done. Where, we collect same words (Noun, verbs, adverbs, adjective) which has been come in all definitions and at the same we also count number of frequency of word (Noun, verbs, adverbs, adjective). In this Table 4.3, we shows the frequency of words repeated or comes in different definitions of aesthetics.

Table 4.3. Cluster analysis

Number of words	Words	Total number of time repetition or frequency
1	Philosophy (Noun)	5
2	*Beauty (noun/adjective)*	9
3	*Visual beauty (pleasing to eyes and senses) (adjective/noun)*	4
4	***Combining 2 and 3, Beauty (noun/adjective)***	(9+4=13)
5	Sensory (adjective) perception (Noun)	9
6	deals with (Verb)	7
7	Attractiveness (noun)	3
8	comprises of	3
9	which influences	4

4.10. Developing the definition

Once we have the constituents, we aim to develop a definition of the term ‘aesthetics’ from philosophy point of view.

“In Philosophy, aesthetics comprises of beauty and attractiveness, which influences sensory perception.”

Here we try to combine the most commonly occurring terms as discussed in the Table 4.3 and create a possible definition of aesthetics. The assumption is that if the researchers uses similar words to describe aesthetics more often, it possible means that aesthetics can be generically expressed using these terms. For instance, beauty is a part of aesthetics as the terms beauty is been used often by the researchers. It would be interesting to note here that we used influences in the definition to depict ‘deals with’. We agree that, apart from this above proposed or developed definition, there could be other possible combination of the words and a different definition could be developed. However the essential compositions would be similar.

After developing a philosophical definition of aesthetics, we also discussed each and every definition factor. Thus, first we discuss; beauty term, then attractiveness term and then last the relation of sensory perception with these factors. After developing a philosophical definition of aesthetics, we also discussed each and every definition factor. Thus, first we discuss; beauty term, then attractiveness term and then last the relation of sensory perception with these factors.

4.11. Beauty

In western countries, art is more involved in the visual domain, and the perception of aesthetics has been used as synonymous with “visual beauty” (Guyer, 2008). Santayana (1896) defines beauty by using three features value positive, objectified, and intrinsic (essential/innate nature) are not as many technical words; Beauty is the feeling of satisfaction observed as the attribute of a thing. This definition defines “beauty as a value,” and this means it is not the ability to “understand a relation” or a “matter of fact”. This definition is similar to the “Thomas of Aquinas” definition i.e. “what provides the feeling of satisfied or being happy at sight,” suggesting instant joy without in-between reasoning (Scott, 2012). Beauty is defined in terms of objective features of any stimuli, for example, symmetry, contrast, clarity, and figure (Santayana, 1896; Kostellow, 2002; Hekkert, 2006; Scott, 2012). Beauty describes the link/correlation among the design elements' competence is physically perceived as lovely (Kostellow, 2002). Although the critical method of aesthetics (Hassenzahl, 2008) supports the general confidence that absolute beauty is present, new research work accepts that “beauty lies in the eye of the beholder,” and as a result, aesthetics consider subjective (Kumar & Garg, 2010; Baskerville et al., 2018). Therefore, a design can be highly aesthetic to one person but not to others, as visual aesthetics is based on psychological mechanisms reflecting individual and detailed features (Kumar & Garg, 2010). Beauty always accompanies a particular arrangement (Galanter, 2010) in which the “design principles” are created based on that arrangement (Kostellow, 2002), and it is independent of human perception (Khalid & Helander, 2006).

Beauty results from objective qualities like symmetry/proportion, pureness/purity, and contrast. New research acknowledges subjectivity and the idea that beauty is in the eye of the beholder, despite the belief of some in absolute beauty. Individual psychological preferences and systems have an impact on visual aesthetics. Beauty is linked to precise groupings and design concepts independent of how others perceive it.

4.12. Attractiveness

Khalid and Helander (2006), studied that attractiveness is totally dependent on the time. It is produced by functionality (Mono, 1997; Verma & Wood, 2001; Singh & Sarkar, 2023), and it can vary according to the peoples (Huang & Henry, 2009; Singh & Sarkar, 2023). Cognitive features generate ‘beauty’ (Coates, 2003; Crilly et al., 2004), and behavioural features of aesthetics create ‘attractiveness’ (Desmet, 2003; Norman, 2002) as the key integral elements of aesthetics (Khalighy et al., 2014). Similarly, a series of studies related to product design and aesthetics (Veryzer, Jr. & Hutchinson, 1998) found that unity (i.e., congruity among the elements of a design) and prototypicality (i.e., the degree to which an object is representative of a category) positively influenced aesthetic evaluations. Aesthetic comprises one’s cognitive reactions to particular objects and shapes and is an integral feature of product design (Veryzer, Jr. & Hutchinson, 1998; Kumar & Garg, 2010; Heitmann et al., 2020). In the meantime, visual aesthetics refers to customers’ insights into the product’s beauty and the physical feeling of satisfaction that it suggests (Moshagen & Thielsch, 2010; Bhandari et al., 2019). Further, Baskerville (2018) explains that, from a non-practical perspective, visual aesthetics is objective (against subjective) and replicates comprehensive gratitude (against the influence of specific design aspects).

Time and functionality have different effects on attractiveness depending on the individual. Both are essential components of aesthetics, with behavioral characteristics contributing to attractiveness and cognitive features helping to produce beauty. Unity and prototypicality favorably affect aesthetic assessments of product design, highlighting the significance of consistency between design aspects and the portrayal of a category.

4.13. Sensory perception

The word "aesthetics" is a translation of the Greek word "aisthsis," which denotes sensory experience. When he initially outlined aesthetics as "the science of sensory knowledge aimed towards beauty" and saw art as "the perfection of sensory awareness" in the middle of the eighteenth century, Alexander Baumgarten stayed true to the original Greek definition (Baumgarten, 1750). The philosophical field of philosophy, which includes the consideration of definition and ontology, has grown from the original sense of the word "aesthetics" in terms of its technical application. However, its modern description has expanded to include anything attractive and pleasing to the eye. Instead of a celebratory stance, our understanding of aesthetics is distinguished by a descriptive and a priori analysis of visual experiences. However, the word "aesthetics" has become overly generalized in modern usage to mean something attractive and pleasing to the eye. Additionally, we now consider the complete spectrum of negative numbers to be part of aesthetics in addition to positive numbers. Aesthetic philosophy encompasses all human experience and goes beyond the natural world and fine arts. The realization that aesthetic appreciation does not only depend on an object-centered reaction requiring psychological detachment and distance has been made. Instead, it entails a subtle, multi-sensory perceptual interplay controlled by a sophisticated sensibility. For instance, the sensory characteristics of a typical human being should be taken into mind while designing everyday items like the Coca-Cola bottle. The bottle's twin-spaced body creates a melodic contour that fits comfortably and luxuriously in the palm, creating a relaxing and delicious experience even when wet and cold.

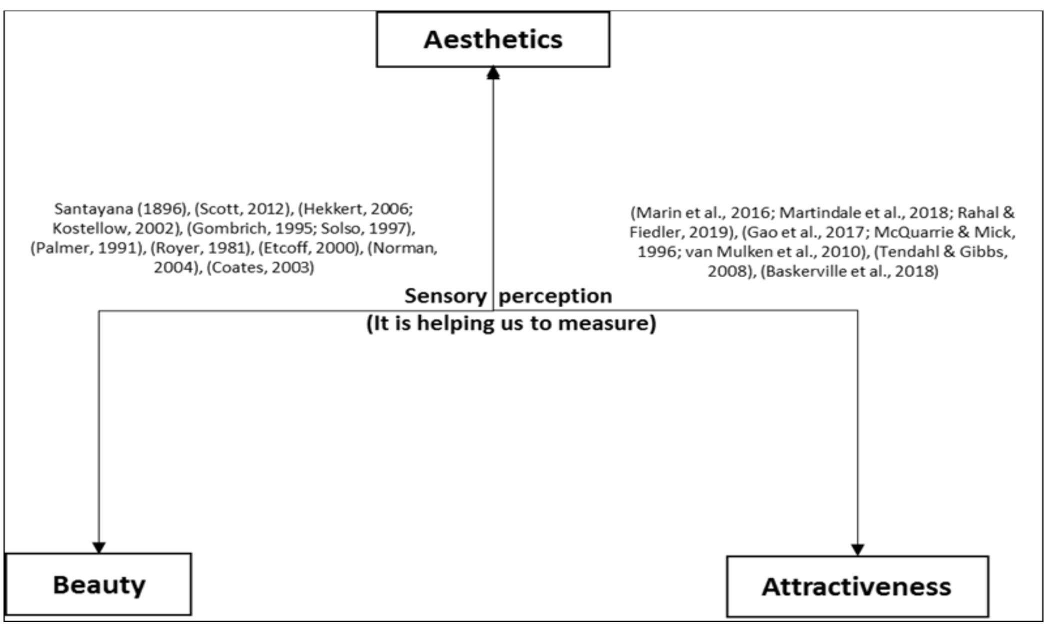


Figure 4.2. Block diagram of the hierarchical relationship of aesthetics with other factors

In our research, we first looked at the general idea of beauty and aesthetics from a philosophical perspective. This was like understanding what people generally mean when they talk about things being beautiful or aesthetically pleasing. We found different definitions and ideas related to aesthetics in philosophy. Then, we moved on to the next step, where we focused specifically on how aesthetics applies to engineering – this is what we call "engineering aesthetics." Now, why did we do this? Well, when we looked at the philosophical ideas about aesthetics, we found that they have a lot to do with big, general concepts. But when it comes to actual engineering – designing and making things – we needed a more specific understanding. So, we used the philosophical ideas as a starting point, like a foundation, and built on them to create a definition that fits better with the practical side of engineering. We didn't want to just copy the philosophical ideas; we wanted to adapt them to the real challenges and considerations that come with designing and making things in the engineering world. This way, our study is like a bridge between the big, theoretical world of philosophy and the hands-on, practical world of engineering. It helps us better understand and use aesthetics in the specific context of creating things in engineering.

4.14. Understanding aesthetics from engineering point of view (Engineering aesthetics)

The scientific discipline known as "engineering aesthetics" should focus on two important issues:

- How scientific and engineering approach might be used to investigate aesthetic concepts in system and product design?
- How may scientific practices and engineering be included into the evaluation and creation of aesthetics, beyond the "hunches" of trend analysts and designers?

In this article, we explore the ongoing conversations among philosophers and art critics regarding the meanings of beauty and other aesthetic concepts. It's essential to acknowledge that these discussions are not scientific inquiries; rather, they involve the exchange of insightful perspectives on aesthetics. Similar to how architects gather design insights and successes from diverse fields, industrial designers follow suit. This compilation serves as a rich source of inspiration, offering opportunities for the field of engineering aesthetics to evolve and benefit from these diverse contributions. It's crucial to recognize that the principles followed by designers, though valuable, were never intended to be strictly scientific. The term "aesthetics" is commonly used in everyday language, spanning a broad spectrum of contexts, from cosmetics and beauty salons to the enjoyment of pleasures and the arts. In this thesis, our objective is to devise methods that can elevate aesthetics. To achieve this, a crucial step is the development of a definition for aesthetics, specifically tailored for engineering purposes. This definition, referred to as engineering aesthetics, serves as the foundation for measuring and enhancing the aesthetic qualities of products or systems. The aim is to establish a clear framework that enables the quantification and improvement of aesthetics through systematic methods. Nonetheless, the terms "aesthetics" and "art theory" are currently most frequently used in academic settings and intellectual discourse (Honderich, 1995). Thankfully, a number of empirical studies of aesthetic concepts have been conducted, both beyond and within the arts domain (e.g., (Langlois and Roggman, 1990; Hekkert and Wieringen, 1996)). Empirical studies and theoretical debates both agree that aesthetic replies and evaluations expand outside beauty judgements. Instead, there are many different aesthetic ideas present, such as the beautiful, the attractive, the sublime, the comic, the hilarious, the "cool," the tragic, the ugly, the funky, and the fashionable (Honderich, 1995). The enchantment of aesthetics emerges within this complex interaction of various aspects, enrapturing our senses and generating severe reactions. Philosophers, art critics, and designers disagree on what these qualities are and how they influence whether an aesthetic reaction is positive or negative. In this section, the main aim is to systematically identify and measure the constituent factors related to engineering aesthetics. Thus, first, we perform a thorough literature search and we identify critical constituents related to engineering aesthetics. Further, in the next section, we will briefly discuss every constituent.

4.15. Constituent of engineering aesthetics

Many aesthetics and psychology researchers contend that in addition to the shape or outward appearance of the stimuli, human aesthetic responses are also influenced by their content or symbolic meaning. Different persons may have diverse aesthetic responses to the same object or stimulus because they have different symbolic or connotative meanings for each person and elicit different memories or mental associations.

4.15.1. Beauty

A classic example often referenced in design literature is the iconic Apple iPod, introduced by Apple Inc. in 2001. The iPod's design, attributed to Jony Ive, exemplifies the integration of aesthetics and beauty into a functional product. The iPod's sleek and minimalist design, characterized by smooth curves, a simple interface, and a polished aluminum exterior, not only made it visually appealing but also contributed to its overall user experience. The seamless blend of form and function in the iPod's design is often cited as a prime example of how beauty enhances the usability and desirability of a product (Heskett, 2002). The aesthetic quality of a design or an engineered object is frequently described as beauty in the context of engineering. It includes the design's aesthetic appeal, grace, harmony, functionality, and effectiveness. Engineering beauty is the art of designing systems, structures, or products that not only fulfil their intended purpose well but also thrill and inspire awe in the viewer. Clean and aesthetically beautiful lines, balanced proportions, the careful fusion of form and function, rigorous attention to detail, and the overall coherence and unity of the design are just a few examples of how engineering beauty may be created. It entails giving careful consideration to the visual impact of the product or structure, the materials and finishes employed, and how all the aspects work in harmony to provide an aesthetically pleasing whole. Additionally, engineering beauty goes beyond just how something looks outside and includes how users engage with the design. It includes elements like ergonomics, usability, and the emotional response a user has when using a manufactured thing. In the end, engineering beauty is about coming up with designs that are not only technically effective but also aesthetically beautiful, increasing customer happiness and producing an enjoyable and engaging experience. To produce designs that are not only functional but also aesthetically pleasing, form, function, and human elements must be harmoniously combined. Visual aesthetics talk about the significance (Kieran, 1997), which can be subjectively interpreted (Crilly et al., 2009) can be objectively calculated (Crilly et al., 2004), or as a volunteer consumer reaction (Ulrich, 2006) as an external actuality (Khalid & Helander, 2006). The objective phase is more intuitive (Crilly et al., 2004), while the subjective phase of aesthetics is associated with the emotional characteristics of consumers or users (Khalid & Helander, 2006; Norman, 2004). Most of the earliest beauty researchers believed that an object's attractive qualities were inherent. It was believed that the stimulus under consideration's beauty was an objective quality. There was a belief that certain angles, ratios, shapes, and colours were naturally beautiful. This method implies that every object will have a perfect shape that, once obtained, will typically be viewed favourably by all. Aesthetic proportions and exact geometrical laws are frequently used in historical art and building. In the 1920s and 1930s, the Bauhaus school was at the forefront of using this methodology in product design. Their designs were well-known for being logical and were influenced by Gestalt psychologists' results (Crilly et al., 2004). These psychologists discovered that even when symmetry, regularity, and harmony are not directly present, we are predisposed to notice them. The Gestalt Rules is a collection of aesthetic rules inspired by this innate need for visual order. These guidelines cover many concepts, including symmetry, closeness, similarity, continuity, recurrence, and closure. They act as guidelines for producing attractive designs. According to Crozier (1994), believing in universal aesthetic principles is difficult because innate responses "may be a mirage" because of the discernible discrepancies between people's aesthetic evaluations. He contends that sociocultural, social, historical, and technological elements all have an impact on an object's visual appeal. As a result, other cultures might not share some of the goals and norms that one culture holds dear. This issue of cultural taste shows that evaluations of an object's attractiveness cannot be fully explained by the object's objective properties alone. Additionally significant in influencing visual perceptions are the consumers' subjective experiences. Whereas the human eye is getting information (Arnheim, 1969; Etcoff, 2000), it is an examined by the human brain (de Pontual et al., 2009). After they relate the information (Hekkert et al., 2003) with data (Coates, 2003) involves of users' or human's experiences (Hung & Chen, 2012) and understanding (Rojas & Kang, 2001), and with 'concinnity' "(concinnity means harmony in the arrangement of the different parts of something)" (Crilly et al., 2004) it is centered around on pleasant principles (Hekkert, 2006). Thus, two kinds of reactions are created: cognitive (for example, remembering, reasoning, or thinking) and affective (emotional actions or feelings or activities controlled by emotions) (Crilly et al., 2004). Balance among these two opposite characteristics generates a favorable opinion of the aesthetic (Coates, 2003). Specifically, the physical look of a product is perceived as pleasurable when it is capable of pleasing a customer/user in logical as well as sentimentally (Bloch, 1995; Jacobsen et al., 2006), which are connected to the design principles (Kostellow, 2002) human factors (Jordan, 1998) and as a part of product concinnity (Crilly et al., 2004), and product characteristics (Shank & Langmeyer, 1994; van Breemen & Sudijono, 1999) usability (Sonderegger et al., 2012; Tuch, Roth, et al., 2012) and as a part of product functionality (Verma & Wood, 2001). Additionally, engineering beauty goes beyond just how something looks outside and includes how users engage with the design. It contains elements like ergonomics, usability, and the user's emotional response when using a manufactured thing. Coates contends that a product's perceived information and consistency derive from both the subjective experiences of the buyer and the product's intrinsic attributes. The consumer's acquaintance with other products, entities, and concepts also influences their perception of the product's aesthetics, in addition to the combination of lines, colours, textures, and details that make up its visual shape.

As a result, the knowledge and consistency perceived in a product can be separated into its objective and subjective parts. Cognitive features generate 'beauty' (Coates, 2003; Crilly et al., 2004), and Behavioural features of aesthetics create 'attractiveness' (Desmet, 2003; Norman, 2002) as the key integral elements of aesthetics (Khalighy et al., 2014).

Tinio and Leder (2009) presented participants with images containing geometric shapes differing in symmetry and stimulus complexity. Complexity of an image was defined as the number of individual elements (e.g., squares, rectangles, triangles) in the image. Their results showed that images containing many elements were preferred over images containing fewer elements; and that symmetrical images were preferred over asymmetric ones. This argued against an inverted-U relation between complexity and beauty. A series of studies, which is related to product design and aesthetics (Veryzer, Jr. & Hutchinson, 1998) found that unity (i.e., congruity among the elements of a design) and prototypicality (i.e. the degree to which an object is representative of a category) positively influenced aesthetic evaluations. Aesthetics comprises one's cognitive reactions to particular objects and shapes and is an integral feature of product design (Heitmann et al., 2020; Kumar & Garg, 2010; Veryzer, Jr. & Hutchinson, 1998). Visual aesthetics refers to customers' insights into the product's beauty and the physical satisfaction it suggests (Bhandari et al., 2019; Moshagen & Thielsch, 2010). From a base on a non-practical perspective (Baskerville et al., 2018), visual aesthetics is objective (against subjective) and replicates comprehensive gratitude (against the influence of specific design aspects). Although the critical method of aesthetics supports the general confidence that complete beauty is present, new research work accepts that "beauty lies in the eye of the beholder," and as a result, aesthetics consider subjective (Hassenzahl, 2008) (Baskerville et al., 2018; Kumar & Garg, 2010). Therefore, a design can be highly aesthetic to one person but not to others, as visual aesthetics is based on psychological mechanisms reflecting individual and detailed features (Kumar & Garg, 2010). Therefore there is a need to discuss the importance of beauty.

4.15.1.1. Constituents of beauty

4.15.1.1.1. Contrast

Beauty is "absolute" (Coates, 2003), "timeless" (Etcoff, 2000), "independent of function" (Norman, 2004), and "rational" (Khalid & Helander, 2006). Beauty is produced from logical or rational physical appearance relations (Kostellow, 2002; Khalighy et al., 2012) in that a proper sense of balance among these relationships produces the most favorable pleasantness. The standard of beauty is primarily generated from the critical element, which makes human beings capable of distinguishing visual elements. It is necessary to initiate at the fundamental level to describe powerful and measurable essential aesthetic features. By imagining/visualizing a completely spotless or fresh or new painting board, the first feature or thing that attracts any human being is a visual element of design elements known as "contrast." Kostellow (2002) defines the relationship among beauty and different design elements. They described how a product could be visually delightful using design elements. The visually delightful is a critical characteristic that comes to designers' perception when designing any new product. Since visual aesthetic is a physical/visual appearance, it is straightly associated with "what is seen" by a human being. The eye can recognize any entity because of the difference between the properties of the object and the properties of the background (Kostellow, 2002). For example, in current situations, what things or object makes you capable of understanding or recognizing the script on this manuscript or chapter is the difference in the color and proportion of the words/text on it. According to Del Coates (2003), this event is named 'contrast.' "Contrast" is associated with the visual properties of the product, and it is not only restricted to the product context. But, contrast is produced by variations between the visual/physical properties of the design element and the background of the product. For instance, a product's length and height variation produces a contrast (Elam, 2001). Furthermore, the sum of these variations intensifies the contrast (Coates, 2003; Crilly et al., 2004). Consequently, contrast is made by the quantity and the quality of the variations produced by the "elements" and the "composition of the gestalt." The higher the variation in elements and composition, the higher the contrast, or the lower the variation, means lower the contrast (Khalighy et al., 2014).

4.15.1.1.2. Pureness

Purity in engineering aesthetics describes a design without extra complexity, extraneous components or clutter. It strongly emphasizes minimalism, a clean and a simple aesthetic. By removing unnecessary aspects/details or elements that do not contribute to the product's overall aesthetic appeal or functionality, pureness in design seeks to create a feeling of harmony elegance, and clarity. Pureness is commonly connected to a sense of cleanliness, visual balance, and aesthetic righteousness. Minimalistic forms, restrained color scheme, and sleek lines can all help to achieve pureness. Without any unnecessary distractions or embellishments, the focus is on producing a visually appealing and unified design. Kostellow (2002) suggests in their work that "pureness" can be measured quantitatively as a form of "contrast". Fundamentally, it relates to the degree of simplicity or purity or clarity or in a design. Coates (2003) also defines the design elements that fascinate human beings in their study. According to Khalighy et al. (2012), a higher level of pureness in a design specifies a lesser level of an intrigue or curiosity. In other terms, when there is lower simplicity or clarity in the design, it inclines to grasp the human's focus more efficiently. On the other hand, higher level of pureness denotes a design that is less visually complex and more straightforward. Similarly, the quantity of visual/physical elements rises; another factor is known as "pureness." This factor is expressible in quantity, an essential characteristic of "beauty." Pureness in engineering leads to achieving an efficient and streamlined design that concentrates on crucial functions and removes any redundant or superfluous elements. By offering a straightforward and user-friendly design that is simple to comprehend and engage with, this strategy improves the user experience.

4.15.1.1.3. Proportion

Another factor, "proportion," is defined based on similarity as dissimilarity when the visual elements interact with everyone. Moreover, these three factors are the main constituent combinable and represent "beauty" (Kostellow, 2002; Coates, 2003; Norman, 2004). The term "proportion" is a qualitative portion of "contrast". In design, the phrase "proportion" is a qualitative element that works with the idea of "contrast." In contrast to proportion, which deals with the relationship and balance of proportions, forms, and other design aspects, contrast focuses on the visual disparities between elements. Contrary to certain other design concepts that can be determined scientifically, proportion mainly relies on customer or user observation and perception and it depends more on the consumers/user's observation and real-time case studies (Kostellow, 2002). Since it depends more on the consumers/user's observation and real-time case studies. Proportion is described based on the visual similarity among the properties of the design elements, for example, size, nature, place, and color. The relationship between different aspects, such as size, shape, location, and color, creates visual harmony and balance in a design. This is referred to as proportion. It entails ensuring that these components complement one another in a pleasing and balanced fashion and are aesthetically similar and coherent. When used correctly, the proportion contributes to a design's visual balance and aesthetic cohesion. Designers may create a composition that fascinates the spectator and exudes a sense of harmony and order by carefully examining the proportions of design elements. (Papanek, 2022). In other words, proportion determines the stability generated by the visual weights of the gestalt composition (Coates, 2003). Thus, a lower likeness means a lower proportion, and a higher likeness represents a higher proportion." A design not only has to be structural, but it also has to appear to be structural. You have to get to recognize structure like you recognize a hot stove." "Always imagine these things one hundred times as large, and you will see that the proportions make a huge difference."

4.15.1.1.4. Attractiveness

In marketing, the interplay between perceived value, aesthetics, and attractiveness reveals a dynamic relationship that guides consumer behavior. Perceived value, encompassing utilitarian and hedonic dimensions, influences consumers' rational problem-solving and emotional experiences. Aesthetics, driven by attractiveness, serve as key components, heightening both utilitarian and hedonic values. The higher the perceived utilitarian and hedonic value, the greater the consumer's attraction and, subsequently, their purchase intent. This intricate connection showcases the pivotal role of aesthetics in shaping consumer perceptions, emotions, and ultimately, purchasing decisions. Further, in consumer behavior domain, aesthetics and attractiveness play a pivotal role in shaping perceptions of product quality. Consumers make inferences about various product attributes, especially functional aspects, based on the product's visual appearance. A positive correlation exists between stimulus attractiveness and perceived product quality, observed across contexts like websites and retail stores. Garber et al. 2000 and Marin et al 2016 highlight that consumers' views of product attractiveness positively impact their perceptions of quality. Particularly when consumers lack additional information and prior experience, the product's visual appearance serves as a key extrinsic cue, influencing and facilitating their judgments of product quality. This emphasizes the integral relationship between aesthetics and attractiveness in shaping consumer perceptions and evaluations. Attractiveness arises with psychological reactions (Khalid and Helander, 2006) appears when an entity becomes meaningful/functionality to a customer (Mono,1997). Even though the integral features of attractiveness can vary depending on the nature of the entity/object, customer factors are every time effective (Bloch, 1995; Pham, 1999; Breemen et al., 1998; Coates, 2003; Noble and Kumar, 2008; Crilly et al., 2009). On the other hand, in large quantities of manufacturing, the essential factors must be universal and extensive so that subjective replies (“based on personal opinions and feelings rather than on facts”) can be objectively quantified. The Design of Everyday Things" by Donald A. Norman (2003), the author discusses the importance of aesthetics, including attractiveness, in product design. Norman emphasizes that aesthetic considerations significantly influence users' perceptions and experiences with everyday objects. These abilities are directly associated with the object's function (Verma and Wood, 2001). The term "attractiveness" is very closely connected with "creativity" (Christiaans, 2010; Sternberg, 2006), and the key elements of a "creative design" are appropriateness, i.e., perception of function (Lubart and Sternberg, 1995). In design, "attractiveness" and "creativity" go hand in hand. Appropriateness is one of the essential components of "creative design," which contributes to its appeal. When a design is considered appropriate, it means that it functions as intended or is perceived to do so (Lubart and Sternberg, 1995). In a creative design, the designer considers the usability and functionality of the product in addition to aesthetics. The design should efficiently achieve its goals and be suitable for the intended application. Users are more likely to find a design appealing when they believe it to be acceptable and useful. Design creativity entails coming up with novel and unique ideas while also ensuring that they are pertinent to and appropriate for the context in which they will be employed. Designers can make sure that their works effectively fulfill the purpose they were meant for by integrating appropriateness into the creative design process. This relationship between appropriateness and beauty emphasizes how crucial it is to take into account both aesthetic and practical considerations when looking for successful and appealing designs.

4.15.1.1.5. Appropriateness

Aesthetics is concerned with the functionality and concinnity of the product. Further, beauty is linked to concinnity, and attractiveness is related to functionality (Yadav et al., 2013). On the other hand, attractiveness or unattractiveness is the perception developed through the product's aesthetic impression. In the early 21st century, Coates (2003) described their theory related to product attractiveness perception. He positively describes aesthetics with concinnity and information factors. Concinnity is associated with logic and order (for example, in a proper way, connecting meaning of design elements), which supports the customer in understanding the product. In addition, Coates (2003) also defines aesthetics as a combination of objective and subjective qualities. Furthermore, subjective quality is a combination of colors, lines, textures, and information that contains the product's physical look, user knowledge of competitive products, and entities that influence the consumer's aesthetic impression of any product. Similarly, in case of objective quality, the two factors may consider the objective quality of product aesthetics; the first one is the amount of contrast present by design (product) in contradiction to its background or surrounding itself, and the second is the order (meaning) perceived in the design. Subjective quality is concerned with the consumer's familiarity with the product and to what extent the product design makes sense to the consumers. This is determined by the customer's personal, cultural, and visual experiences that assist them in understanding the product. The customer's cultural, visual, and personal engagement, which enables them to understand the essence of the thing, determines subjective quality.

In conclusion, objective information in engineering aesthetics relates to the degree of contrast a design displays inside and against its surroundings. This is accomplished by combining different design components like color, lines, forms, and textures. Contrarily, subjective data emphasizes perceived uniqueness in the design, which is determined by how much the object deviates from well-known forms. Designs that use unusual shapes and lines draw attention because of their appealing and distinctive qualities. As a result of using design concepts like the Gestalt Rules, objective concinnity in engineering aesthetics refers to the perceived order and organization in a design. High symmetry and orthogonality in a design demonstrate rationality, sense of order, and simplicity. Contrarily, subjective concinnity refers to what extent a design creates sense to the observer/humans, visual experiences, influenced by their personal, and cultural. Designs that use well-known design cues or share characteristics with already-existing designs are frequently easy to understand. Therefore, if the facts/information is greater than concinnity, in that case, the product could be confusing, ugly, and meaningless. On the other hand, if the facts/information is less than concinnity, the product will be boring and dull. That is, balance is required among shapes, forms, and functionality to create an attractive product. According to the appropriateness, which is sometimes mistaken for product character (Baxter, 1995; Hekkert, 2006), consumers choose certain design features for a particular function (Langmeyer and Shank, 1994). As a result, many design elements are produced for various product categories, and a recognized pattern is produced as a normal visual expectation (Veryzer and Hutchinson, 1998; Hung and Chen, 2012). For example, due to their known typical pattern of design features, which are mainly developed because of the constraints in attaining the goal of the product, low-height automobiles may be perceived by customers as sports cars and hence fit for this role.

From the above discussion, one has seen that engineering aesthetics is influenced by attractiveness and beauty. Then, we have also seen contrast influence beauty. In addition to that, pureness and proportion influence contrast. We have also found appropriateness influences attractiveness. And from the literature, we found that appropriateness is a measure of attractiveness.

4.16. Flow Chart

Based on the above discussion this flow chart has been prepared.

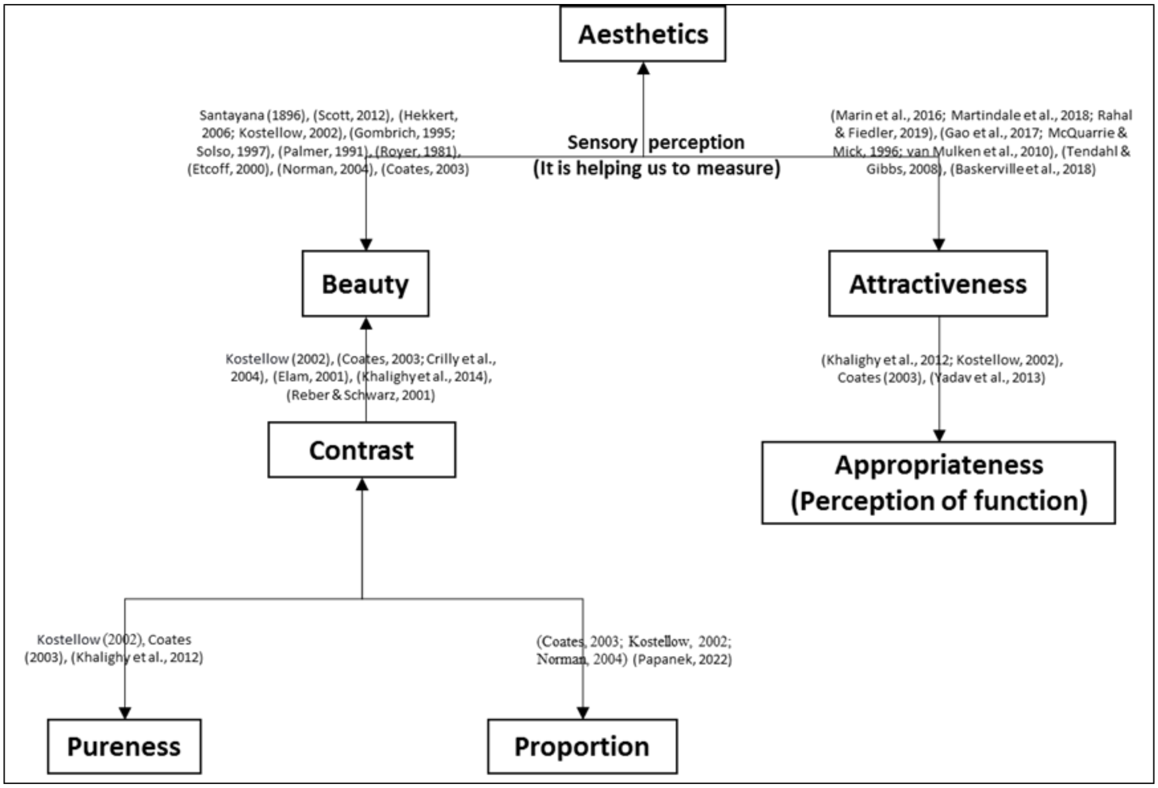


Figure 4.3. Shows the relationship between engineering aesthetics and their constituents

From the above discussion we see that essentially engineering aesthetics consists of beauty and attractiveness. Beauty can be expressed in terms of contrast. Contrast can also be assessed by pureness and proportion and attractiveness by appropriateness.

Once we have the constituents, we aim to develop a common definition in term of 'engineering aesthetics'. Before developing this definition, we also provide these factor and discuss with them about these definition. During finalizing this engineering aesthetic definition, we took help from experts in the field of product design, including both engineering and design professionals, to validate our definition. Their insights will provide valuable perspectives and help refine our understanding of "engineering aesthetics" to ensure its acceptance within the academic and professional communities.

"In Engineering aesthetics comprises of pureness, proportion, and attractiveness, which influences sensory perception." Engineering aesthetics is the branch of design that involves the application of principles and techniques to create visually pleasing and emotionally satisfying products or systems, considering both the form and function, with a particular focus on the unique considerations and challenges present in engineering disciplines.

Different measure (how to measure different constituents of aesthetics):

- **Pureness:** Since fewer elements produce higher pureness, pureness is a measure of the number of elements. Purity in engineering aesthetics describes a design without extra complexity, clutter, or redundant components. It places a strong emphasis on clarity, minimalism, and a fresh aesthetic. By removing any extraneous elements or aspects that do not enhance the overall functionality or aesthetic appeal of the product, pureness in design seeks to create a feeling of elegance, clarity, and harmony. Pureness is frequently linked to cleanliness, visual harmony, and a sense of purity in terms of aesthetics. It can be accomplished using streamlined shapes, smoothness, simple forms, and a subdued colour scheme. The goal is to produce a design that is visually appealing and coherent, free of extraneous details or unwanted distractions. Overall, simplicity, fewer elements, visually clean and elegance leads to higher pureness.

- **Proportion:** According to the definition, items in the right proportion draw the eye for the same period of time due to identical visual forces. In the context of "engineering aesthetics," the term "proportion" describes how different design elements are positioned and related to one another to produce visual harmony and balance. Due to the balance of visual forces at work, items that are in the appropriate proportion equally catch and hold the human-being attention for the same amount of time period. Achieving the appropriate proportion in "engineering aesthetics" is making sure that the shapes, sizes, and placements of various design elements or features within a design are aesthetically pleasing and balanced. This requires thinking about the roles of each element plays in the overall composition and how it relates with other elements. The appropriate proportions between elements give the design a sense of stability, making it easy for the spectator/humans to move their eyes across it. Each element is significant in and of itself without dominating or obscuring the others. The viewer's/ humans attention is guided by this balanced distributed visual forces, creating an engaging and cohesive aesthetic experience. On the other hand, if the "proportion" is not executed in well manner, few elements may govern the human's observance, triggering a visual discomfort or imbalance. Disproportionately small or large or elements can disturb the overall agreement, harmony, synergy, and divert from the designed or targeted aesthetic appeal. In summary, the "engineering aesthetics" concept of proportion refers to the harmonious placement of design features that assures an equal visual impact and maintains the viewer's attention for an equal amount of time. Engineers can produce aesthetically pleasing designs that inspire a sense of balance and coherence by carefully evaluating and optimizing the proportions of various components.
- **Appropriateness:** Appropriateness indicates what design elements are preferred by consumers for a specific function. So with the help of the functionality experiment, we can find how appropriateness affects attractiveness. Appropriateness plays a critical role in engineering aesthetics by ensuring that the selected design features/elements are in line with the proposed function of the product. It entails comprehending consumer preferences and applying them to the design process. Engineers can analyze the level of appropriateness and determine how well the design parts match the functional requirements by conducting functionality experiments. Since perceived value consumer happiness and consumer satisfaction are strongly associated to how effectively the design elements serve their intended purpose, this assessment helps in determining the overall attractiveness of the design. Engineers may produce

goods that not only operate well but also align with the desires and expectations of the target market by taking appropriateness into account during the design process.

There were different ways to understand and quantifying the engineering aesthetics by using their constituent factors. First, to understand and measure engineering aesthetics' attractive (appropriateness) features. We will use different beverage bottles' black and white silhouettes as a product. Matlab for creating bottle-perfect white and black silhouettes, Eyetracking as a piece of equipment. An open-ended survey should be conducted to know the cognitive feeling of prospective consumers. Second, to understand and quantify the beauty constituent of engineering aesthetics'. We use different design elements and constituents of beauty such as pureness, proportion/harmony/unity, and contrast. We use different logic images, Camera images for the case study to conduct the experiments. Different dimensions, colour scheme, design elements, lines, and shapes will be used during this case study. We can use eye-tracking as a piece of equipment. Python can be used to make the Tool and graphical user interface. An open-ended survey can be conducted to know the cognitive feeling of prospective consumers. The details of the above discussed experiments are explained in Chapter 5.

4.17. Conclusion

The word "aesthetics" is derived from Greek. This words refers to sensory perception, cognition, or sensuous knowledge. First time, the term "aesthetics" was used in the 17th century by the philosopher Baumgarten, who gave it a new definition as the satisfaction of the senses or sensual delight (Goldman, 2001). Aesthetics deals with art, beauty, attractiveness, sensitivity, and philosophy. In previous research work, researchers from marketing domain, philosophy domain, and industrial background studies aesthetics majorly in theoretical manner.

Proportion, attractiveness, and pureness are the three main components of engineering aesthetics. In design, clarity, and simplicity are referred to as pureness, where unneeded complexities are diminished to attain a refined and clean appearance. The harmonic relationship between design elements is called “proportion”, which ensures that their positions, forms, and sizes are visually appealing to eyes and balanced. Contrarily the other hand, attractiveness includes a design's overall aesthetic appeal and other features that appeal to people's senses and elicit favorable emotions. These factors significantly influence how people view and interact with the aesthetics of designed objects, settings, and systems. Attractiveness, contrarily, includes the overall aesthetic qualities and visual appeal of a design, which provoke sensory perceptions and positive emotional responses in every human-being. Collectively, these elements act as an important part in shaping how human-beings experience and perceive the aesthetics of engineered products and systems. As, we know that, in product development, aesthetics plays a significant role for the success of any product. During the product development phase of the product design, we are totally dependent on the guess, intuitions, and previous experiences of product designers (industrial designers). Various researchers have conducted considerable research on various products to assess and quantify product aesthetics. Moreover, depth of understanding is still required for assessing and quantifying aesthetics. This understanding will help or supports the designers in improving the product design. For that, we have found the fundamental constituents of aesthetics related to art, psychological, design, and engineering perspectives. After that, we relate these constituents under one umbrella and try to build a simple common definition or statement representing aesthetics from an engineering perspective. Further, we tried to quantify these constituents to help the designer to improve the product aesthetics, which can minimize the rejection rate of the product.

Several "common" components of aesthetics have been proposed, along with common philosophical and engineering definitions of aesthetics. After compiling a list of 24 definitions. Their similarities were examined, resulting in the creation of a "common" definition. It should be emphasized that we attempted to create a generic definition of aesthetics in terms of philosophy as well as engineering based on the findings of recognized researchers. As a result, some of the researchers' definitions are probably reflected in the final definition of aesthetics in terms of philosophy as well as engineering. In an ideal world, it would have matched all of the definitions, and we could have said that the term aesthetics means the same to all academics through all the research domains. In the absence of a circumstance like this, we created a generic definition. The philosophical aesthetics definition is created by merging two words: beauty and attractiveness. Similarly, for the development of engineering aesthetics definitions, we took the help of philosophical aesthetics and then found different constitutes which is related to aesthetics and can be defined in term of engineering. With the generic definition, we find suitable tests, features, and methods of engineering aesthetics. In this study, "the most difficult task in calculating aesthetics is to define what is to be measured; that is, to define aesthetics in terms of engineering." To identify the suitable test from the definition is precisely what we attempted to do in a portion of this effort. In a perfect world, we would test agents to see if they have been producing beneficial and distinctive outcomes over a long period of time. To analyse the product aesthetics of agents, we propose the use of "product characteristics tests" and "assessment of previous product aesthetics based tests".

"Engineering aesthetics" refers to the application of aesthetic principles and considerations in the field of engineering. It involves the integration of design and aesthetic elements into the engineering process to enhance the visual appeal, user experience, and overall aesthetic quality of products or systems. In essence, engineering aesthetics seeks to combine functionality and practicality with artistic and design-oriented approaches to create products that not only perform well but also satisfy aesthetic preferences and contribute to a positive user experience.

In this research, it's crucial to clarify that we don't aim to create divisions among product/industrial designers; instead, we bring both professionals, including engineering designers and product/industrial designers, together on a collaborative platform. This collaboration allows us to employ various multi-criteria decision-making techniques and statistical methods to gain insights into their thought processes and how they may differ from the perspectives of potential consumers. Regarding the definitions of aesthetics, it's essential to underscore that we are not seeking to separate these concepts. Rather, we are distinguishing between aesthetics from a philosophical standpoint and design/engineering aesthetics. Engineering aesthetics, in many ways, encompasses elements of philosophical aesthetics or a more common definition of aesthetics. Philosophical aesthetics often lack quantitative measures, making it challenging to quantify. However, during the development of engineering aesthetics definitions, which share similarities with philosophical aesthetics, we've identified quantitative measures and variables related to the aesthetic quality of products from diverse fields, including design, psychology, consumer behavior, and science. These quantitative elements, combined with the philosophical aesthetics perspective, contribute to the development of a new definition, which we refer to as engineering aesthetics definition. This approach allows us to bridge the gap between the qualitative and quantitative aspects of aesthetics and create a more comprehensive understanding of the concept. In section 4.17, we found various engineering features/elements that helps to towards our brief understanding and analysis of aesthetics. Whereas various definitions of aesthetics highlight different factors or elements/, it is essential to note that calculating aesthetics stays a big challenge. In spite of our wide-range investigation, no perfect techniques/methods or have been found to precisely measure aesthetics in an objective way. Therefore, we developed engineering aesthetics definitions, where we found a different set of features related to beauty and attractiveness, which are the most essential factors of aesthetics. With the help of these features, such as contrast, appropriateness, proportion/rhythm/harmony/unity, and appropriateness (perception of function), some mathematical tools, experimental equipments, we can measures engineering aesthetics. Philosophical definitions of aesthetics are more bend toward the domain of drama, literature, music, and poetry. However, the generic engineering aesthetics definitions are more toward the logical and mathematical point of view and include the sense of philosophy and art. In the real world, this definition and its factors and features. The work may have advantages or implications for design educators and professionals. We think that many businesses might benefit from this effort in various ways. Designers should be helped to improve the aesthetics of their products with the right testing and techniques.

4.18. Summary

In this Chapter, by comparing and contrasting 24 different definitions of aesthetics, this study sought to develop a generic definition. Even though it was impossible to match every description, a general report incorporating philosophical and engineering viewpoints was created. Philosophical aesthetics served as the foundation for the concepts of engineering aesthetics, and many aspects of beauty and attraction were discovered. Although it is still challenging to measure aesthetics objectively, the study suggested technical elements, mathematical tools, and experimental approaches. While engineering aesthetics definitions take a rational and quantitative stance while combining elements of philosophy and art, philosophical definitions of aesthetics concentrate on fields like theatre, literature, music, and poetry. The conclusions have ramifications for design professionals and educators, offering understanding to support efforts to enhance product aesthetics through proper testing and procedures.

CHAPTER 5

Factual analysis of factors influencing consumer cognitive thinking and automobile designing using Fuzzy-AHP

In Chapter 5, we examined both non-visual and visual factors of an engineered product that have an influence on both designers and consumers. This chapter is divided into three sub chapters: 5.1, 5.2, and 5.3. In Chapter 5.1, we concentrated on finding the non-visual factors of a product. Afterward, we measured the perceptions of automobile designers and consumers regarding the importance of these non-visual factors by allocating those weightages.

5.1.1. Introduction

Identifying consumers' feelings and integrating these beliefs in products is needed for diverse research capabilities. Feelings usually refer to the conscious and subjective experiences that arise from our emotions. Feelings are the mental experiences and interpretations of emotions. This includes psychological study of human behaviour for finding the prospective buyers requirements investigated through product design and marketing field (Moulson & Sproles, 2000a; Peighambari et al., 2016a). The outcomes or research in these fields support the social scientific concepts that further help in determining the human cognitive state of mind. The output of marketing research related to consumers in product design requires a seamless corridor with different fields, such as; social study, marketing, physiology, psychology, and statistical investigations. In product design, the main objective is to untangle the customer approaches, experiences, and cognitive insight (Simmonds & Spence, 2017a). The previous studies unveil that industrial experts utilize their guess, internal insight, and years of experience to create a feasible and attractive product for fulfilling the consumer's needs (Agost & Vergara, 2014a; Jitender & Sarkar, 2018). In the present scenario, the business environment is changing dynamically. This creates a challenging task for designers, marketing executives, and analysts to predict and clearly understand consumers' thinking and emotional behaviour changes while purchasing new products and assessing services (Alba & Williams, 2013; Ghodeswar Bhimrao M., 2008; Gilal et al., 2018). Thus, various companies try to create a good image of their products in the current competitive marketplace by knowing the consumer's cognitive appeal for any product (Eastman & Iyer, 2012). Social media appeared as a communication channel among the industry and prospective buyers to design the most acceptable products and their services (Heller Baird & Parasnis, 2011). However, the statistics suggest that the social media inputs are far more different from the realistic scenario of purchasing products. This raises the question regarding considering the consumers significant opinion while designing a product for their usage. Thus, the studies reveal a gap between the interest of the consumer and the designer's approach (Fuchs et al., 2015; Ansary & Nik Hashim, 2018; Idemen et al., 2021). Later, it is observed that consumer input plays a crucial role in the success of any product (Kotler, 1999; Y. Huang et al., 2012; Creusen, 2015). In product design and automobile industries, the design elements are one of the important characteristics with which designers produce well acceptable end products for the market. Since the likings of prospective buyers exceedingly influence car sales, it is also a common belief that visual factors such as; form of the car, texture, and color predominately influence the consumers purchase behavior (H.-C. Chang et al., 2007b; Yadav, Jain, Shukla, et al., 2013b).

Visual factors of any product often affect the human cognitive appeal during purchase. The exterior design of any product provides the initial information for the consumer to recognize a product. Thus, it is required that a product's exterior design should attract consumers and communicate the right impression of its characteristics. For instance, in the earlier days of the 1980s, any person driving a Porsche sports car in 'Great Britain' counts as a higher status symbol due to its exterior design. The Porsche car is portrayed as purchased by a young successful executive who works for a top multinational company and earns a fat salary package. Every Porsche owner made a hidden statement: I'm rich, 'I'm young, and I'm successful' (Hennighausen et al., 2016). Such distinct designing holds its importance especially in today's marketplace because product design has become a principal means of distinguishing the several products. The former chairman of Sony, Norio Ogha, truly states the importance of product design by commenting, "At Sony, we assume that all products of our competitors have the same technology, price, performance, and features. The design is the only thing that differentiates one product from another in the marketplace" (Homburg et al., 2015). Thus, the visual appearance plays a vital role in the successful product purchase rate.

There are some other factors in addition to visual factors which affect the consumer's cognitive feeling while purchasing. According to Jordan and Bloch numerous visual/non-visual factors affect the consumer's cognitive appeal that varies from consumer to consumer as well as from product to product (Bloch, 2011; Jordan, 2003). Although, the consumers made their judgment based on visual information gathered by using their senses (Burtan et al., 2021) and considering the functionality (Candi et al., 2017), elegance (Eastman & Iyer, 2012), and social significance of the product (Bloch, 1995b). These decisions often show a connection between the perceived characteristics of products which are centralized on the behaviour of consumers' desires rather than their needs (Monö, 2004). In this paper, we discuss that apart from visual factors, non-visual factors also play a critical role in influencing consumers' cognitive appeal. This paper aims to find out the various non-visual factors and further investigate the relationship between the cognitive appeals of the consumers for the non-visual factors. These factors affect the consumer behaviour which is discussed in regards to purchasing a new car. Further, the designer's perception is also considered in the aspect of newly designed cars. However, non-visual factors also substantially influence as discussed through an extensive literature survey given in Table 5.1.1.

Table 5.1.1. Shows the list of non-visual factors found from literature review

Non-visual factors	Description	References
Self-expression, social class/status, Prestigious, feeling of wealth	"High-status individuals tend to have disproportionate influence, such that social status can be defined as the degree of leverage one possesses over resource allocations, conflicts, and group decisions. In contrast, low-status individuals often passively give up these benefits, deferring to higher-status group members. As a result, high status tends to promote higher fitness than low status, and a large body of	(Berger et al., 1980; Tasaki et al., 1999; Heaney et al., 2005; Cheng et al., 2010; J. S. Kumar, 2017)

	evidence attests to a strong relationship between social rank and fitness or well-being.”	
Quality	“Term “quality” is used broadly to refer to all the related aspects of the product that affect its perceived desirability, such as functionality, performance, features, and reliability.” Meanwhile, product quality is the primary factor that impacts the consumer-product relation and impacts the cost-effectiveness of a company.	(Elliott & Cameron, 1994; Archer & Wesolowsky, 1996; Sethi, 2000)
Mileage/fuel-efficient	“Manufacturers’ and consumers’ statements about how quickly fuel savings must repay any additional cost are not consistent with the theory of economically rational decision making.”	(Greene, 2018)
Feeling (Psysio-pleasure)	“The term pleasure was derived from the sensory organs such as touch and smell as well as sensual/sexual pleasure, for instance; The tactile sensation from using controls or the olfactory sensation from the smell of a new car”.	(Hardy et al., 1999; Jordan, 2005)
Attention secures	Luxury liking customers desire special attention through services and products from luxury brands. They believe that if they purchase/use these things, they are considered or treated as celebrities. According to some authors, as they revealed in their study, there is a strong relation between attention-seeking and status consumption.	(Heaney et al., 2005; Okonkwo, 2007)
Past experience / Perceptions	What a human-being notices about a brand is what causes him/her to make a purchase. If the hum-being has constructive views related to a brand, they will keep buying products off and on. As soon as the brands flourish, they are pleased to provide the consumer with estimated importance. On the other hand, if the consumer's observed value surpasses the consumers’ predictable value, they are stunned and might be attached to a particular brand for an extended period.	(Okonkwo, 2007; Kamp, 2012; Tanusondjaja et al., 2016)
Ergonomic (Physio-pleasures)	The definition implies that ergonomics has both a social goal (well-being) and an economic goal (total system performance) considering both physical and psychological human aspects; and that ergonomics is looking for solutions in both technical and organizational domains. Performance aspects could include output volume, lead time, production flexibility, quality levels and operating cost among others.	(Jordan, 1998b; Tuch et al., 2009; Alba & Williams, 2013)
Resale value	“Nowadays the market is changing continuously, and everyday new products are arriving in the market with new features and technology. Due to this, the term resale value of the product comes into the picture. Therefore, it plays a significant role for the success of the product and companies.”	(Hardy et al., 1999)
Emotional design	“Human-product relations’ and “affective design” permits various kinds of personal impressions to be identified. Even though the affective design is related with SD, from that they examine the product meanings. Various kinds of meanings can be acclaimed in a product, such as; functionality, aesthetics, symbolic values, etc., which have been given dissimilar creeds in the previous work, for example product messages, communicative functions, product appearance. Emotions are related to the above mentioned functions.	(Jordan, 1998b; Crilly et al., 2004b; Chakrabarti & Gupta, 2007; P. Desmet & Hekkert, 2007; Ho & Siu, 2012)

The Table 5.1 includes the studies acquired from the several articles and books mentioning the non-visual factors that affect the consumers’ emotional behaviour during the purchase of the new cars. However, the correspondence between the consumer purchase behavior and product designers is not considered in the previous articles and thus limiting the industrial growth. Numerous techniques/methods have been applied to attain and find prospective buyers emotions relating to the product’s emotional impression. "Emotions" typically refer to relatively brief, intense, and often automatic responses to specific events or stimuli. Emotions are usually considered more basic and universal across cultures. In our study, we specifically concentrated on the conscious experiences that stem from emotions, which we refer to as "feelings." This terminology has been consistently employed throughout our main thesis work to enhance precision and maintain clarity and accuracy. For instance, at the end of the 19th century, Nagamachi developed a technique/approach known as Kansei engineering for product development. With this technique, the potential buyer's input (feelings or desires) is considered in the linguistic form to develop products for the future (Nagamachi, 1995b). In the early 20th century, a semantic differential (SD) method was used to find buyers' cognitive perception for the different forms/shapes of the upcoming products (Hsu et al., 2000b). Some researchers use the Likert scale technique to draw the consumers' intention related to an image of a brand. This is accomplished by focusing on the functionality and value of the brand and product (Belén del Río et al., 2001). Petiot and Yaanou use a collective combination of the SD method, multidimensional scaling, factor analysis, and AHP to measure the consumer's opinion related to product semantics (Petiot & Yannou, 2004b). The word-to-mouth technique is used to find the relationship between the buyer's cognitive behavior and their status of consumption which varies with age (Eastman & Iyer, 2012). Luo uses a 3-phase methodology that includes Kansei engineering, ranking method, and SD method, to assess cognitive response of buyers for the wheel hub design of the car (Luo et al., 2012). Still, there are many unsolved issues related to Kansei engineering and SD methods that lack the input of the consumer decision subjectively and quantitatively that relates to the consumers/designers' satisfaction. With the help of the method mentioned above, we found out the potential criteria, but not their weights/preferences with respect to other criteria. Thus, few other techniques can help researchers make an accurate decision related to the designers and consumers hidden desires related to any product.

The assessment criteria for the cognitive thinking of human-being is studied by various researchers using a combination of AHP and fuzzy set theory (Chou & Yu, 2013; Ooi et al., 2018). There were some other studies in which Fuzzy Analytical Hierarchy Process (F-AHP) technique is used to resolve real/actual-life problems such as supplier selection of washing machines (Kilincci & Onal, 2011) and vendor selection for competing in the volatile business environment (Kaur, 2014). A hybrid F-AHP approach is used to resolve the ambiguity and multi-criteria decision-making in the implementation factors that affect the enterprise resource planning (Ooi et al., 2018). The assumption in the Fuzzy-AHP approach is that all the criteria are independent of each other. In actuality, the relationship between criteria is quite complex, and there might be interdependencies/similarities among the factors that affect the selection criteria. In previous literature, the work lacks finding the top non-visual factors of a car and limits the prioritization of the perception gap between the consumers and industrial automobile designers. Our studies paves a way in identifying the various non-visual factors among the consumers by considering their recent purchase of a car. Further, the top factors and their weights among experienced consumers and industrial automobile designer's, respectively, are explored. Thus, our study provides excellent support to industrial experts by providing them a platform to understand the cognitive thinking of designers and consumers generalized to any product.

5.1.2. Aim and methodology

The understanding of the consumer desire in the initial stage is the main requirement for the development of a product (Khalid & Helander, 2006a; G. Norman, 2010). Bloch also defined that the form of any product produces emotional responses in human beings (Bloch, 1995a). The blend of cognitive perception and feelings eventually convey the behavioral reactions of humans (Cox & Cox, 2002). These responses can be utilized to study the consumer requirement, which can ultimately guide the development of a new product. Thus, studying customers' purchasing habits is not only the requirement of the multinational industries but it scales from medium, small, and micro enterprises (MSMEs), entrepreneurs, and even for start-ups which helps them to examine the behaviour of consumers for their splendid success.

5.1.2.1.Aim

In this study, we investigated the top non-visual factors which affected the perception of both the potential customers and the industrial designers for a car considered as a product. The mapping of the consumers' cognitive perception is done just before or after purchasing a new car. In addition, the cognitive feelings of industrial experts for the new product are examined. Our studies are relatively novel as they recognize the realistic scenario which considers the in-depth study of the behavior of consumers and product designers which is reviewed on the ground.

5.1.2.2.Methodology

According to Blessing and Chakrabarti the whole motive of design study is to "make the design more efficient and effective, to allow design exercise to develop more effective and popular products" (Blessing & Chakrabarti, 2009b). They developed "Design Research Methodology (DRM)" with the intention to anchor a highly rigorous methodology to initiate design research. Many researchers from different fields and designers use this methodology to create new products and succeed in the competitive market. These studies convey the theoretical findings in design studies through critical sampling difficulties (Cash et al., 2022), assessing the design research quality (SUMMERS & BLANCO, 2013), and examining the influence of design support in susceptible rural communities (Smits, 2019). During this study, a two-phase methodology is applied for prioritizing the top non-visual factors among consumers and designers related to the perception of cars. In the first phase (Phase I), we use literature and an open-ended survey for determining the non-visual factors. A mathematical technique is then used to identify the top non-visual factors that affect the likeness and purchase behaviour of consumers at the time of purchasing a car. In the next phase (Phase II), we use the Fuzzy-AHP to determine a comparative understanding of the factors from consumers and designers points of view. The next section 5.3 discusses Phase I and Phase II of this study. Based on this context, the rest of this article is organized as follows: In section 5.1, we critically reviewed the previous articles in related research areas that convey the gap in the understanding of consumers and designers behavior. In section 5.2, we describe the methodology used to obtain the data for the present study. The collection of the data is explained in section 5.3. Further, the results collected from the surveys are presented in section 5.4 and section 5.5 discusses the outcomes of the current work. Finally, we conclude in section 5.6 with providing future aspects of the work.

5.1.3. Identification of the different non-visual factors from the literature review and from consumer perspective (Phase I)

First, we conducted an extensive literature survey and listed all the non-visual factors affecting consumers' cognitive appeal during a car purchase. Various non-visual factors are obtained through a comprehensive literature survey, as shown in Table 5.1.1. We searched in Web of science, Scopus, Springer, Willy, and Elsevier search engines for articles with many keywords such as class, status, and feeling for finding suitable references, as mentioned above.

5.1.4. Participants details

Identify the target population: We define the specific group of individuals or entities with that want to conduct an experiment.

Choose a survey method: We choose an in-person interviews, and paper-based surveys.

Sampling: We select the sample size above 100 to ensure representativeness.

Design the Survey: We create the survey questions. Ensure they are clear, concise, unbiased, and relevant to your research objectives. Consider using a mix of question types, such as multiple choice, Likert scales, open-ended, and demographic questions. Pilot test the survey with a small group to identify and address any issues.

Data Collection: Data is collected through in-person interviews, and paper-based surveys. Ensure that the survey process is consistent and standardized to minimize bias.

Data Analysis: We analyze the survey data and this may involve both descriptive and inferential statistics.

Data Interpretation: We interpret the results in the context of our research objectives and the existing literature.

Ethical Considerations: We took an ethical approval before starting the experiment and we follow the institute guideline.

In this research, the identification and assessment of additional non-visual factors and their significance are determined through an open-ended survey. This approach enables the identification of dominant non-visual factors influencing consumers and designers in their decision-making process for car purchases. The study engages a total of 135 prospective participants and 10 industrial designers or experts. A structured interview process is employed, and factors are collected through printed papers. The participants are briefed on the study's purpose, distinguishing between visual and non-visual factors, and proceeding only if they confirm understanding. Participants are then asked to list their preferred factors from one to ten. A pilot survey with 15 participants is initially conducted, followed by the main survey involving 110 participants. Adjustments to the survey questions are made based on feedback from the pilot survey to enhance clarity for participants. During the pilot experiment, the factors obtained from the literature were provided to participants as examples of the non-visual factors. However, it is observed that the participants are being vastly influenced by the list provided, which affected the credibility of the survey as participants lacked their thought process. This generated the idea of conducting the survey by only providing a few factors from the literature as sample factors. A copy of the survey questions is provided in Appendix 5.A, and the details of participants is given in Table 5.1.2. Additionally, in the final survey, we also ask all the participants to rank the non-visual factors affecting cars purchase, according to their preference from one to ten.

Table 5.1.2. Participant details for Phase-I and Phase –II

<table>
<tr><td colspan="9">Participant details: Phase-I</td></tr>
<tr><td colspan="3">Gender</td><td colspan="3">Living place</td><td colspan="3">Age Group</td></tr>
<tr><td>Total</td><td>86</td><td>100%</td><td>Metro City</td><td>17</td><td>19%</td><td>18-30</td><td>46</td><td>53%</td></tr>
<tr><td>Male</td><td>66</td><td>76%</td><td>City</td><td>50</td><td>59%</td><td>31-40</td><td>36</td><td>42%</td></tr>
<tr><td>Female</td><td>20</td><td>24%</td><td>Town</td><td>19</td><td>22%</td><td>41-50</td><td>4</td><td>5%</td></tr>
<tr><td colspan="3">Education</td><td colspan="3">Number of student</td><td colspan="3">Percentage</td></tr>
<tr><td colspan="3">Graduate</td><td colspan="3">65</td><td colspan="3">76%</td></tr>
<tr><td colspan="3">Post Graduate</td><td colspan="3">14</td><td colspan="3">16%</td></tr>
<tr><td colspan="3">Other</td><td colspan="3">7</td><td colspan="3">8%</td></tr>
<tr><td colspan="3">Area of expertise</td><td colspan="3">Number of student</td><td colspan="3">Percentage</td></tr>
<tr><td colspan="3">Science</td><td colspan="3">13</td><td colspan="3">15%</td></tr>
<tr><td colspan="3">Arts</td><td colspan="3">4</td><td colspan="3">5%</td></tr>
<tr><td colspan="3">Engineering</td><td colspan="3">60</td><td colspan="3">70%</td></tr>
<tr><td colspan="3">Management</td><td colspan="3">7</td><td colspan="3">8%</td></tr>
<tr><td colspan="3">Commerce</td><td colspan="3">2</td><td colspan="3">2%</td></tr>
<tr><td colspan="9">Participant detail: Phase-II</td></tr>
<tr><td>Designer</td><td>Working area</td><td>Sex</td><td>Experiences</td><td>Consumers</td><td colspan="2">Working area</td><td>Sex</td><td>Driving Experiences</td></tr>
<tr><td>6</td><td>Automobi le</td><td>Male</td><td>5 to 10 year</td><td>6</td><td colspan="2">All are having ten year of working experience</td><td>Male</td><td>5 to 10 year</td></tr>
</table>

In the initial phase, our participant pool consisted of 86 respondents, all of whom were prospective car consumers. These individuals were poised to enter the car market, providing us with invaluable insights into the preferences and factors that influence their car purchase decisions. It's worth noting that this demographic was a key focus in our investigation. Subsequently, we transitioned to the second phase of our study, where we engaged with a select group of participants. This phase involved six experienced industrial designers who brought a wealth of expertise and insight into the aesthetics and functional aspects of car design. In parallel, we also involved six experienced car buyers, all of whom possessed a car and were contemplating the purchase of a second one. Their real-world experiences as car owners and potential repeat buyers enriched our research, enabling a more holistic understanding of the dynamics at play in the automobile market.

In phase I stage of our research, we aimed to comprehend the participants' characteristics fully. There were 86 people in our participant group, with a relatively even distribution of men and women. Notably, 76% of participants were men, and 24% were women. We looked at where they lived to learn more about their backgrounds and found that most of them (59%) lived in cities, followed by those in metro cities (19%) and towns (22%). We also looked at the age distribution of the participants and discovered that the majority (53%) of them were in the 18–30 age range, followed by those in the 31–40 age range (42%) and those in the 41–50 age range (5%). The educational backgrounds of our participants were also looked into. Most (76%) had graduate degrees, while 16% had finished postgraduate work. Another 8% of respondents fell into the "Other" category. Finally, we asked them about their areas of expertise, which revealed a wide range. The majority (70%) had engineering backgrounds, followed by science (15%), management (8%), the arts (5%), and business (2%). These demographic data serve as the basis for our study and enable us to consider a wide range of participant perspectives and experiences, essential for comprehending their responses in the subsequent stages of our research.

In Phase II of our research, we concentrated on particular participant details to learn more about their traits and experiences. All participants in this phase had a minimum of ten years of professional experience, demonstrating a wealth of specialized knowledge. We discovered that the participants in this group were all male. This gender distribution offers a distinctive viewpoint because it enables us to examine specific areas of our research through the eyes of male professionals. Additionally, we discovered that all participants had five to ten years of driving experience. This consistency in driving experience is significant because it eliminates any potential variations related to experience levels and enables us to investigate particular study topics with a stable baseline of driving proficiency. Their extensive professional background and consistent driving experience together produce a narrowed-down and specialized viewpoint that will be helpful for our research in Phase II. Appendix 5.1.A**,** shows the survey form used to collect non-visual factors (Table 5.1.A).

5.1.5. Data collection

5.1.5.1.Phase I

During the open-ended survey, participants add their preferences (non-visual factors) according to their choice. After that, we have segregated all the non-visual factors based on their rank (i.e., from first, second, third, and up to the tenth rank). The responses of all the participants differ in ranking as it is observed that some participants give first preference or rank to the reliability, while others to status, safety, and other non-visual factors, as shown in Table 5.3.

Table 5.1.3. Ranking of non-visual factors by participants

S. No.	Participant	Rank 1	Rank 2	Rank 3	Rank …	Rank 10
1	Participant 1	Ergonomics	Reliability	Past experience	-----	Quality
2	Participant 2	Feeling	Innovative Feature	Fuel efficient	------	Past experience
3	Participant 3	Status/feeling of prestige	Ergonomics	Innovative Technology	------	Fuel-Efficient
4	Participant 4	Comfort zone	Reliability	Feeling of prestige	-----	Materialistic
------						
125	Participant 110	New Technology	Ergonomics	Attention	-----	Safety

As evident from Table 5.1.3, the rank value method involves assigning a unique multiplication factor to each factor based on its position in the rankings. The top-ranked factor is assigned the highest multiplication factor, usually 10, while the next factor is assigned 9, and so on, descending according to each factor's position in the rankings. By multiplying these factors by their respective multiplication factors and summing up these values, a comparative value is obtained for each non-visual factor for every rank.

To clarify this process, consider the following example: Let's say one participant ranked "Ergonomics" as their first preference, "Reliability" as their second, and "Past experience" as their third. Using the rank value method, "Ergonomics" would be assigned a value of 10 (highest rank), "Reliability" would be assigned a value of 9 (second rank), and "Past experience" would be assigned a value of 8 (third rank). These values are then summed up for each factor across all participants, resulting in a score that represents the cumulative preference for each factor. Table 5.1.4 provides a glimpse of this process, illustrating the cumulative scores for some of the non-visual factors. However, it's important to note that this table includes only a subset of the 19 non-visual factors considered in the study. The full dataset would encompass all 19 factors, each with its calculated cumulative score based on participants' rankings. This approach allows for a more in-depth understanding of the collective preferences of participants regarding non-visual factors in product design. Eighty-six participants from India comprised a diverse group for the study, including graduates and professionals with essential positions in the public or private sectors or currently interning. Twenty percent (20) of the participants were women, but men made up the majority. Geographically, the participants came from various areas; roughly 56% were from urban areas, 19% were from major cities, and the remaining 22% were from rural areas. Notably, the study ignored cultural considerations to concentrate on preferences-related factors. However, the geographical context and other pertinent factors will be appropriately considered in future research. The results of this study provide insightful information about the preferences of educated people from various backgrounds and lay the foundation for future research that will explore more general topics like cultural influences and regional differences.

Table 5.1.4. Partial table showing 4 out of 19 non-visual factors, their rank frequency, and total values, after multiplying with the multiplication factors

Reliability				Comfort/ergonomics			
Rank	Frequency	Multiplication value	Total score	Rank	Frequency	Multiplication value	Total score
1	3	10	30	1	5	10	50
2	12	9	108	2	11	9	99
3	5	8	40	3	5	8	40
4	9	7	63	4	7	7	49
5	11	6	66	5	1	6	6
6	1	5	5	6	3	5	15
7	3	4	12	7	0	4	0
8	0	3	0	8	1	3	3
9	1	2	2	9	0	2	0
10	0	1	0	10	0	1	0
			326				262
Cost/budget				Status/feeling of prestige/materialistic			
Rank	Frequency	Multiplication value	Total score	Rank	Frequency	Multiplication value	Total score
1	6	10	60	1	6	10	60
2	7	9	63	2	5	9	45
3	1	8	8	3	5	8	40
4	1	7	7	4	10	7	70
5	1	6	6	5	3	6	18
6	0	5	0	6	11	5	55
7	1	4	4	7	3	4	12
8	0	3	0	8	5	3	15
9	0	2	0	9	0	2	0
10	0	1	0	10	0	1	0
			148				315

Table 5.1.4 demonstrates that while purchasing a car, according to 12 participant's reliability is the second top non-visual factor. Thus, in the fourth row of the table with frequency as 12 and 9 as the multiplication factor, a subtotal of 108 is obtained. Additionally, from Appendix 5.1.B and Table 5.1.B, we see 20 non-visual factors stating 'new technology' and 'new features' that can be considered as the same according to various articles, blogs, and books and thus, are merged in the study. The above analysis and segregation allows to find the 19 most frequent non-visual factors that should be considered while purchasing or designing cars, as shown in Table 5.1.5.

Table 5.1.5. Rank value method and average method summary of non-visual factors

	Rank/Average value method		
Sl no.	Factor	Subtotal	Average weight
1	Average mileage/fuel efficient	561	8.428
2	New technology/features	535	9
3	Reliability	326	6.833
4	Status/feeling of prestige/materialistic	315	6
5	Quality	275	3.286
6	Ergonomics	262	5.286
7	Design/form*	256	4.571
8	Past experience	214	4.571
9	Safety	163	3.625
10	Cost/budget	148	1.571
11	Attention	146	3.111
12	Resale value	106	2.25
13	Warranty	102	1.556
14	Service center	70	1.142
15	Brand	62	0.174
16	Accomplished feeling	24	0.571
17	Power	24	1
18	Culture	10	1
19	No. of seats	9	0.2

However, it is noticed that few participants also considered the design of the car as a non-visual factor that impacts its purchase. The example includes that consumers prefer brand "A" as compared to other brands "B" on the basis of their designs. Here, a particular form of a car is not referred to; instead, the entire gamut of the forms of cars made by these companies is referred to. Thus, our next step is to select the top non-visual factors. However, based on their subtotal values it is difficult to choose which factors are very important. Therefore, to identify the top few non-visual factors from Table 5.1.5, the Pareto principle (i.e., 80/20 rule) is used, and the detailed description of the Pareto principle is provided below. Detailed studies among the designers and consumers will be carried out to find the top non-visual factors.

Pareto principle: Pareto principle is also known as the "80/20 rule" or Pareto's principle of unequal distribution, and it was coined by famous economist Vilfredo Pareto (Grosfeld-Nir et al., 2007a; Ivančić, mag.oec, 2014). According to Pareto, 20% of the Italian country's population holds less or more than 80% of the wealth (or its total income) of the rest of the population. With the help of this principle, scarce resources are effectively allocated among all. Therefore, it is quite essential to note that this rule is applied to the current study as it does not consider the up and down probability rather it considers the major factors affecting the perspective of the consumer and designer. Allocate resources, such as customer support or distribution, according to the principle. Provide better support or service to the 20% that generates most of your revenue, and streamline services for the 80%. It's essential to understand your specific situation and customer base to determine whether reversing the Pareto Principle makes sense for your business or objectives. The 80/20 rule is a useful guideline, but the exact percentages and strategies can vary based on the context. Be sure to continually analyze your data and customer behavior to adapt your approach as needed.

In our study, the application of the inverse of the Pareto principle was particularly relevant during the analysis of factors obtained through the rank value method. In the rank value method, prospective participants provided their input and assigned weights to various non-visual factor during an open-ended survey. Usually, the Pareto principle suggests focusing on the vital 20% that contributes the most to the overall outcome. However, in our case, due to the nature of the data obtained through the rank value method, we encountered factors with varying degrees of importance. Some factors received higher weightage and were deemed more critical by the prospective participants, while others had lower weightage. Considering only the top 20% would overlook the nuances and potential insights provided by the less prominent factors. Therefore, we adopted the inverse of the Pareto principle, ensuring that we didn't disregard the factors with lower weightage. Instead, we recognized the importance of a comprehensive understanding by giving due attention to the entire spectrum of factors identified by the prospective participants. This approach allowed us to capture a more nuanced and holistic view of the factors influencing engineering aesthetics in product design. In essence, the inverse of the Pareto principle was instrumental in guiding our resource allocation strategy, ensuring a balanced exploration of both significant and less significant factors for a thorough analysis. Thus, a Pareto chart is created with the Pareto principle or 80/20 rule, as shown in Figure 5.1.1.

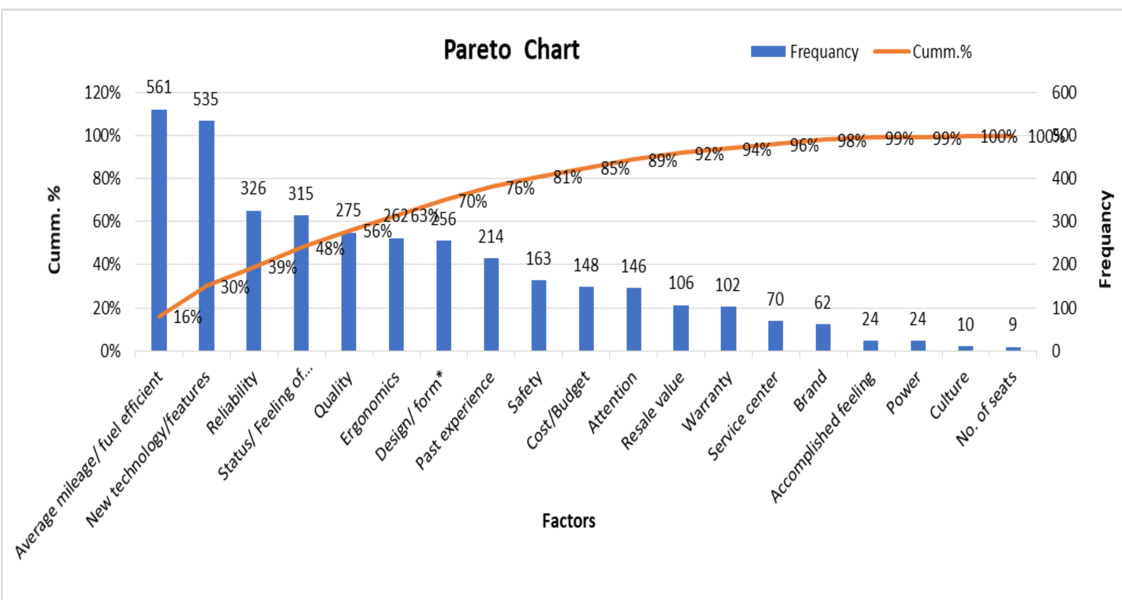


Figure 5.1.1. Inverse of the Pareto principle chart for non-visual factors affecting the consumer cognitive thinking during car purchase

The principle suggests that out-off of 19 non-visual factors, only 9 factors come under 80% of the population, and the rest of 11 factors act as a spectator (20% of the population). Therefore, we eliminate the rest of the 11 non-visual factors because their contribution is only up to 20% or less. Table 5.6 shows those 9 - non-visual factors. On the other hand, the calculation of this Inverse Pareto principle is given in Appendix 5.C, and represented in Table 5.C. Figure 5.1 shows the Inverse Pareto chart of all the non-visual factors and we observed that there are only nine non-visual factors that influence prospective consumers' decision-making while purchasing new cars. However, these 9 factors still cannot be ranked on the basis of their importance. Thus, for finding the answer, an appropriate approach is required, which will be discussed later.

Table 5.1.6. List of nine visual factors from inverse of the Pareto principle

Reliability	Status/feeling of prestige	Average mileage/fuel-efficient
Quality	Design/form	New technology/new features
Ergonomics	Safety features	Past experience

Note: A brief description of all these above mentioned factors are given below:

Social class/status, feeling of Prestigious/wealth: "High-status individuals tend to have disproportionate influence, such that social status can be defined as the degree of influence one possesses over resource allocations, conflicts, and group decisions (Berger et al., 1980). In contrast, low-status individuals often passively give up these benefits, deferring to higher status group members. As a result, high status tends to promote higher fitness than low status, and a large body of evidence attests to a strong relation between social rank and fitness or well-being" (Cheng et al., 2010; Steckler & Tracy, 2014). Berger and Kraus (1992 - 2017) "explain social status as status inequalities generated by expectations about future performances." "A number of researchers have asserted that social status is one of the persuasive cues of the source that has the potential to generate social influences".

Quality: The term "quality" is used broadly to refer to all the related aspects of the product that affect its perceived desirability, such as functionality, performance, features, and reliability. In other words, the quality levels of the product in the two periods may differ. And, this is swiftly becoming a key competitive issue in the current market scenario (FALL, 1984).

Mileage/fuel-efficient: According to Greene, the consumers' statements about how quickly fuel savings must repay any additional cost are not consistent with the theory of economically rational decision making. What matters is how much money we will be spending on fuel over the lifetime of driving a car" (Greene, 2018). The vehicle makers in India from several years have promoted fuel efficiency through values of Km/l to attract the consumers. However, consumers are unaware of the quantitative calculation of the fuel efficiency with cost of fuel over the lifetime of the vehicle, or over a long period of, say, five years. Consider this. The consumer is given a choice to buy a car that gives 15km/l and costs ₹ 5 lakh, and on other hand a car with efficiency of 12 km/l and costing around ₹ 4.5 lakh has been seen to purchase a car at a low cost. Most consumers think that the fuel efficiency for a car giving 15km/l is not that significantly different from a car that gives 12 km/l. The behavioural science studies find that making such calculations is not intuitive for most people rather they use simple rules of thumb to make quick decisions, which leads to biases and errors.

Ergonomics: “The definition implies that ergonomics has both a social goal (well-being) and an economic goal (total system performance) considering both physical and psychological human aspects; and that ergonomics is looking for solutions in both technical and organizational domains. Performance aspects could include output volume, lead time, production flexibility, quality levels and operating cost among others” (Nagamachi, 1995b).

Reliability: Reliability has a deep impact in our day to day life. In technical manners, *reliability* is described as the possibility that an object accomplishes its expected activity without failure under a defined environment for a specified duration. In engineering terms a product/object will be trustworthy when functioned in a definite means and in actual terms, failures are unavoidable (Yang, 2007).

Safety feature: “Safety is which is added in product/services to ensure a user’s safety”. “The Asian market has decided to develop a new product for young adults who are going to buy their first car. They want a modern car with state-of-the-art safety features and also within their budget (Helander et al., 2013).

New technology/features: “The technology addresses the safety issues associated with human-related errors and increases mobility for the elderly and people with disabilities”. “Particularly, scholars of car psychology often regard driving as an expression of the driver’s self-identity (Gössling & Metzler, 2017; X. Wang et al., 2020)”. Driving can be not only instrumental (i.e. mobility), but also ‘adventurous, thrilling and pleasurable’ (Steg, 2005). Through driving, the driver develops a sense of control, capability, strength, efficiency, comfort and entertainment.”

Past experience: “Think about all the decisions you’ve made today. Even if you’re reading this in the morning, you’ve probably already made hundreds or even thousands of decisions, without even thinking consciously about most of them (Kamp, 2012).”

Design/unique form: “Automotive design is a creative process used to define the physical appearance of motor vehicles such as cars, trucks, motorcycles etc. It encompasses interior and exterior design (Sheller, 2004)”.

5.1.5.2.Phase II

The nine non-visual factors are investigated so far, however the above mentioned methods are insufficient to determine the ranking of these factors. The multi-criteria decision-making technique such as Saaty’s AHP and Fuzzy-AHP approach can be used for finding the top non-visual factor. However, there are some limitations associated with Saaty’s AHP approach, which are as follows: (i) it cannot manage the impreciseness and vagueness in the human decision. (ii) Saaty uses an unbalanced scale of judgment. (iii) Preferences of decision-makers broadly impact the end results of the traditional AHP approach. Considering these drawbacks, a fuzzy-based analytical hierarchy process has been used in this research work (Saaty, 1979; Wind & Saaty, 1980). The Fuzzy-AHP process has an advantage of handling the imprecise and ambiguous judgment of professionals. It is mostly used for decision-making in several areas that includes the planning for the selection of underground mining (Naghadehi et al., 2009), selection of best renewable alternatives

(Kaya & Kahraman, 2010), location selection for thermal power plant (Choudhary & Shankar, 2012), and many others. The steps involved in fuzzy AHP are as follows:

Step 1. Defining the scale of relative importance used in the pair-wise comparison matrix

In this step, the triangular Fuzzy numbers (TFNs), 1 to 9 are used to improve the orthodox nine-point scaling, as provided in Table 5.7. The fuzziness of consumers qualitative assessments are taken into consideration by defining the nine TFN's with an equivalent relationship function.

Table 5.1.7. Characteristic function of the fuzzy number (Triangular Fuzzy Number of linguistic comparison matrix)

Linguistic variables	Triangular fuzzy number	Triangular fuzzy reciprocal number
Equally strong	1 = (1, 1, 1)	(1, 1, 1)
Intermediate	2 = (1, 2, 3)	(1/3, 1/2, 1)
Moderately strong	3 = (2, 3, 4)	(1/4, 1/3, 1/2)
Intermediate	4 = (3, 4, 5)	(1/5, 1/4, 1/3)
Strong	5 = (4, 5, 6)	(1/6, 1/5, 1/4)
Intermediate	6 = (5, 6, 7)	(1/7, 1/6, 1/5)
Very strong	7 = (6, 7, 8)	(1/8, 1/7, 1/6)
Intermediate	8 = (7, 8, 9)	(1/9, 1/8, 1/7)
Extremely strong	9 = (9, 9, 9)	(1/9, 1/9, 1/9)

Step 2. Construct the fuzzy comparison matrix

Triangular Fuzzy Numbers (TFN) represent the pairwise criteria comparisons when building the Fuzzy Analytic Hierarchy Process (Fuzzy-AHP) comparison matrix. The decision group, made up of seasoned buyers and designers, is asked for their assessments of the relative weighting of each criterion about the others. Here is a step-by-step breakdown of the procedure:

Determine the criteria that need to be compared by defining them. For instance, the criteria for comparing various product design concepts might be reliability, unique form, safety, etc.

Determine the Comparison Scale: Assign a scale to describe how much one criterion is preferred or considered more important than another. This scale may be numerical, with a range of 1 to 9, where 1 denotes "Equal strong" and 9 denotes "Extremely strong." Ask the decision-making group, which consists of seasoned buyers and designers, to compare the criteria in pairs. They should offer their opinions based on the comparison scale for each pair.

Pairwise Comparisons are converted to TFNs: Triangular Fuzzy Numbers (TFNs) are created by converting the numerical scale values. Three values make up a TFN: (a, b, and c). While b is the most probable value (or the modal value), a and c represent the triangular fuzzy number's lower and upper bounds, respectively.

With the help of TFN, the decision group constituted by the experienced consumer and designer is further asked to make pairwise comparisons of the criteria. A matrix is constructed according to the arithmetic mean of pairwise comparisons from the decision group.

$$A = [1\ a_{12}\ \cdots\ a_{1n}\ a_{21}\ \vdots \ddots \vdots\ \ldots \ldots\ldots\ a_{n1}\ a_{n2}\ \cdots\ 1] \qquad \text{Eq. (5.1.1)}$$

Whereas, $a_{ij} = 1$, if "i" equals to "j" and $a_{ij} = (1, 2,3,4,5,6,7,8,9)$ or ${a_{ij}}^{-1}$ if "i" is not equal to "j". When scoring is conducted for a pair, a reciprocal value is automatically assigned to the reverse comparison within the matrix (i.e., A_{ij} = matrix score assigned to the comparison of factors "i" to factors "j", then $A_{ij}\ is\ equal\ to \frac{1}{A_{ij}}$).

Step 3. Converting the fuzzy comparison matrix into a crisp comparison matrix

In this matrix, all experts provided their scores that are converted into a triangular fuzzy number. If there is an "n" number of experts, then the final value for a particular factor is given by adding all the scores and divided by the number of experts (i.e., "n").

The fuzzy numbers provided by all the experts must be combined to transform the fuzzy comparison matrix into a crisp one. For each matrix element, the procedure entails averaging the fuzzy numbers. Here's a step-by-step breakdown of how to do it:

Gather Fuzzy Comparison Scores: There should be a set of fuzzy numbers that represent the assessments made by each expert for each element in the fuzzy comparison matrix. The most common form of these fuzzy numbers is a triangular unclear number (TFN), though other vague representations can also be used.

Calculate the average of the fuzzy numbers offered by all of the experts for each element in the fuzzy comparison matrix. To do this, multiply each sum by the quantity of experts (n), then add up the fuzzy numbers' a-, b-, and c-values.

Step 4. Finding the fuzzy geometric mean value (r_i)

The fuzzy geometric mean value (ri) for each criterion in the crisp comparison matrix must be determined in step 4. The fuzzy geometric mean determines the relative importance or weights of the criteria in a fuzzy decision-making process. Here is a thorough breakdown of the procedure:

Identify the Crisp Comparison Matrix: The first step is to identify the crisp comparison matrix representing the combined expert opinions. According to Step 3's explanation, this matrix's crisp values for each element are derived from the experts' fuzzy estimates.

Determine how many criteria there are: Count the number of factors that were taken into account when making the decision. Assume that s criteria exist.

Divide the Crisp Comparison Matrix's Elements: Extract the corresponding crisp values (a, b, c) for each criterion (i) from the crisp comparison matrix.

Conduct the Fuzzy Geometric Mean (ri) calculation: Apply the following formula to each value in the TFN to determine the fuzzy geometric mean for each criterion (ri):

$$r_i = \left[\{l_1 * l_2 \ldots * l_s\}^{\frac{1}{s}},\ \{m_1 * m_2 \ldots * m_s\}^{\frac{1}{s}}, \{n_1 * n_2 \ldots * n_s\}^{\frac{1}{s}}\ \right] \qquad \text{Eq. (5.1.2)}$$

The above-mentioned multiplication procedure is used to find out the fuzzy geometric mean value for all factors.

Step 5. Finding the fuzzy weights (fw_i)

Based on the fuzzy geometric mean values (ri) computed in Step 4, Step 5 finds each criterion's fuzzy weights (fwi). The fuzzy weights represent the relative weights of each criterion in the decision-making process. Here is a thorough breakdown of the procedure:

Find out the fuzzy geometric mean values (ri): Remember that we determined the fuzzy geometric mean values (ri) for each criterion in Step 4? These values show the relative importance or weight of the standards.

Calculate the Sum of Fuzzy Geometric Mean Values: Add up all fuzzy geometric mean values (ri) for each criterion obtained in Step 4. This total reflects the overall influence of all the factors considered during the decision-making process.

Assume there are n criteria and that each criterion's fuzzy geometric mean values (ri) are represented as follows: $r_i = [l_i, m_i, n_i]$

Following is a list of the fuzzy geometric mean values ($r_1 + r_2 + ... + r_n$):

The equation is ($l_1 + l_2 + ... + l_n$, $m_1 + m_2 + ... + m_n$, $n_1 + n_2 + ... + n_n$) = $r_1 + r_2 + ... + r_n$.

Calculate the Inverse Fuzzy Value: Take the reciprocal of each component of the fuzzy number to determine the inverse fuzzy value of the sum of fuzzy geometric mean values. Each value in the TFN is treated individually in this manner.

Make a Fuzzy Weights (fwi) calculation for each criterion: Multiply the fuzzy geometric mean value (ri) of each criterion element-wise by the inverse fuzzy value determined in the previous step to obtain the fuzzy weights (fwi). Each value in the TFN is multiplied component-by-component.

The mathematical expression considered to find the fuzzy weights (fw_i) for each factor is given below:

$$fw_i = [r_i * (r_1 + r_2 + \cdots r_n)^{-1}] \qquad \text{Eq. (5.1.3)}$$

Whereas,

$$r_1 + r_2 = (l_1, m_1, n_1) + (l_2, m_2, n_2)$$

$$= (l_1 + l_2, m_1 + m_2, n_1 + n_2)$$

$$(r_1 + r_2 + \cdots r_n)^{-1} = (l_s, m_s, n_s)^{-1}$$

$$= \left[\frac{1}{n_s}, \frac{1}{m_s}, \frac{1}{l_s}\right]$$

After getting $(r_1 + r_2 + \cdots r_n)^{-1}$ value for each criterion, the corresponding criteria (r_i) is multiplied with each value and the fuzzy weights for particular criteria is calculated.

Step 6. After finding the fuzzy weights (fw_i), the next step is to find out the weights for each criterion by using center of the area (COA),

The Centre of Area (COA) method is used in Step 6 of the Fuzzy Analytic Hierarchy Process (Fuzzy-AHP) to determine the crisp weights (wi) for each criterion based on the fuzzy weights (fwi) obtained in Step 5. The COA method is a popular method for defuzzifying numbers and producing crisp values. Here is how to do it:

Recall that in Step 5, we calculated each criterion's fuzzy weights (fwi). Now, we need to get those fuzzy weights. These fuzzy weights represent the relative weights of each criterion in the decision-making process.

The Centre of Area (COA) Method should be used: The Centre of Area (COA) method is used to transform fuzzy weights (fwi) into crisp weights (wi). The arithmetic mean of the fuzzy weights determines the crisp weight for each criterion. The COA method is a defuzzification technique that identifies the fuzzy number's centre of mass, corresponding to its crisp value.

$$w_i = \left(\frac{l+m+n}{3} \right) \qquad w_i = \left(\frac{l+m+n}{3} \right)$$ Eq. (5.1.4)

Step 7. After finding the weights (W_i), we normalize and get the respective weights for each criteria as N_{Wi}.

We found nine factors based on the Pareto principle as shown in Table 5.1.6. A total of 10 experienced consumers and 10 industrial designers/experts are contacted through in-person. Both six out of the ten designers as well as consumers' agreed to be a part of this study. The details of designers and consumers are provided in section 3. The industrial designers are associated with the automobile industries. The identified non-visual factors were given to industrial professional/designers and consumers who purchased cars. An open-ended survey (questionnaires), are given to designers and consumers made with the help of using the characteristic function of the fuzzy number using TFNs of linguistic comparison matrix. Further, the perception of consumers and designers are obtained, relative to the importance of each non-visual factor with respect to other factors. Then, fuzzy-AHP techniques are used to obtain the weights for each non-visual factor against the other factors. The weights provided by consumers and designers are compared with each other to see whether there is any difference in cognitive thinking of designers and consumers.

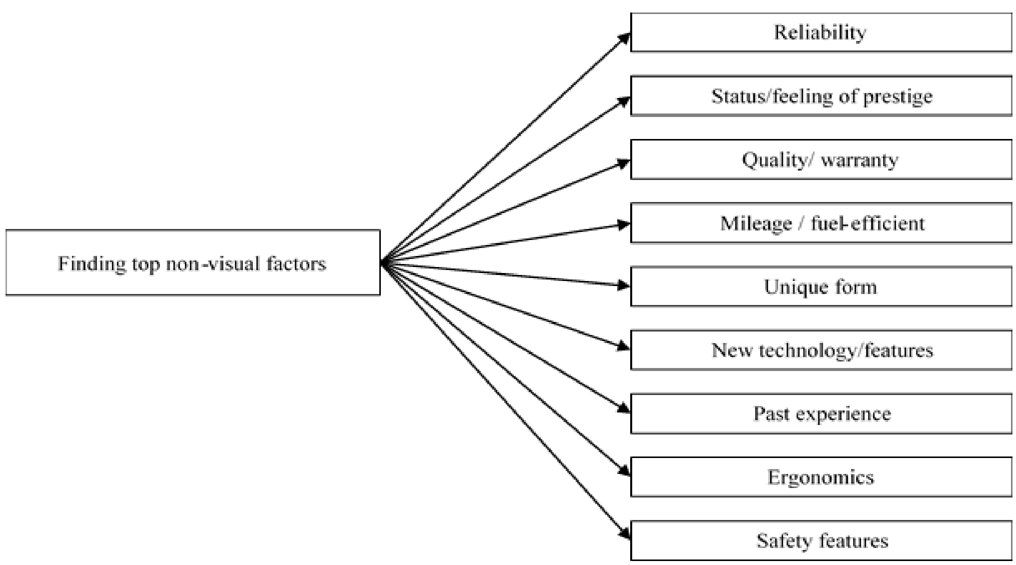


Figure 5.1.2. List of non-visual factors for the weightage identification

Whereas, Reliability (C_1), Status/feeling of prestige (C_2), Quality/ warranty (C_3), Mileage / fuel-efficient (C_4), Unique form (C_5), New technology/features (C_6), Past experience (C_7), Ergonomics (C_8), Safety features (C_9).

5.1.6. Results and analysis

Using the inverse Pareto principle, we collected the top nine non-visual factors, as shown in Table 5.1.6. However, some of the participants give higher preference to one factor, and some prefer another factor. We use a fuzzy analytical hierarchy process to get weights of the non-visual factors to solve this problem. They identified nine non-visual factors that were given to six designers and six consumers having cars. Next, these designers are requested to give their opinion using fuzzy numbers about the relative importance of each non-visual factor with respect to other remaining factors. Then, a fuzzy AHP approach is used to obtain the weight for each non-visual factor. The weights provided by each designer are compared with weights provided by the consumer by using the factorial analysis to ascertain whether there is any gap in-between the perception of consumers as well as designers. The questionnaire is shown in Appendix 5.1.D. Although, before conducting the final survey, we conducted a pilot study. In the pilot study (second pilot for Phase-II), we considered six consumers and three designers for prioritizing the factors using the scale given in Table 5.1.7. The pilot experiment conveyed the clarity about the questionnaire considering the level of understanding about the questions enquired from the designers and consumers. Further, the valuable inputs obtained from pilot study are indulged in the final survey. At the time of the final survey, 36 open-ended comparative questionnaires in matrix form are made by considering the scale of Table 5.1.7. A pairwise comparison matrix obtained from the consumer and designers are constructed using a linguistic scale, as shown in Table 5.1.8 and Table 5.1.9, respectively. This pair-wise matrix is used to calculate the weights of each factor, as discussed in the previous section. All these six consumers have experience in driving cars and have purchased cars in the last two years. The designers with a minimum experience of five years are considered.

Table 5.1.8. Comparison matrix to obtain weights of consumers for non-visual factors

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	(1, 1, 1)	(6.5, 7.17, 7.83)	(2, 2.67, 3.33)	(0.241, 0.33, 0.56)	(4.83, 5.833, 6.833)	(3.93, 4.639, 5.417)	(0.171, 0.21, 0.275)	(1.889, 2.42, 3.0)	(0.613, 0.653, 0.76)
C_2	(0.128, 0.14, 0.154)	(1, 1, 1)	(1.56, 2.242, 2.93)	(0.16, 0.199, 0.26)	(1.44, 2.0, 2.667)	(0.528, 0.61, 0.833)	(0.5, 0.91, 1.45)	(0.48, 0.667, 0.88)	(0.13, 0.145, 0.17)
C_3	(0.30, 0.375, 0.5)	(0.34, 0.45, 0.64)	(1, 1, 1)	(0.14, 0.159, 0.19)	(2.556, 3.42, 4.33)	(2.556, 3.25, 4)	(0.79, 1.17, 1.583)	(2.08, 2.764, 3.47)	(3.667, 4.5, 5.333)
C_4	(1.786, 3.03, 4.15)	(3.85, 5.03, 6.135)	(5.26, 6.29, 7.299)	(1, 1, 1)	(6.33, 7.33, 8.333)	(5.67, 6.67, 7.667)	(5.88, 6.389, 7.25)	(5.67, 6.67, 7.667)	(1.408, 1.93, 2.47)
C_5	(0.146, 0.17, 0.207)	(0.375, 0.5, 0.694)	(0.231, 0.293, 0.39)	(0.12, 0.14, 0.158)	(1, 1, 1)	(2, 2.833, 3.667)	(0.354, 1.08, 0.56)	(0.372, 0.45, 0.653)	(0.13, 0.15, 0.179)
C_6	(0.185, 0.22, 0.254)	(1.2, 1.64, 1.894)	(0.25, 0.308, 0.39)	(0.13, 0.15, 0.176)	(0.28, 0.353, 0.5)	(1, 1, 1)	(1.22, 2.083, 3)	(0.354, 0.41, 0.561)	(0.18, 0.215, 0.28)
C_7	(3.636, 4.77, 5.848)	(0.69, 1.11, 2)	(0.632, .857, 1.263)	(0.138, 0.16, 0.17)	(1.783, 0.93, 2.825)	(0.333, 0.48, 0.818)	(1, 1, 1)	(1.06, 1.583, 2.17)	(0.31, 0.34, 0.381)
C_8	(0.333, 0.414, 0.53)	(1.135, 1.5, 2.101)	(0.29, 0.36, 0.482)	(0.130, 0.15, 0.176)	(1.531, 2.22, 2.688)	(1.783, 2.45, 2.825)	(0.46, 0.63, 0.947)	(1, 1, 1)	(0.15, 0.178, 0.22)

C_9	(1.323, 1.53, 1.631)	(5.88, 6.897, 7.94)	(0.188, 0.22, 0.27)	(0.41, 0.518, 0.71)	(5.59, 6.579, 7.576)	(3.54, 4.651, 5.714)	(2.63, 2.985, 3.226)	(4.57, 5.618, 6.667)	(1, 1, 1)

Note: Reliability (C_1), Status/feeling of prestige (C_2), Quality/ warranty (C_3), Mileage / fuel-efficient (C_4), Unique form (C_5), New technology/features (C_6), Past experience (C_7), Ergonomics (C_8), Safety features (C_9).

Table 5.1.8 shows the comparison of criterion C_1 (reliability) with respect to the other eight criteria (factors). In row 2, we can see that the consumers prefer criterion C_2 (Status/feeling of prestige) over C_1 (reliability) and vice versa. Similarly, we can see the preference of the C_1 criterion on other criteria or vice versa. Each cell of the pairwise comparison matrix is allocated linguistic terms or fuzzy numbers during the fuzzy pairwise comparison stage of the Analytic Hierarchy Process (AHP). This is accomplished using the data in Table 5.1.7.

Table 5.1.9. Comparison matrix to obtain weights of designers for non-visual factors

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9
C_1	(1, 1, 1)	(5.333, 6.167, 7)	(1, 1, 1)	(4.167, 5, 5.833)	(3.667, 4.67, 5.667)	(2.556, 3.25, 4)	(2.367, 2.71, 3.056)	(1.216, 1.56, 1.913)	(0.114, 0.128, 0.147)
C_2	(0.143, 0.16, 0.188)	(1, 1, 1)	(0.132, 0.149, 0.174)	(0.167, 0.12, 0.253)	(0.337, 0.39, 0.511)	(0.97, 1.180, 1.456)	(1.42, 1.61, 1.802)	(0.296, 0.32, 0.363)	(0.140, 0.165, 0.2)
C_3	(1, 1, 1)	(5.747, 6.711, 7.576)	(1, 1, 1)	(3.83, 4.833, 5.833)	(0.137, 0.16, 0.189)	(1.53, 1.694, 1.867)	(3.03, 3.542, 4.056)	(2.67, 3.333, 4)	(0.272, 0.288, 0.309)
C_4	(0.171, 0.2, 0.24)	(3.953, 8.475, 5.989)	(0.171, 0.21, 0.261)	(1, 1, 1)	(6.5, 7.5, 8.5)	(5.33, 6.333, 7.33)	(2.21, 2.718, 3.228)	(0.16, 0.183, 0.225)	(0.137, 0.16, 0.192)
C_5	(.176, 0.214, 0.273)	(1.957, 2.571, 2.967)	(5.29, 6.289, 7.299)	(0.12, 0.133, 0.154)	(1, 1, 1)	(0.35, 0.403, 0.5)	(1.589, 2.11, 2.639)	(0.135, 0.16, 0.185)	(0.118, 0.134, 0.16)
C_6	(0.25, 0.308, 0.391)	(0.687, 0.847, 1.031)	(0.54, 0.590, 0.656)	(0.136, 0.16, 0.186)	(2, 2.481, 2.857)	(1, 1, 1)	(0.65, 0.861, 1.111)	(0.604, 0.794, 1)	(0.259, 0.266, 0.280)
C_7	(0.327, 0.37, 0.422)	(0.555, 0.623, 0.705)	(0.25, 0.282, 0.33)	(0.31, 0.368, 0.452)	(0.38, 0.474, 0.629)	(0.9, 1.163, 1.538)	(1, 1, 1)	(1.733, 2.25, 2.778)	(3.7, 4.208, 4.722)
C_8	(0.523, 0.64, 0.822)	(2.755, 3.106, 3.378)	(0.25, 0.3, 0.375)	(4.444, 5.46, 6.452)	(5.405, 6.41, 7.407)	(1, 1.259, 1.656)	(0.36, 0.444, 0.577)	(1, 1, 1)	(1.111, 1.3, 1.5)
C_9	(6.80, 7.813, 8.772)	(5, 6.061, 7.143)	(3.236, 3.472 3.676)	(5.208, 6.25, 7.3)	(6.45, 7.463, 8.48)	(3.57, 3.759, 3.861)	(0.21, 0.238, 0.27)	(0.67, 0.769, 0.9)	(1, 1, 1)

Note: Reliability (C_1), Status/feeling of prestige (C_2), Quality/warranty (C_3), Mileage/fuel-efficient (C_4), Unique form (C_5), New technology/features (C_6), Past experience (C_7), Ergonomics (C_8), Safety features (C_9).

In Table 5.1.9 we observe the comparison of factor C_1 (reliability) with respect to the other eight factors. Similarly, comparison of factor C_2 is done with respect to the other seven factors that goes up to factor C_8 (i.e. ergonomics) with respect to last factor C_9 (i.e. safety). Each cell of the pairwise comparison matrix is allocated linguistic terms or fuzzy numbers during the fuzzy pairwise comparison stage of the Analytic Hierarchy Process (AHP). This is accomplished using the data in Table 5.1.7. These language words or fuzzy numbers represent the relative relevance or preference of the factors under consideration. Each cell in the matrix represents a comparison of two criteria, with the values in brackets corresponding to the fuzzy triangular numbers provided in the rating scale. As, we can see, the numerical values in Table 5.1.9 are the input of the average values of all six designers. Table 5.1.D, shown in Appendix 5.1.D illustrates the preferences a designer (D_1) gives to one factor compared to other factors. Let us see an example; we get C_2 (factor) value corresponds to C_1 (factor) i.e. (5.333, 6.167, 7). This value is the average of input of six designers from the open-ended questionnaire by using the scale from Table 5.1.7, as shown below. Since, D_1 = 9 = (9, 9, 9), D_2 = 8 = (7, 8, 9), D_3 = 5 = (4, 5, 6), D_4 = 5 = (4, 5, 6), D_5 = 5 = (4, 5, 6), D_6 = 5 = (4, 5, 6), are the values given by six designers and the average of these values is shown in second row, third column (i.e. (5.333, 6.167, 7)) of Table 5.1.9 where $D_{1,}$ $D_{2\ldots,}$ $D_{6,}$ are considered as a designer input. For example, in the cell (5.333, 6.167, 7), we compare the importance of Criteria C_2 to Criteria C_1. Similarly, in the cell (0.143, 0.16, 0.188), we compare the importance of Criteria C_1 to Criteria C_2. On the other hand, due to size constraints, we show only two designer's input in Table 5.1.D, E, of Appendix 5.1.D.

Table 5.1.10. Weights for each non-visual factors given by designers and consumers

Designers					Consumers				
	fuzzy geometric mean value (r_i)	fuzzy weights (fw_i)	Weights (Wi)	Normalized Weights (Nwi)		fuzzy geometric mean value (ri)	fuzzy weights (fwi)	Weights (Wi)	Normalized Weights (Nwi)
C_1	(1.599, 1.85, 2.10)	(0.13, 0.174, 0.228)	0.178	0.17	C_1	(1.315, 1.57, 1.91)	(0.09, 0.132, 0.195)	0.139	0.13
C_2	(0.34, 0.364, 0.453)	(0.028, 0.034, 0.05)	0.037	0.04	C_2	(0.449, 0.573, 0.73)	(0.03, 0.048, 0.074)	0.051	0.05
C_3	(1.293, 1.46 1.62)	(0.11, 0.137, 0.176)	0.14	0.14	C_3	(0.936, 1.176, 1.46)	(0.065, 0.099, 0.15)	0.104	0.08
C_4	(0.83, 1.032, 1.14)	(0.068, 0.097, 0.13)	0.096	0.09	C_4	(3.401, 4.174, 4.90)	(0.235, 0.351, 0.5)	0.362	0.35
C_5	(0.499, 0.589, 0.69)	(0.04, 0.055, 0.075)	0.057	0.06	C_5	(0.335, 0.447, 0.51)	(0.023, 0.038, 0.052)	0.038	0.04
C_6	(0.515, 0.61, 0.706)	(0.04, 0.057, 0.077)	0.059	0.06	C_6	(0.376, 0.467, 0.58)	(0.03, 0.04, 0.06)	0.043	0.04
C_7	(0.68, 0.794, 0.938)	(0.056, 0.075, 0.10)	0.078	0.08	C_7	(0.704, 0.819, 1.19)	(0.049, 0.069, 0.12)	0.08	0.08
C_8	(1.148, 1.353, 1.61)	(0.094, 0.127, 0.18)	0.132	0.13	C_8	(0.518, 0.65, 0.81)	(0.036, 0.055, 0.082)	0.058	0.06
C_9	(2.31, 2.592, 2.874)	(0.189, 0.244, 0.31)	0.249	0.24	C_9	(1.73, 2.044, 2.367)	(0.12, 0.172, 0.241)	0.178	0.17

Note: (C_1), Status/feeling of prestige (C_2), Quality/warranty (C_3), Mileage/fuel-efficient (C_4), Unique form (C_5), New technology/features (C_6), Past experience (C_7), Ergonomics (C_8), Safety features (C_9). Fuzzy geometric mean value (r_i), Fuzzy weights (fw_i), Weights (W_i), Normalized weight (NW_i).

The calculation of average comparison matrices for consumers and designers is performed. The fuzzy geometric mean value (ri) and fuzzy weights (fwi) are computed using equation (5.1.3) and (5.1.4) for each non-visual factor as given in Table 5.1.10. After finding Weights (Wi), the Normalized weight (NWi) value for all factors is calculated such that the sum of weights of all the factors is equal to one (equation 5.1.5).

The results are shown in Table 5.1.11 being presented offers a thorough comparison of the weights that consumers and designers assigned to various non-visual factors that affected their cognition during the purchase and design of cars. The percentages show how important each group views each element relative to the others and provide helpful information about how dominant each factor is at different stages of the decision-making process.

Mileage/fuel efficiency: With a weight of 35%, this factor stands out as the most critical factor for consumers. It demonstrates how seriously they take long-term cost-effectiveness and fuel efficiency. However, designers only give it 9% of their total weight, suggesting they place more importance on other aspects of car design than mileage.

Safety features: Both designers and consumers value safety features, but designers give them a higher weight—24%—than consumers—who give them a weight of 17%. This implies that designers might put more effort into incorporating cutting-edge safety technologies and laws.

Consumers and designers agree that reliability is essential in car design, with consumers giving it a 13% weight and designers giving it a slightly higher 17% weight. Customers want a car that needs little upkeep and repair, so this factor is essential for guaranteeing their satisfaction and loyalty.

Ergonomics: Designers place a higher priority on a car's ergonomics, giving them a 13% weight, compared to consumers, who give it a 6% weight. This shows that when designing a car, designers are more focused on comfort and safety, considering things like driving posture and usability.

Designers give Quality and warranty a more significant weight (14% vs. 8% by consumers), who place more value on these factors. This discrepancy may result from designers considering product performance and durability, whereas consumers may rely on their own prior experiences with car quality.

Status/sense of prestige: Consumers and designers give this factor relatively less weight, with consumers giving it 5% and designers giving it 4%. This suggests that while some consumers may take a car's prestige value into account, it is not usually a top priority for buyers.

Unique form: With a weight of 4% for each group, consumers and designers place relatively less weight on a car's distinctive shape. Consumers might place more importance on certain functional elements than designers on aesthetics and branding. Like the unique form, consumers and designers give new technology or features 4% of their weight. This implies that, even though consumers value cutting-edge features, they may not be the primary determinant of buying a car.

Table 5.1.11. Weights for consumers and designers

S. No	Non-visual factors	Weights by consumers	Weights by designers	Difference in Weights
1	Mileage/fuel-efficient	35%	9%	26%
2	Safety features	17%	24%	7%
3	Reliability	13%	17%	4%
4	Ergonomics	6%	13%	7%
5	Quality/warranty	8%	14%	6%
6	Past experience	8%	7%	1%
7	Status/feeling of prestige	5%	4%	1%

8	Unique form	4%	6%	2%
9	New technology/feature	4%	6%	2%

Also, it has been explored that the interpretation of the quality/warranty of the car perceived from both the consumer and designers varies. We find that designers provide warranty on the car parts considering the test experiments performed on the various elements. Such as the product quality design differs from region to region and its warranty also depends on the viability of the car. Thus, designers give nearly two times more weightage (14%) to “quality/ warranty” as compared to consumers (8%) who decide quality on the basis of their experience. Thus, consumers’ value around 8% of their past experience while purchasing a car and designers understand this factor and provide the approximately same weightage to the past experience. However, in our studies we find that the designer's experience is based on their empirical and quantitative experience adapted from the success of their car parts. The factors such as status/feeling of prestige, unique form, and new technology/feature are considered of less weightage in contrast to other factors.

This section provides some key interpretations which are based on the results of this study as well as the interview of the consumers conducted in the phase II of the study. Fuel efficiency of cars is the most important factor as per the perspective of the consumers but the designers think that there are other factors such as safety features and reliability which must be given higher priority while conceptualizing a car design. As discussed above, the factors such as safety and reliability are also emphasized by the consumers, however several consumers are unwilling to pay a significant amount only for having a better safety feature. It was observed that past experience of consumers is a key factor which influences their decision making while buying a car. Designers also learn from their previous experiences but their experiences are more related to their previous designs whereas the past experience of consumers is mainly derived from information they gather from other resources about different brands of cars. An overall comparison of the perspective of designers and consumers makes it evident that the focus of designers is much towards the policy and regulation based aspects such as safety and quality of the cars. On the other hand, consumers are more concerned about the economic aspects such as fuel efficiency. It is further interesting to note that most of the consumers do not give much importance to the aspects of socio-pleasure i.e. status or feeling of prestige and this aspect is also given the least preference by the designers. We observed that the unique form of a car has been assigned with a low priority by the designers as well as the consumers. However, during the interview, designers mentioned that unique form has a key role to maintain the brand image. It should be noted that the perceptions, needs, and likability of the customers for the cars are changing rapidly.

In previous literature, we observed that numerous factors affect consumers and the designer’s cognitive appeal. A lot of research has been entertained related to the visual factors considered for the cars design in perspective of the consumer only. Here, we strongly convey that our research work builds a bridge to overcome the gap between consumers and designers' cognitive thinking while purchasing and designing a car. We considered the non-visual factors of the car to furnish our research. One possible reason might be that the designers often work in isolation with minimal interaction with common people or consumers, therefore they do not receive substantial inputs directly from consumers. The designers always get input from marketing personnel in technical languages and sometimes in terms of data. Therefore, designers did not receive conceptual and emotional responses from consumers.

5.1.7. Chapter summary

Chapter 5.1., the research presents an approach for investigating the non-visual factors that impact the cognitive approach of consumers and designers in the context of car products. In today's competitive market, pressure on each and every section of automobile industries increasing continuously. The biggest reason is; perceptions, needs, and likability of the consumer for cars are changing day by day. Whereas in literature, we observe that there are many factors which affect consumers as well as the designer's perception. We also see that a lot of research has been done or going on visual factors related to cars and other products. During our research work, we found that there is a gap between the thinking of consumer and designer related to non-visual factors of the car. One possible reason might be that the designers often work in isolation with minimal interaction with common people or consumers and therefore, they do not get substantial inputs from their consumers. They always get input from marketing personnel in technical language and sometimes in term of data. So, there are some emotional, personal values, and thinking which they do not receive from marketing personnel in a very clear manner. Nowadays, these factors (non-visual) play an equivalent role as that of visual factors for the success of any product (or car) and industries should start thinking towards this aspect.

During this study, we left some factors which had lower recurrence values as compared to others (as shown in Table 4). This may affect our conclusions, if the data is quite large enough. In future study, we are thinking of a good sample of the survey so that we can include those factors also which we left in this study and try to see if we can enhance these factors also. Apart from the factors discussed in this study, there are some other factors such as corporate strategy, R&D vision, organizational communication and trans-disciplinary collaboration that indirectly affect the work of individuals in any organization. For example; organizational communication is proposed as an influencing factor of group’s innovativeness and creativity (Bloch, 2011). Organizational boost, workgroup support, supervisory boost, freedom, resources, challenging work are vital factors which are positively linked with creativity. Companies also need to emphasize on their corporate strategies such as excellent after-sale services to gain a competitive advantage. Similarly, marketing peoples, industries and R&D need to focus on the hidden needs of today’s consumers. The only way to know these need or wishes which affect consumer perception during the purchase of a new car, companies have to work with normal peoples, by collecting data’s from social networking sites, their daily lifestyle, etc. Surveys were conducted for both consumers and designers to identify these factors, bridging the gap between their perspectives. Various techniques, such as the rank/average value method and fuzzy-based analytical hierarchy process, were used to analyze and prioritize the factors. The dominant factors identified include mileage/fuel efficiency, safety features, reliability, ergonomics, and quality/warranty. The study provides valuable insights for designers to understand consumer requirements better. Future research can involve a larger sample size and apply the findings to other industries. Factors like corporate strategy, R&D vision, organizational communication, and trans-disciplinary collaboration indirectly influence work in organizations. In the next chapter, we will study various visual factors of a car product from the consumer's and designer's perspective.

CHAPTER 5.2.

Study of cognitive behavior of consumers and designers for visual factors of a car using Fuzzy Analytical Hierarchy Process

In Chapter 5.2, a Fuzzy analytical hierarchy approach is used for finding the visual factors of a product. In this study, we measured the perceptions of automobile designers and consumers regarding the importance of these visual factors by allocating those weightages. During the analysis of results, we find out that there is a gap in the cognitive perception of the consumers as well as the designers while buying and designing a new car, and it was presented in terms of weights.

5.2.1. Introduction

Innovation in manufacturing, product design, new technology, and in the supply chain sector are essential during these days. Further, the product-oriented field faces a massive quantity of competition. In recent times, companies have been competing with their competitors, but in the meantime, they have to maintain their market share and brand value (Bloch, 2011; Bruner, 2015). The consumer market places a high value on product design, usability, quality, and functionality. Understanding consumers' cognitive processes has long been a significant concern for product designers (Chuang 2001, Yadav 2013). The fundamental goal of product design and development in the modern period is to give high-quality items, outstanding service, and optimal functionality to clients worldwide. According to Norman (2003-2004), product design goes beyond simple functionality, which was the traditional method of product creation. While functionality is still necessary, it is now seen as one of the foundations of new product development. Before any product is developed, several variables must be considered, including customer behaviour before and after using the product and users' psychological and physiological characteristics. Product designers seek to build goods that meet practical requirements and correspond with consumers' cognitive preferences by considering these elements. This customer-centric strategy ensures that products provide a superior user experience, resulting in higher customer satisfaction and a market competitive advantage. Further, Products' performance in the consumer-oriented sector relies highly on physical, hedonic, and utilitarian characteristics. Regarding product design, product designers have always prioritized understanding consumers' perceptions and preferences (Chuang et al., 2001; Yadav et al., 2013). The ultimate purpose of product design and development is to provide high-quality products or services to clients all over the world at reasonable prices (Norman, 2003, 2004). Businesses may produce products that meet functional requirements, elicit good feelings, and provide value to customers by connecting their design strategies with consumer expectations. This consumer-centric methodology assists businesses in gaining a competitive advantage in the market and fostering long-term consumer loyalty.

Users' expectations when purchasing a product throughout the last five decades have been predominantly focused on its utility and usefulness. However, these two elements are now regarded as conventional criteria in today's industry. A substantial shift in product design has happened, with inspirational design now playing an essential role in determining consumer preferences and buying decisions (Creusen, 2015). Users generally have little direct engagement with the industrial designers who create the things they use daily. Despite this, product designers use a variety of approaches to understand and cater to the emotional demands of their customers. These methods include conducting open-ended surveys through marketing specialists, analyzing information from consulting agencies or groups, and researching prior product sales performance (Singh & Sarkar, 2019). Product designers use these tactics to bridge the gap between their designs and consumers' emotional demands, creating goods that elicit positive feelings and resonate with their intended demographic. This emphasis on emotive design improves the overall user experience and raises the chances of consumer happiness and loyalty. Consumers have increasingly relied on their cognitive abilities when purchasing various products and services, such as electronic items (coffee machines, ovens, refrigerators), FMCG products, home decor items, furniture, and automobiles (cars or two-wheelers) (Holbrook & Hirschman, 1982). The visual elements linked with products are the focus of this study, with the automobile industry serving as a case study. Our study attempts to uncover and analyse the visual aspects that influence the cognitive thinking of both car buyers and designers. Several aspects play a critical role in the automobile industry, and these factors can be visual or non-visual, impacting both the perception of designers throughout the design process and the consumers' purchase decisions (Cretu & Brodie, 2007a; Yadav et al., 2013). Numerous studies on consumer behaviour have been undertaken involving designers and researchers who use a variety of approaches and methodologies to capture consumer feelings and desires in developing new products and services. These studies primarily concern the user-centered domain, which seeks to comprehend the user-product experience from many angles. Nagamachi (1995, 2002; 2006) is a famous player in this sector whose work has acquired substantial favor among industrial designers for addressing clients' emotional demands. Nagamachi's method has been successfully applied in a wide range of fields, including kitchen appliances (Goonetilleke & Feizhou, 2001), seat comfort (ergonomics) (Aktar Demirtas et al., 2009), car steering wheel design (Helander et al., 2013), coffee-making machines (Creusen, 2015), trade booth design (Huang et al., 2011), and many others.

Numerous elements are critical in the automobile industry and can considerably influence the perceptions of designers and buyers when designing and purchasing a new car. These features include visual and non-visual components that contribute to the overall experience and perception of the vehicle. Cretu and Yadav (2007; 2013) conducted studies on the importance of these elements in the automobile business. The car's aesthetic qualities, such as its exterior design, color, shape, and visual appeal, are referred to as visual factors. These visual aspects have the potential to elicit emotions and impact customer preferences and perceptions. Some of the factors find out from literature search which is given Table 5.2.1.

Table 5.2.1. Shows the list of visual factors find out from literature search

Visual factors	References	Description
Brand name / Value	(Cretu & Brodie, 2007; Culbertson & Simpson,	Today’s luxury consumer is brand literate and highly sophisticated. Their personal selection of luxury products is built more on

	2014; Ghodeswar, 2008; Hiebert, 2001)	comprehension of their personal style desires and less on the 'brand value' factor.
4 wheel drive (4WD)	(Archer & Wesolowsky, 1996; Chevalier & Mazzalovo, 2015; Creusen, 2015)	4WD is often manufactured for pickup trucks and other heavy vehicles intended for off-road driving conditions, but from the last few years 4WD progressively popular in passenger vehicles like crossovers and SUVs. 4WD is given maximum control and traction for the driver on rough terrain.
Design/style	(Arasu, 2015; Arienti, 2012)	Data on sales and aesthetic design revealed that consumers are not interested in cars that look too dissimilar from other cars, at the same time they also not interested which look too similar. When purchasing a high-end car, it is essential that car appearances are consistent with the brand. The consumer wants less similarity in car design which presents in the market.
Accessories	(Dryl & Bęben, 2014; Hennighausen, Hudders, Lange, & Fink, 2016)	Consumers always believe luxury cars have better comfort and quality in terms of driving experience, safety, and less failure rate. This quality, somehow related to accessories that are provided by car manufacturing companies.
Emotional design	(Jordan, 1998)	According to Jordan, emotional design is one of the major factors among any consumer to choose their car, model, car segments or car brand.
Hedonic/Symbolic Purchase motivation	(Creusen, 2015; Schoormans & Robben, 1997)	Marketers have explored the idea of apparent value, distinguishing among the hedonic and utilitarian value, either from focusing on a variety of levels or general points of view, such as products, brands, stores, services, or buying experience.
New technology/features	(Dubois & Prade, 1979; Mumcu & Kimzan, 2015)	Among all the factors, new technology/features are the most valuable factors during the purchase of a car.
Color	(Arienti, 2012; Chadgar, 2015)	The color of a car is certainly not an accessory. Many colors that not go out of style: black, white, silver, dark gray, and reds. Beware of colors that might be popular, because they may be out of style when the car is eventually sold.
Lifestyle	(Arasu, 2015)	Innovations in V2X connectivity, apps, mobile phones, and smart cards are distracting the automotive companies. Furthermore, automotive customers will gradually assume consumer experiences that go beyond the service or sales and powerful technology to incorporate with their related lifestyles, outside as well as inside of the vehicle.
Logo	(Kumar & Tiwar, 2014; Melewar & Saunders, 1999)	According to Melewar and Saunders companies use the logo as a symbol of expressing the qualities and strengths. Companies' logo represents the exceptionality of industries; Logo signifies the determination of companies. According to the author, a company logo may be designated carefully and may assure to connect to the marketplace by a range of designs by the marketing executive.
Ergonomics (Physio pleasures)	(Jordan, 1998)	They include pleasures connected with taste, smell and taste as well as feelings of sensory desire. In the context of cars, physio-pleasures related to olfactory and tactile properties.

In this study, we mainly focus on the visual factors of products and we consider automobile as a case study. In this work, we are trying to find various visual factors related to a car that affect consumers' and designers' cognitive thinking. This study is not intended to be 'the last word on the subject' but is an inflamed research and argument on this main topic. The rest of the article is organized so that, in the second section of this research article, we have completed a literature review related to different types of visual factors related to the automobile industry, especially for cars. In the next section, we have done a brief discussion about our aim, and after that, we have discussed what steps have been followed in the methodologic area to achieve our purpose. In the fourth section, we have analyzed all the data which we have collected during this work. In the last section, we have briefly discussed summary of this work.

5.2.2. Aim and Research Methodology

Understanding consumer purchase behaviors are beneficial for multinational companies as well as for entrepreneurs, medium, small and micro industries, and even for start-ups. The main aim of this study is to help companies to find a way to examine the effect of various visual elements in the design of a car on the purchase behavior of future buyers. Additionally, since the cars are designed by industrial designers, it would be interesting to understand any difference in the perception of industrial designers from that of the users. Thus, this study would also focus on how the perception of potential buyers differs from that of the prediction of automobile designers especially while styling. To achieve this, we focus on finding the top visual factors which affect the perception of existing as well as prospective customers of the car and the experienced automobile designers. To achieve the above aim in this paper, we use a two-phase methodology for prioritizing the top visual factors among consumers and designers related to the perception of the car. In phase I, we first identify the different visual factors from the literature review and then corroborate them, and as well as add more visual factors through an open-ended survey of potential car purchasing users. We select only those people who have purchased a car or are planning to purchase a car in the coming five years. In phase II, we use the Fuzzy analytical hierarchy process to rank the factors found in phase 1 and find the top factors among them. These two phases are discussed in the next sections.

5.2.2.1.Aim

In this study, we investigated the top visual factors which affected the perception of both the potential customers and the industrial designers for a car considered as a product. The mapping of the consumer's cognitive perception is done just before or after purchasing a new car. In addition, the cognitive feelings of industrial experts for the new product is examined. Our studies are relatively novel as it recognize the realistic scenario which consider the in-depth study of the behavior of consumers and product designers which is reviewed on the ground.

5.2.2.2.Methodology

According to Blessing and Chakrabarti the whole motive of design study is to "make the design more efficient and effective, to allow design exercise to develop more effective and popular products" (Blessing & Chakrabarti, 2009). They developed "Design Research Methodology (DRM)" with the intention to anchor a highly rigorous methodology to initiate design research. Many researchers from different fields and designers use this methodology to create new products and succeed in the competitive market. These studies conveys the theoretical finding in design studies through critical sampling difficulties (Cash et al., 2022), assessing the design research quality (David summers et al., 2013), and examining the influence of design support in susceptible rural community (Smits, 2019). During this study, a two-phase methodology is applied for prioritizing the top visual factors among consumers and designers related to the perception of cars. In the first phase (Phase I), we use literature and an open-ended survey for determining the visual factors. A mathematical technique is then used to identify the top visual factors that affect the likeness and purchase behaviour of consumers at the time of purchasing a car. In the next phase (Phase II), we use the F-AHP to determine a comparative understanding of the factors from consumers and designers points of view.

Based on this context, the rest of this article is organized as follows: In section 5.2.1, we critically reviewed the previous articles in related research areas that convey the gap in the understanding of consumers and designers behavior. In section 5.2.2, we describe the methodology used to obtain the data for the present study. The collection of the data is explained in section 5.2.3. In next section (5.2.4), we discussed about phase - I and II study. Further, the results collected from the surveys are and discusses the outcomes of the current work are presented in section 5.2.5. Finally, we conclude in section 5.2.6 with providing summary of this study.

5.2.3. Data collection

Pilot survey: In the first phase of this study, we have conducted an open-ended survey for the collection of different visual factors related to a car. For that, we create a survey form seen in Appendix 5.2.A. In which, we requested all the respondents to write down their perspective visual factors that affect their cognitive thinking during the purchase of a car. Before proceeding with the final open-ended survey, we conduct a pilot survey. During this, we give an idea about our research work and our self-i.e. why we are doing this research and where we are. And also, we gave them some basic ideas about what is a visual factor and also wrote down some examples of visual factors, which we found during the literature review. Meanwhile, we request all the respondents to rank each visual factor from one to ten i.e. 1-highest, 2-next lower, etc. After the completion of the pilot experiment/survey, we ask every participant about the language and grammar of the survey form, whether it is understandable or not.

During the analysis of the pilot survey, we noticed that when we provide all the visual factors which were collected from the literature review as an example in the pilot survey form for the understanding of what visual factor is. As of the survey results, respondents were influenced by the given factors and they were filled only by these factors. So, while conducting the final open-ended survey, we correct all the language mistakes which happen during the pilot survey and write down only two to three examples of visual factors in the survey form. Although, at the time of the pilot survey, we consider only those participants who have a car. Pilot survey data were not included in the study. During the pilot survey, we considered only fifteen participants, and their details are not considered in the final survey.

5.2.3.1. Participants' details

In this study, to determine the additional visual factors and their importance, an open-ended survey is conducted. This allows recognition of the dominant visual factors among consumers and designers for the car purchase. In this whole study, we meet with a total of 135 prospective participants and 10 industrial designers/experts. Initially, a pilot survey with 15 participants is conducted which is then followed by the main survey of 110 participants. After the pilot survey, the questions are tweaked to provide more clarity to them. During the pilot experiment, the factors obtained from the literature were provided to participants as examples of the visual factors. However, it is observed that the participants are being vastly influenced by the list provided, which affected the credibility of the survey as participants lacked their thought process. This generated the idea of conducting the survey by only providing a few factors from the literature as sample factors. A copy of the survey questions is provided in Table 6.A, in Appendix 6.A, and the details of participants is given in Table 6.2. Additionally, in the final survey, we also ask all the participants to rank the visual factors affecting cars purchase, according to their preference from one to ten.

Table 5.2.2. Participant details for Phase-I and Phase –II

<table>
<tr><td colspan="9">Participant details: Phase-I</td></tr>
<tr><td colspan="3">Gender</td><td colspan="3">Living place</td><td colspan="3">Age Group</td></tr>
<tr><td>Total</td><td>86</td><td>100%</td><td>Metro City</td><td>17</td><td>19%</td><td>18-30</td><td>46</td><td>53%</td></tr>
<tr><td>Male</td><td>66</td><td>76%</td><td>City</td><td>50</td><td>59%</td><td>31-40</td><td>36</td><td>42%</td></tr>
<tr><td>Female</td><td>20</td><td>24%</td><td>Town</td><td>19</td><td>22%</td><td>41-50</td><td>4</td><td>5%</td></tr>
<tr><td colspan="3">Education</td><td colspan="3">Number of student</td><td colspan="3">Percentage</td></tr>
<tr><td colspan="3">Graduate</td><td colspan="3">65</td><td colspan="3">76%</td></tr>
<tr><td colspan="3">Post Graduate</td><td colspan="3">14</td><td colspan="3">16%</td></tr>
<tr><td colspan="3">Other</td><td colspan="3">7</td><td colspan="3">8%</td></tr>
<tr><td colspan="3">Area of expertise</td><td colspan="3">Number of student</td><td colspan="3">Percentage</td></tr>
<tr><td colspan="3">Science</td><td colspan="3">13</td><td colspan="3">15%</td></tr>
<tr><td colspan="3">Arts</td><td colspan="3">4</td><td colspan="3">5%</td></tr>
<tr><td colspan="3">Engineering</td><td colspan="3">60</td><td colspan="3">70%</td></tr>
<tr><td colspan="3">Management</td><td colspan="3">7</td><td colspan="3">8%</td></tr>
<tr><td colspan="3">Commerce</td><td colspan="3">2</td><td colspan="3">2%</td></tr>
<tr><td colspan="9">Participant detail: Phase-II</td></tr>
<tr><td>Designer</td><td>Working area</td><td>Sex</td><td>Experiences</td><td>Consumers</td><td colspan="2">Working area</td><td>Sex</td><td>Driving Experiences</td></tr>
<tr><td>6</td><td>Automobile</td><td>Male</td><td>5 to 10 year</td><td>6</td><td colspan="2">All are having ten year of working experience</td><td>Male</td><td>5 to 10 year</td></tr>
</table>

In phase I, we have considered participants from different age groups ranging from 18 – 40 years that include students, novice designers, technical, and non-technical employees in educational institutes. The participants have different cultures and belong to different states of India. We visited universities for unbiased data collection to get senior research students and staff participants. The integrity of this work is improved by considering participants from different industries and design studios, where the experienced automobile designers shared their concealed perspective. We met 110 potential participants, and among them, 86 responses are valid and helpful for our research work. These 86 participants include 66 male and 20 females. Responses of 24 participants (out of 110) were discarded due to invalid or insufficient information which includes not purchasing a car in the last six months or filling an incomplete survey form. Appendix 5.2.A, shows the survey form used to collect visual factors (Table 5.2.A).

5.2.4. Phase I: Identification of the different visual factors from the literature review as well as from the respondent's point of view

First, we conducted an extensive literature survey and listed all the visual factors affecting the cognitive appeal of consumers during a car purchase and the list visual factors are given in Table 5.2.1 which is shown below. After that, we collect the top nine factors on the higher recurrence basis as shown in Table 5.2.3. First, we review existing literature and collect all the visual factors as found by the researchers. These factors are discussed in Table 5.2.1 of section 5.2.1. To corroborate the finding and to collect any missing visual factor that might influence the cognitive appeal of the user, we conducted an open-ended survey of potential customers. We request all respondents to write down all the visual factors which they think will affect their perception during the purchase of a car and then rank them, according to their preferences. Appendix 5.2.B, shows some of the responses to the survey. For instance, 'Colour,' is mentioned under column 2 row 2, depicting that respondent "2" opted for this factor as the first important factor, followed by 'Brand value/name', 'Logo', and upto 'Alloy wheel'. With the help of this survey, we collect a sufficient amount of visual factors and we justify that some other visual factors existed in the consumer mind apart from those that are found from the literature (see Table 5.2.B).

Phase I: During the final open-ended survey, a survey form was floated among the hundred thirty participants for the collection of visual factors, and we requested all the respondents to write down their preferences (visual factors) and give them ranking in terms of descending order i.e., from one to ten as shown in Table 5.2.3. During the final open-ended survey, we take all the precautions before making a new survey form for the collection of visual factors. Whereas the second row of Table 5.2.3, shows a number of participants, and the first column of Table 6.3, represents a rank scale.

Table 5.2.3. Ranking of a visual factor with the help of a participant

	Participants				
Ranks	1	2	3	----	130
Rank 1	Shape	Alloy wheel	Brand		Aerodynamic look
Rank 2	Size	Color	Design		Spoilers
Rank 3	Color	Aerodynamic look	Accessories		Alloy wheel
Rank 4	Texture	Front/ back design	Aerodynamics look		Color
Rank 5	Logo	Curves	Texture		Backside look
Rank 6	Navigation system	Height	4 wheel drive		Shape/design of headlamp/tail
Rank 7	Aerodynamic s look	Metal finishing /Glossiness	Color		Tires design
Rank 8	Accessories	Shape/design of headlamp/tail	Logo		Height
Rank 9	Four-wheel drive	Tires design	Shape		Metal finishing /Glossiness
Rank 10	3rd-row seats	Spoilers	Size		Brand logo

A partial example of implementing the simple multiplication order method for selecting the most prevalent visual element among respondents is shown in Table 5.2.4. The table shows the visual factor "Brand name or value" and its rank, frequency (number of responders), multiplication value, and total score.

As an example, consider the following: Seventeen respondents ranked the "Brand name or value" item first. Rank 1 has a multiplication value of 10. As a result, the total score for this component is 17 (the number of responders multiplied by 10) for a total score of 170. Similarly, the calculation is repeated for each rank, frequency, and multiplication value combination, yielding their corresponding total scores. It is crucial to note that the example in Table 5.2.4 only partially depicts the calculations for one of the 19 visual elements addressed in the study. Due to space limits, just the results for this particular factor are displayed.

Table 5.2.4. Partial table showing one out of 19 visual factors, their rank frequency (Number of respondents), and total values after multiplying with the multiplication factors

Brand name or value			
Rank	Frequency (Number of respondents)	Multiplication value	Total score
1	17	10	170
2	8	9	72
3	19	8	152
4	5	7	35
5	4	6	24
6	3	5	15
7	1	4	4
8	0	3	0
9	0	2	0
10	0	1	0
			472

As we can see in Table 5.2.4, it provides basic information about how the collected data from the participants is analyzed and how the ranking of the various visual factors has occurred. Let us consider an example of the "Brand name/value" factor and the preference for this factor is given by different respondents during the open-ended survey. We can observe that, in the third row and the second column of Table 5.2.4, out of hundred and six respondent's total of seventeen respondents give their first preference to the "Brand name or value". After that, we multiply all the preferences with the simple multiplication order i.e. first rank is multiplied with a positive integer number "Ten", a respondent who gives the second rank to design is multiple with positive integer number "Nine" and so on up to "One". All the factors we get from prospective consumers are given in Appendix 5.2.C, Table 5.2.C. And, the values of each factor as per the rank value method and the average method are also given. After, finding the nineteen visual factors among the prospective consumers by using an open-ended survey. Now, the next step is to segregate the most important visual factors from nineteen one. For that, we use the Pareto principle and it is explained in detail given below. Allocate resources, such as customer support or distribution, according to the principle. Provide better support or service to the 20% that generates most of your revenue, and streamline services for the 80%. It's essential to understand your specific situation and customer base to determine whether reversing the Pareto Principle makes sense for your business or objectives. The 80/20 rule is a useful guideline, but the exact percentages and strategies can vary based on the context. Be sure to continually analyze your data and customer behavior to adapt your approach as needed. In our study, the application of the inverse of the Pareto principle was particularly relevant during the analysis of factors obtained through the rank value method. In the rank value method, prospective participants provided their input and assigned weights to various visual factor during an open-ended survey. Usually, the Pareto principle suggests focusing on the vital 20% that contributes the most to the overall outcome. However, in our case, due to the nature of the data obtained through the rank value method, we encountered factors with varying degrees of importance. Some factors received higher weightage and were deemed more critical by the prospective participants, while others had lower weightage. Considering only the top 20% would overlook the nuances and potential insights provided by the less prominent factors. Therefore, we adopted the inverse of the Pareto principle, ensuring that we didn't disregard the factors with lower weightage. Instead, we recognized the importance of a comprehensive understanding by giving due attention to the entire spectrum of factors identified by the prospective participants. This approach allowed us to capture a more nuanced and holistic view of the factors influencing engineering aesthetics in product design. In essence, the inverse of the Pareto principle was instrumental in guiding our resource allocation strategy, ensuring a balanced exploration of both significant and less significant factors for a thorough analysis.

Pareto principle: The use of Pareto principle/charting is an analytical process of charting and counting the arduous and the rate of problems or defects incidences of several potential businesses, quality concerns, marketing, and product. It is also known as Pareto's principle of unequal distribution (80/20 rule) and this rule was coined at the beginning of the 19th century by famous Italian sociologist and economist Vilfredo Pareto (Grosfeld-Nir et al., 2007b; Ivančić, 2014). Vilfredo states that "20 percent" of his (Italian) country population holds less or more than "80 percent" of the country's capital (or its total wealth) (Alecu, 2010; Grosfeld-Nir et al., 2007b; Ivančić, 2014). With the help of this rule, we can understand in a better way than how scarce wealth is allocated. Thus, it is essential to note that this principle is based on recommended actions on the existing data. It does not take into account the probability of ups or downs and the expected ploy of any one causal factor.

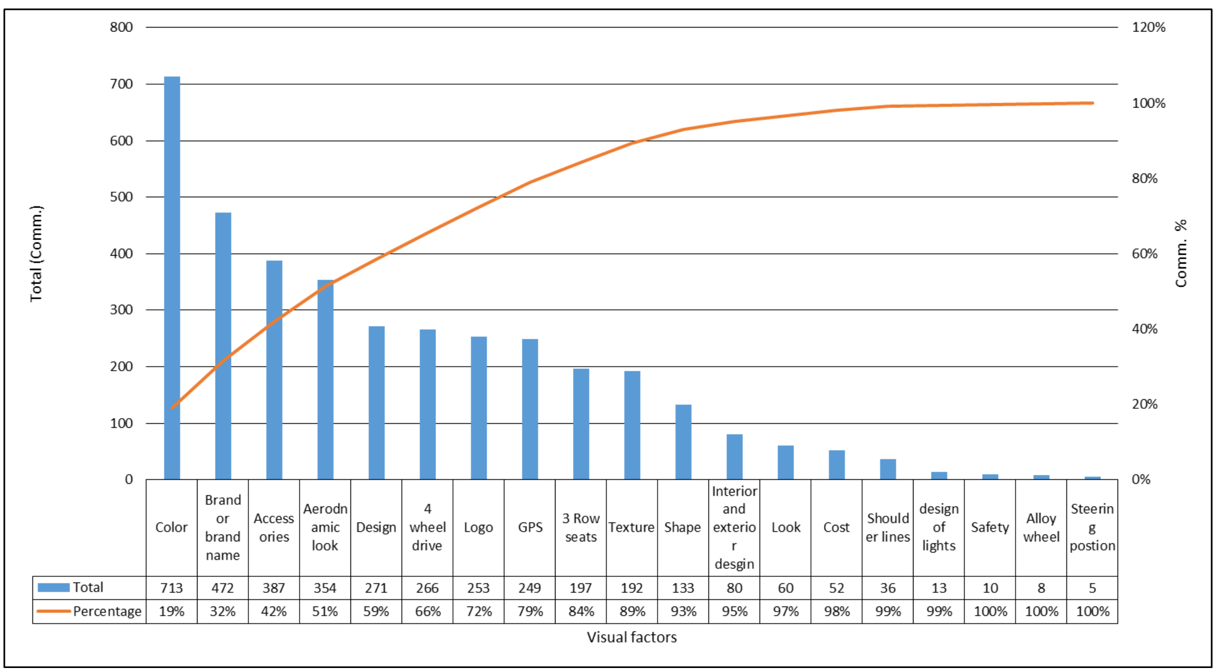


Figure 5.2.1. Inverse Pareto chart for visual factors affecting the consumer cognitive thinking during car purchase

The principle suggests that out-off of 19 visual factors, only 9 factors come under 80% of the population, and the rest of 11 factors act as a spectator (20% of the population). Therefore, we eliminate the rest of the 11 visual factors because their contribution is only up to 20% or less. Table 5.2.5 shows those nine visual factors. On the other hand, the calculation of this Inverse Pareto principle is given in Appendix 5.2.C, and represented in Table 5.2.C. Figure 6.1 shows the Pareto chart of all the visual factors and we observed that there are only nine visual factors that influence prospective consumers' decision-making while purchasing new cars. However, these 9 factors still cannot be ranked on the basis of their importance. Thus, for finding the answer, an appropriate approach is required, which will be discussed later. From that chart, we can justify that only nine-factor visual factors influence the cognitive appeal of the prospective consumer during the purchase of a new car, and the list of those nine visual factors is provided in Table 5.2.5. After finding the nine visual factors we move towards the second phase of our methodology i.e., Fuzzy-AHP.

Table 5.2.5. List of visual factors with the highest recurrence score given by respondents

Colour	Brand	Design
Aerodynamic look	4 wheel drive	G.P.S
Logo	Accessories	3-row seats

5.2.4.1.Phase II: Fuzzy analytical hierarchy process

Phase II: We use the Fuzzy Analytic Hierarchy Process (AHP) methodology to rank the visual factors and select the top elements. Wind and Saaty created the AHP in 1980 as a quantitative technique for multi-criteria decision-making. The standard AHP approach, on the other hand, has some things that could be improved, such as its application only in sharp situations, the lack of uncertainty handling, imbalanced judgment scales, and subjective judgment selection (Wind & Saaty, 1980). The fuzzy technique is frequently combined with the AHP methodology to address these issues. Professionals supply statements or data using language variables in Fuzzy AHP, which are subsequently transformed into a mathematical form to aid decision-making. The inherent uncertainties and lack of precision can be efficiently controlled by using Fuzzy AHP.
Researchers are currently using fuzzy AHP in a variety of sectors. Examples include retail center site selection in densely populated cities, public transit system review in large and overcrowded cities, and selecting the finest value-added services for mobile telecommunication sector (D.-Y. Chang, 1996; Nassereddine & Eskandari, 2017b; Önüt et al., 2010). We want to overcome the constraints of standard AHP by using Fuzzy AHP to comprehensively evaluate the visual aspects based on expert views and data, thereby finding the top factors in our study.

Various steps involved in this model are as follow:

Step 1. Defining the scale of relative importance used in the pairwise comparison matrix

In this step, the TFNs, 1 to 9 are used to improve the orthodox nine-point scaling (look Table 5.2.6). To take the fuzziness of consumer’s qualitative assessments into consideration, the nine TFN’s are defined with an equivalent relationship function.

Table 5.2.6. Characteristic function of the fuzzy number (Triangular fuzzy reciprocal number of linguistic comparison matrix)

Linguistic variables	Triangular fuzzy number	Triangular fuzzy reciprocal number
Equally strong	1 = (1, 1, 1)	(1, 1, 1)
Intermediate	2 = (1, 2, 3)	(1/3, 1/2, 1)
Moderately strong	3 = (2, 3, 4)	(1/4, 1/3, 1/2)
Intermediate	4 = (3, 4, 5)	(1/5, 1/4, 1/3)
Strong	5 = (4, 5, 6)	(1/6, 1/5, 1/4)
Intermediate	6 = (5, 6, 7)	(1/7, 1/6, 1/5)
Very strong	7 = (6, 7, 8)	(1/8, 1/7, 1/6)
Intermediate	8 = (7, 8, 9)	(1/9, 1/8, 1/7)
Extremely strong	9 = (9, 9, 9)	(1/9, 1/9, 1/9)

Step 2. Construct the fuzzy comparison matrix

Triangular Fuzzy Numbers (TFN) represent the pairwise criteria comparisons when building the Fuzzy Analytic Hierarchy Process (Fuzzy-AHP) comparison matrix. The decision group, made up of seasoned buyers and designers, is asked for their assessments of the relative weighting of each criterion about the others. Here is a step-by-step breakdown of the procedure:

Determine the criteria that need to be compared by defining them. For instance, the criteria for comparing various product design concepts might be reliability, unique form, safety, etc.

Determine the Comparison Scale: Assign a scale to describe how much one criterion is preferred or considered more important than another. This scale may be numerical, with a range of 1 to 9, where 1 denotes "Equal strong" and 9 denotes "Extremely strong." Ask the decision-making group, which consists of seasoned buyers and designers, to compare the criteria in pairs. They should offer their opinions based on the comparison scale for each pair.

Pairwise Comparisons are converted to TFNs: Triangular Fuzzy Numbers (TFNs) are created by converting the numerical scale values. Three values make up a TFN: (a, b, and c). While b is the most probable value (or the modal value), a and c represent the triangular fuzzy number's lower and upper bounds, respectively.

With the help of TFN, the decision group constituted by the experienced consumer and designer is further asked to make pairwise comparisons of the criteria. A matrix is constructed according to the arithmetic mean of pairwise comparisons from the decision group.

$$A = [1\ a_{12}\ \cdots\ a_{1n}\ a_{21}\ \vdots \ddots \vdots\ \ldots\ \ldots\ldots\ a_{n1}\ a_{n2}\ \cdots\ 1\ ] \qquad \text{Eq. (5.2.1)}$$

Whereas, $a_{ij} = 1$, if "i" equals to "j" and $a_{ij} = (1, 2,3,4,5,6,7,8,9)$ or $a_{ij}{}^{-1}$ if "i" is not equal to "j". When scoring is conducted for a pair, a reciprocal value is automatically assigned to the reverse comparison within the matrix (i.e., A_{ij} = matrix score assigned to the comparison of factors "i" to factors "j", then $A_{ij}\ is\ equal\ to \frac{1}{A_{ij}}$).

Step 3. Converting the fuzzy comparison matrix into a crisp comparison matrix

In this matrix, all experts provided their scores that are converted into a triangular fuzzy number. If there is an "n" number of experts, then the final value for a particular factor is given by adding all the scores and divided by the number of experts (i.e., "n"). The fuzzy numbers provided by all the experts must be combined to transform the fuzzy comparison matrix into a crisp one. For each matrix element, the procedure entails averaging the fuzzy numbers. Here's a step-by-step breakdown of how to do it:

Gather Fuzzy Comparison Scores: There should be a set of fuzzy numbers that represent the assessments made by each expert for each element in the fuzzy comparison matrix. The most common form of these fuzzy numbers is a triangular unclear number (TFN), though other vague representations can also be used. Calculate the average of the fuzzy numbers offered by all of the experts for each element in the fuzzy comparison matrix. To do this, multiply each sum by the quantity of experts (n), then add up the fuzzy numbers' a-, b-, and c-values.

Step 4. Finding the fuzzy geometric mean value (r_i)

The fuzzy geometric mean value (ri) for each criterion in the crisp comparison matrix must be determined in step 4. The fuzzy geometric mean determines the relative importance or weights of the criteria in a fuzzy decision-making process. Here is a thorough breakdown of the procedure:

Identify the Crisp Comparison Matrix: The first step is to identify the crisp comparison matrix representing the combined expert opinions. According to Step 3's explanation, this matrix's crisp values for each element are derived from the experts' fuzzy estimates.

Determine how many criteria there are: Count the number of factors that were taken into account when making the decision. Assume that s criteria exist.

Divide the Crisp Comparison Matrix's Elements: Extract the corresponding crisp values (a, b, c) for each criterion (i) from the crisp comparison matrix.

Conduct the Fuzzy Geometric Mean (ri) calculation: Apply the following formula to each value in the TFN to determine the fuzzy geometric mean for each criterion (ri):

$$r_i = \left[\{l_1 * l_2 \ldots * l_s\}^{\frac{1}{s}}, \{m_1 * m_2 \ldots * m_s\}^{\frac{1}{s}}, \{n_1 * n_2 \ldots * n_s\}^{\frac{1}{s}} \right] \quad \text{Eq. (5.2.2)}$$

The above-mentioned multiplication procedure is used to find out the fuzzy geometric mean value for all factors.

Step 5. Finding the fuzzy weights (fw_i)

Based on the fuzzy geometric mean values (ri) computed in Step 4, Step 5 finds each criterion's fuzzy weights (fwi). The fuzzy weights represent the relative weights of each criterion in the decision-making process. Here is a thorough breakdown of the procedure:

Find out the fuzzy geometric mean values (ri): Remember that we determined the fuzzy geometric mean values (ri) for each criterion in Step 4? These values show the relative importance or weight of the standards.

Calculate the Sum of Fuzzy Geometric Mean Values: Add up all fuzzy geometric mean values (ri) for each criterion obtained in Step 4. This total reflects the overall influence of all the factors considered during the decision-making process.

Assume there are n criteria and that each criterion's fuzzy geometric mean values (ri) are represented as follows: $r_i = [l_i, m_i, n_i]$

Following is a list of the fuzzy geometric mean values ($r_1 + r_2 + ... + r_n$):

The equation is ($l_1 + l_2 + ... + l_n$, $m_1 + m_2 + ... + m_n$, $n_1 + n_2 + ... + n_n$) = $r_1 + r_2 + ... + r_n$.

Calculate the Inverse Fuzzy Value: Take the reciprocal of each component of the fuzzy number to determine the inverse fuzzy value of the sum of fuzzy geometric mean values. Each value in the TFN is treated individually in this manner.

Make a Fuzzy Weights (fwi) calculation for each criterion: Multiply the fuzzy geometric mean value (ri) of each criterion element-wise by the inverse fuzzy value determined in the previous step to obtain the fuzzy weights (fwi). Each value in the TFN is multiplied component-by-component.

The mathematical expression considered to find the fuzzy weights (fw_i) for each factor is given below:

$$fw_i = [r_i * (r_1 + r_2 + \cdots r_n)^{-1}] \quad \text{Eq. (5.2.3)}$$

Whereas,

$$r_1 + r_2 = (l_1, m_1, n_1) + (l_2, m_2, n_2) = (l_1 + l_2, m_1 + m_2, n_1 + n_2)$$

$$(r_1 + r_2 + \cdots r_n)^{-1} = (l_s, m_s, n_s)^{-1} = \left[\frac{1}{n_s}, \frac{1}{m_s}, \frac{1}{l_s}\right]$$

After getting $(r_1 + r_2 + \cdots r_n)^{-1}$ value for each criterion, the corresponding criteria (r_i) is multiplied with each value and the fuzzy weights for particular criteria is calculated.

Step 6. After finding the fuzzy weights (fw_i), the next step is to find out the weights for each criterion by using center of the area (COA),

The Centre of Area (COA) method is used in Step 6 of the Fuzzy Analytic Hierarchy Process (Fuzzy-AHP) to determine the crisp weights (wi) for each criterion based on the fuzzy weights (fwi) obtained in Step 5. The COA method is a popular method for defuzzifying numbers and producing crisp values. Here is how to do it:

Recall that in Step 5, we calculated each criterion's fuzzy weights (fwi). Now, we need to get those fuzzy weights. These fuzzy weights represent the relative weights of each criterion in the decision-making process.

The Centre of Area (COA) Method should be used: The Centre of Area (COA) method is used to transform fuzzy weights (fwi) into crisp weights (wi). The arithmetic mean of the fuzzy weights determines the crisp weight for each criterion. The COA method is a defuzzification technique that identifies the fuzzy number's centre of mass, corresponding to its crisp value.

$$w_i = \left(\frac{l+m+n}{3} \right) \qquad w_i = \left(\frac{l+m+n}{3} \right)$$ Eq. (5.2.4)

Step 7. After finding the weights (W_i), we normalize and get the respective weights for each criteria as N_{Wi}.

Step 7. After that, we use the normalization process to get the weightage for each factor or criteria.

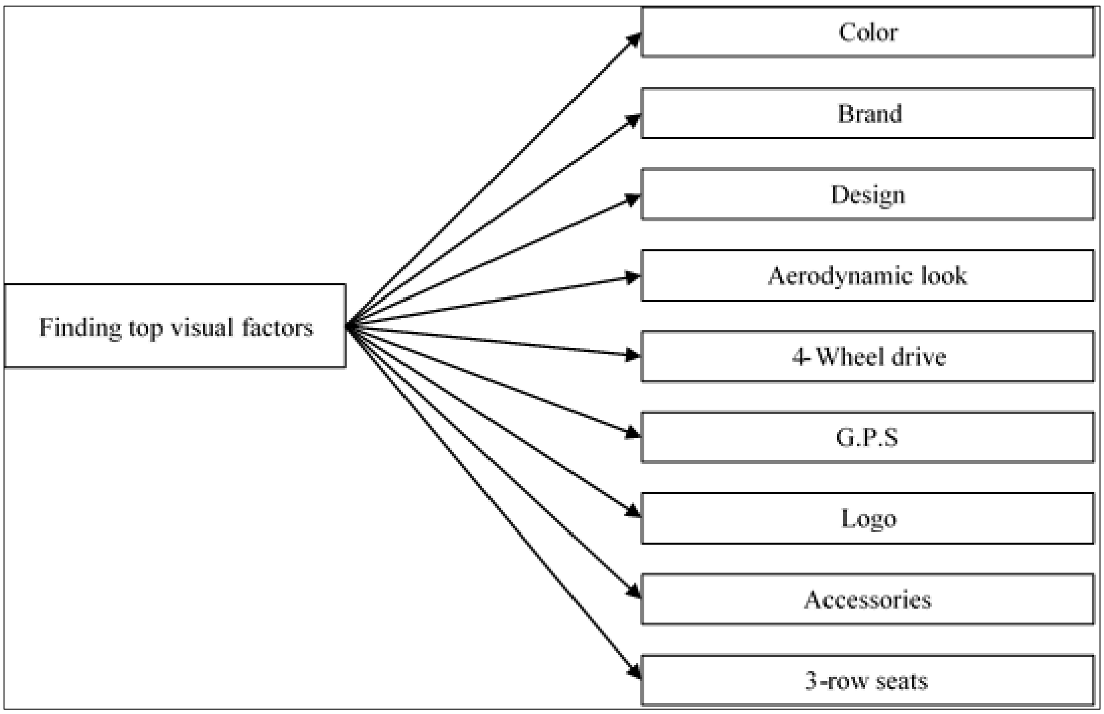


Figure 5.2.2. List of visual factors for the weightage identification

Note Colour (P_1), Brand (P_2), Design (P_3), Aerodynamic look (P_4), 4 wheel drive (P_5), G.P.S (P_6), Logo (P_7), Accessories (P_8), 3-row seats (P_9).

5.2.5. Results and analysis

We found nine factors based on the recurrence value as shown in Table 5.2.5. The identified visual factors were given to six industrial designers and six consumers who have cars respectively. All industrial designers are related to the automobile industry and all have more than six-year industrial experience. Open-ended questionnaires, which have been given to designers as well as a consumer, were made with the help of using the characteristic function of the fuzzy number (Triangular Fuzzy Number of linguistic comparison matrix). In Table 5.2.6, 1: equally strong, 2: intermediate, 3: moderately strong, 4: intermediate, 5: strong and so on. After that, we collect their opinion about the relative importance of each visual factor with respect to other factors. Then, a fuzzy analytic hierarchy process (F-AHP) approach was used to obtain the weight for each visual factor against the other visual factors. The weights provided by consumers as well as designers were compared with each other to see whether there is any difference in cognitive thinking of consumers and designers.

The study began with a comprehensive, open-ended survey comprising 36 questionnaires focused on nine aesthetic characteristics connected to automotive design. A prototype survey was done before the final survey to get preliminary feedback and insights. The pilot survey findings provided important feedback that was used to improve the final survey design. The final poll was then given to six industrial designers/decision-makers with at least six years of experience from two recognised automotive manufacturing businesses. These designers rated the importance of the specified visual characteristics using the questionnaire shown in Appendix Table 5.2.D. Six consumers with over ten years of driving experience who had previously purchased their second car were also included in the survey. The same questionnaire was used to collect consumers' thoughts on visual aspects during car-buying. Fuzzy-AHP (Analytic Hierarchy Process) approach was used to establish the weights of the primary criteria. This technique aided in incorporating decision-makers' and consumers' subjective judgments and preferences into the decision-making process while addressing ambiguity and uncertainty. Finally, (Kilincci & Onal, 2011) suggested a new classification approach for ranking the visual factors. This methodology allows for more in-depth knowledge of both designers' and customers' cognitive processing in the context of car design and purchase, respectively.

5.2.5.1.Determination of criteria weights

All the groups or decision makers have varying objectives and prospects. As we discussed with designers they considered a car for eight years of possession, i.e., from designing to launch and after three of the launch. Similarly, consumers considered a car as an asset, emotion and status, investment, etc. So, the affecting criteria have a dissimilar level of impact for both designers and consumers. The Fuzzy Analytic Hierarchy Process (Fuzzy-AHP) is used to overcome this issue and consider decision-makers subjective judgments. Fuzzy-AHP assists in incorporating and managing the ambiguity and uncertainty that can develop during decision-making. Designers and customers may give different weight vectors to the criterion due to differences in attitudes, education, cultural backgrounds, and socioeconomic backgrounds. This might result in more detailed assessments and significant disparities during decision-making. A Fuzzy-AHP-based group decision-making strategy is developed to address these issues to improve the pair-wise comparison process. As described in section 5.2.4.1, and table 5.2.6, each decision-maker (designers and consumers) undertakes pair-wise comparisons using a scale developed by (Saaty, 2008). As detailed in Appendix 5.2.D, questionnaires are utilized to collect the pair-wise comparison matrices from each participant (consumer and designer). The average comparison weights of designers and consumers are derived using these comparison matrices. These weights show the relative relevance of the visual characteristics as assigned by each group. The Fuzzy-based computation method is used to determine the designers and consumers weights for visual components, as shown in Table 5.2.7 and Table 5.2.8. The decision-making process becomes more inclusive and complete when the Fuzzy-AHP technique is used and feedback from designers and customers is considered. It aids in capturing the many viewpoints and opinions of the various stakeholders involved in the design and usage of automobiles.

Table 5.2.7. The Fuzzy based calculation to obtain weights of consumers for visual factors

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
P_1	1,1,1	(0.13, 0.15, 0.17)	(0.22, 0.28, 0.39)	(3.67, 4.67, 5.67)	(1.01, 1.40, 1.89)	(0.4, 0.5, 0.75)	(0.53, 0.61, 0.83)	(4, 4.83, 5.67)	(0.24, 0.27, 0.38)
P_2	(5.75, 6.76, 7.79)	1,1,1	(3.83, 4.83, 5.83)	(5.17, 6.17, 6.83)	(3.17, 4.17, 5.17)	(2.33, 3.33, 4.33)	(2.67, 3.67, 4.67)	(6, 7, 8)	(4.5, 5.5, 6.5)
P_3	(2.57, 3.53, 4.56)	(0.17, 0.21, 0.26)	1,1,1	(3.33, 4.33, 5.33)	(3, 4, 5)	(2.33, 3.33, 4.33)	(3.83, 4.83, 5.83)	(2.5, 3.5, 4.5)	(2.83, 3.33, 4.33)
P_4	(0.18, 0.21, 0.27)	(0.15, 0.16, 0.190	(0.16, 0.23, 0.3)	1,1,1	(0.75, 1.11, 1.5)	(0.44, 0.58, 1)	(1.33, 2.33, 3.33)	(3.17, 4.17, 5.17)	(1.7, 2.38, 3.39)
P_5	(0.53, 0.71, 0.99)	(0.19, 0.24, 0.32)	(0.2, 0.25, 0.33)	(0.67, 0.9, 1.33)	1,1,1	(0.44, 0.75, 1.33)	(2.67, 3.67, 4.67)	(1.83, 2.83, 3.83)	(1.33, 2, 2.67)
P_6	(1.33, 2, 2.48)	(0.23, 0.3, 0.43)	(0.23, 0.3, 0.43)	(1, 1.72, 2.25)	(0.75, 1.33, 2.27)	1,1,1	(1.83, 2.83, 3.83)	(1.17, 2.17, 3.17)	(0.26, 0.36, 0.58)
P_7	(1.2, 1.64, 1.89)	(0.21, 0.27, 0.38)	(0.17, 0.21, 0.26)	(0.3, 0.43, 0.75)	(0.21, 0.27, 0.38)	(0.26, 0.35, 0.54)	1,1,1	(3, 4, 5)	(0.26, 0.35, 0.56)
P_8	(0.18, 0.21, 0.25)	(0.13, 0.14, 0.17)	(0.22, 0.29, 0.4)	(0.19, 0.24, 0.32)	(0.26, 0.35, 0.55)	(0.32, 0.46, 0.86)	(0.2, 0.25, 0.33)	1,1,1	(0.24, 0.32, 0.5)
P_9	(2.67, 3.71, 4.19)	(0.15, 0.18, 0.22)	(0.23, 0.3, 0.35)	(0.30, 0.42, 0.59)	(0.38, 0.5, 0.75)	(1.72, 2.78, 3.85)	(1.8, 2.88, 3.91)	(2, 3.13, 4.17)	1,1,1

Note Colour (P_1), Brand (P_2), Design (P_3), Aerodynamic look (P_4), 4 wheel drive (P_5), G.P.S (P_6), Logo (P_7), Accessories (P_8), 3-row seats (P_9). In Table 5.2.7, we can see the comparison of criterion P_1 (Color) with respect to the other eight criteria (factors), and these are the input average values of six consumers.

Based on the average values provided by six consumers, Table 5.2.7 compares criterion P_1 (Colour) to the other eight criteria (factors). These consumers are a subset of the respondents, comprising 105 people who completed the open-ended survey. In row 2 of the table, we see that consumers favour criterion P_2 (Brand) over P_1 (Colour). This suggests that, based on the average values provided by the six consumers, they believe the brand to be more significant than colour when deciding. Based on the average values provided by the consumers, we may also notice a preference for the P_1 criterion over other criteria or vice versa. By studying the results in Table 5.2.7, you may estimate the relative weight consumers assign to each criterion compared to criterion P_1 (Colour). The greater the value in the table for a specific standard, the more buyers prioritize that criterion over color, and vice versa. This information aids in understanding consumer preferences and the relative importance of various elements when making decisions about car design and features.

Table 5.2.8. The Fuzzy based calculation to obtain weights of designers for visual factors

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
P_1	1,1,1	(0.43, 0.56, 0.92)	(0.54, 0.64, 0.92)	(0.17, 0.2, 0.25)	(0.26, 0.35, 0.56)	(0.19, 0.24, 0.32)	(0.17, 0.20, 0.26)	(1.83, 2.83, 3.83)	(0.22, 0.29, 0.44)

P_2	(1.09, 1.8, 2.32)	1,1,1	(2, 2.83, 3.67)	(2.17, 3.17, 4.17)	(1.17, 1.67, 2.17)	(1.83, 2.83, 3.83)	(0.89, 1.08, 1.33)	(4.33, 5.33, 6.33)	(3.67, 4.67, 5.67)
P_3	(1.09, 1.57, 1.85)	(0.27, 0.35, 0.5)	1,1,1	(1.83, 2.83, 3.83)	(1.5, 2.5, 3.5)	(4, 5, 6)	(0.89, 1.08, 1.33)	(5, 6, 7)	(4.5, 5.5, 6.5)
P_4	(3.96, 5, 6.03)	(0.24, 0.32, 0.46)	(0.26, 0.35, 0.55)	1,1,1	(0.28, 0.39, 0.67)	(2.5, 3.5, 4.5)	(0.93, 1.10, 1.42)	(2, 3, 4)	(3.33, 4.33, 5.33)
P_5	(1.8, 2.88, 3.91)	(0.46, 0.6, 0.86)	(0.29, 0.4, 0.67)	(1.49, 2.56, 3.57)	1,1,1	(1.67, 2.67, 3.67)	(0.17, 0.2, 0.26)	(1.06, 1.42, 1.83)	(0.89, 1.08, 1.33)
P_6	(3.13, 4.19, 5.21)	(0.26, 0.35, 0.55)	(0.17, 0.2, 0.25)	(0.22, 0.29, 0.4)	(0.27, 0.37, 0.6)	1,1,1	(0.14, 0.16, 0.2)	(1.17, 1.67, 2.17)	(2.17, 3.17, 4.17)
P_7	(3.91, 4.93, 5.94)	(0.75, 0.92, 1.13)	(0.75, 0.92, 1.13)	(0.71, 0.91, 1.07)	(3.91, 4.93, 5.94)	(5.07, 6.09, 7.1)	1,1,1	(5.17, 6.17, 7.17)	(3.17, 4.17, 5.17)
P_8	(0.26, 0.35, 0.55)	(0.16, 0.19, 0.23)	(0.14, 0.17, 0.2)	(0.25, 0.33, 0.5)	(0.55, 0.71, 0.95)	(0.46, 0.6, 0.86)	(0.14, 0.16, 0.19)	1,1,1	(0.27, 0.38, 0.64)
P_9	(2.25, 3.46, 4.56)	(0.18, 0.21, 0.27)	(0.15, 0.18, 0.22)	(0.19, 0.23, 0.3)	(0.75, 0.92, 1.13)	(0.24, 0.32, 0.46)	(0.19, 0.24, 0.32)	(1.57, 2.67, 3.71)	1,1,1

Note; Colour (P1), Brand (P2), Design (P3), Aerodynamic look (P4), 4 wheel drive (P5), G.P.S (P6), Logo (P7), Accessories (P8), 3-row seats (P9). In Table 5.2.7, we can see the comparison of criterion P1 (Color) with respect to the other eight criteria (factors), and these are the input average values of six designers.

In Table 5.2.8, we can see that the comparison of factor (criterion) P_1 with respect to the other eight factors (criteria), and these values are also the input average values of six designers. In row 2, column 3. We can see the consumer's input (P_1 over P_2 and vice versa). Similarly, we can see the comparison of the P_1 on other criteria and vice versa. Let us take an example; how we get value for P_2 (factor) corresponds to P_1 (factor) i.e. (0.43, 0.56, 0.92). It is an average input of six designers from the open-ended questionnaire by using a linguistic scale as shown in Table 5.2.6. Since, D_1 = 1 = (1,1,1), D_2 = 1/2 = (1/3, 1/2, 1), D_3 = 1/3 = (1/4, 1/3, 1/2), D_4 = 1/2 = (1/3, 1/2, 1), D_5 = 1/2 = (1/3, 1/2, 1), D_6 = 1/2 = (1/3, 1/2, 1) are the values given by six industrial designers and the average of these values is shown in second row, third column (i.e. (0.43, 0.56, 0.92)) in Table 5.2.8. Where D indicates an Industrial designer input. As an input two designer is provided in Appendix table 5.2.D, and table 5.2.E.

Table 5.2.9 shows the Fuzzy geometric mean (ri), Fuzzy weights (fwi), Weights (Wi), and Normalised weights (NWi) values for each factor obtained using the average comparison matrix for both designers and consumers. As the technique states, these computations are carried out using equations 1, 2, 3, and 4. The geometric mean of the values in each row of the comparison matrix is represented by the Fuzzy geometric mean (ri). It assesses each factor's overall preference or importance in comparison to others. Fuzzy weights (fwi) are calculated by normalizing Fuzzy geometric mean values, which aids in reflecting the relative importance of each component in the decision-making process. The Weights (Wi) are calculated by normalizing the Fuzzy weights (fwi), ensuring that the values are between 0 and 1 and add up to 1. These weights show each factor's relative importance to the others. Finally, the Normalised weights (NWi) are obtained by further normalizing the Weights (Wi) to maintain consistency and comparability across different components. Because they are on a standardized scale, these normalized weights provide a clearer understanding of the relative importance of each aspect. You can analyse the specific values of the Fuzzy geometric mean, Fuzzy weights, Weights, and Normalised weights for both designers and consumers in Table 5.2.9. These values enable you to measure the significance of each component and comprehend how they influence decision-making from the standpoints of designers and consumers.

Table 5.2.9. Weightage for each factors given by consumers and designers

	Consumers				Designers			
	fuzzy geometric mean value (ri)	fuzzy weights (fwi)	Weights (Wi)	Normalized Weights (Nwi)	fuzzy geometric mean value (ri)	fuzzy weights (fwi)	Weights (Wi)	Normalized Weights (Nwi)
P_1	(0.65, 0.78, 0.99)	(0.05, 0.06, 0.11)	0.07	0.07	(0.37, 0.46, 0.63)	(0.03, 0.04, 0.07)	0.05	0.05
P_2	(3.4 4.19, 4.92)	(0.24, 0.34, 0.54)	0.37	0.36	(1.74, 2.33, 2.89)	(0.12, 0.21, 0.33)	0.21	0.19
P_3	(1.87, 2.38, 2.92)	(0.13, 0.19, 0.32)	0.21	0.21	(1.59, 2.07, 2.55)	(0.11, 0.18, 0.29)	0.19	0.17
P_4	(0.6, 0.79, 1.03)	(0.042, 0.06, 0.11)	0.07	0.05	(1.01, 1.3, 1.73)	(0.07, 0.12, 0.2)	0.14	0.14
P_5	(0.7, 0.94, 1.27)	(0.05, 0.08, 0.14)	0.09	0.08	(0.77, 1.04, 1.38)	(0.05, 0.09, 0.16)	0.11	0.11
P_6	(0.68, 0.99, 1.37)	(0.05, 0.08, 0.15)	0.09	0.08	(0.52, 0.67, 0.88)	(0.04, 0.06, 0.1)	0.07	0.06
P_7	(0.43, 0.56, 0.76)	(0.03, 0.04, 0.08)	0.05	0.04	(2, 2.43, 2.86)	(0.14, 0.22, 0.33)	0.23	0.21
P_8	(0.25, 0.31, 0.42)	(0.02, 0.03, 0.05)	0.03	0.03	(0.29, 0.36, 0.48)	(0.02, 0.03, 0.05)	0.03	0.02
P_9	(0.74, 1.01, 1.28)	(0.05, 0.08, 0.14)	0.09	0.08	(0.44, 0.56, 0.72)	(0.03, 0.05, 0.08)	0.05	0.05

Note; Colour (P_1), Brand (P_2), Design (P_3), Aerodynamic look (P_4), 4 wheel drive (P_5), G.P.S (P_6), Logo (P_7), Accessories (P_8), 3-row seats (P_9).

In Table 5.2.7, we can see the comparison of criterion P_1 (Color) with respect to the other eight criteria (factors), and these are the input average values of six designers. It is very hard to say which factors are more important as compared to others by using other methods, but ranking them by using the Fuzzy AHP approach makes it more logical and helpful for decision making. The ranking of visual factors has been done by observing the highest weight value, which is given in Table 5.2.9, with the help of Fuzzy AHP, for both consumers as well as designers. Our main focus during this study is to find out the gap between the designers' and consumers' perception during the designing of a car and at the time of purchase of a new car respectively. After analyzing the data, we observed that the perception of designers and consumers for a new car is quite different from each other. In Table 5.2.9, we found that the designer gives 19% weightage to brand value/name, whereas consumer gives 36% weightage (i.e. consumers give almost double). In the case of aerodynamic look, consumers give only 6% weightage and designers give more than double importance (i.e., 14%). Similarly, in case of "design of logo or logo" consumers give only 4% weightage and designers give more than five times to it, i.e., 21%. On the other hand, for 4 wheel drive consumer gives 8% weightage and designers give 11%, in case of other factor like accessories, 3 row seats, and color consumers give little bit higher weightage (i.e., 3%, 8%, 7%) as compare to designers (i.e., 2%, 5%, 5%) respectively. Although, there was another factor named as "design"; for those consumers gave 21% weightage whereas, designers provided less weightage i.e., 17%.

According to the table, the most crucial factor for customers is Brand (P_2), which has a Fuzzy high weight (fwi) of 0.54 and a normalized weight (NWi) of 0.36. This suggests that when acquiring a new car, people value the brand name or value highly. On the other hand, designers give Brand (P_2) a lower weight, showing a difference in perception from customers. The design of the Logo (P_7) has the most weight in the designer's opinion, with an fwi of 0.33 and an NWi of 0.21. This implies that designers place a high value on the design of the vehicle company's logo. This finding differs from the consumer's point of view, where the Logo (P_7) element is given a lower weight.

Another significant distinction between consumers and designers is the importance of Aerodynamic appearance (P4). This element is more meaningful to designers, as indicated by its weight (NWi = 0.14), than to customers (NWi = 0.05). This suggests that designers prioritize a car's aerodynamic appearance more than users. Consumers, on the other hand, give the Design (P_3) factor a more significant weight (NWi = 0.21), while designers give it a somewhat lower weight (NWi = 0.17). This implies that buyers value the vehicle's overall design more than designers do. Furthermore, consumers consider the 3-row seats (P_9) feature the least important, with a smaller weight (NWi = 0.08). On the other hand, designers give this component a somewhat higher weight (NWi = 0.05). This means that, compared to designers, customers emphasize the availability of three rows of seats in an automobile less. It should be noted, however, that the sample size in this study could have been bigger, which may restrict the generalizability of the findings. Future research should examine the reasons for the disparities in consumer and designer perspectives and the variables consumers prioritize when evaluating these criteria. Researchers can bridge the gap between customer and designer perspectives by better understanding these discrepancies, leading to more effective decision-making processes in the automotive sector.

5.2.6. Summary

Research in Chapter 5.2 presents the gap between the thinking of consumers and designers regarding visual factors in car design. During our investigation, we discovered a schism between customer and designer opinions on the aesthetic aspects of automotive design. Our study's findings offer valuable insights for industrial designers and marketing decision-makers, allowing them to increase the brand value of their goods. Designers can disclose their objectives and draw consumer attention by knowing the typicality and originality of a product's design aspects. However, whether still being determined perceptions of design aspects coincide with the designers' aims of generating common or unusual looks to attract attention is unclear. One reason for this disparity is that designers sometimes operate in solitude, with little interaction with prospective clients to understand their desires. They primarily receive feedback from marketing teams in technical terminology or through statistical data, leaving them needing more understanding of consumers' emotions, personal values, and cognitive processes. We might see differences in car design if designers had face-to-face contact with actual buyers before creating a new car. Visual features are critical to the success of automobiles in today's market, and industry professionals must address consumer expectations early in the product development process. In addition to those described in this study, other factors could be incorporated into future research. Corporate strategy, organizational communication, R&D vision, and transdisciplinary collaboration are examples of these, and they all indirectly impact the work of individuals in any organization. Organizational communication, for example, has been identified as a factor influencing a group's innovativeness and creativity. Administrative support, workgroup collaboration, supervisory support, freedom, resources, and demanding work are all associated with increased creativity. To obtain a competitive advantage, businesses should also focus on corporate strategies, such as delivering good after-sales services. Furthermore, marketing and R&D departments must prioritize understanding today's consumers' hidden wants. Companies should engage with ordinary people, collect data from social networking sites, and acquire insights into their daily routines to unearth these requirements and aspirations influencing consumer perception during car sales.

The automotive sector may better align its products with consumer expectations and preferences by considering these variables and encouraging tighter collaboration between designers, consumers, and various organizational divisions. This technique will eventually result in more successful and enjoyable automotive designs. In next study Chapter 5.3, we try to find out the various sub-factors for main nine non-visual factors. And try to found out the relationship between these sub-factors.

CHAPTER 5.3.

A Study of the Non-Visual Factors of Cars Affecting the Consumer's Cognitive Appeal

In Chapter 5.3, we concentrated on finding the sub-factors of non-visual factors of a product (car). In this study we aimed to identify the major non-visual factors of cars that affect the cognitive perception of buyers and estimate their importance relative to each other. Afterward, among these sub-factors, we found the most prominent factors and their relationships with each other and the non-visual factors.

5.3.1. Introduction

In the automobile sector, companies are progressively dedicated to creating a holistic experience for their consumers. Not only do the companies have to keep up with their rivals, but they also have to sustain themselves in the market (Vink & Hallbeck, 2012). For that, industries are in an endless search for improving their products to attract buyers. Therefore, various empirical studies on consumer responses related to product design focused on the relationship among consumers' subjective responses towards objective features associated with the product (Bloch, 1995a). Researchers have tried to measure consumer attitudes or cognitive feelings by presenting a different range of product forms. For the categorization of consumer responses, various theoretical frameworks have been developed related to product design. Thus, product design and its effect on consumer behavior have become a significant area of interest for researchers (Peighambari et al., 2016b; Simmonds & Spence, 2017b; J. Singh & Sarkar, in communication). At the same time, consumer satisfaction is an inherently emotional and cognitive response (McKeown, 2014). Consumers want to purchase unique products in contrast with other available products. Nowadays, aesthetics is one of the prime components of everyday products by which consumers and designers are inspired (Fenko & van Rompay, 2018). In this framework, researchers put more stress on the consumer's cognitive thinking rather than the designer's thinking. The consumer's thinking on a product design is different for different components of the product experience: aesthetic pleasure, emotional response, and attribution of meaning. Although the use of aesthetics is an efficient way to separate/distinguish a product (only by seeing them), it also has a significant impact on the customer's perception at the time of purchase (Crilly et al., 2004a; J. Singh & Sarkar, in communication). Various companies have tried to distinguish their products by using aesthetics, making them look more efficient and innovative (Mumcu & Kimzan, 2015b). Various research works in different product design related areas have been carried out, such as visual product aesthetics (Jagtap, 2017), product form (Crilly et al., 2009a), consumer behavior (Blijlevens et al., 2017), etc. In this study, we tried to identify the non-visual factors that influence the attractiveness of a car. After that, we identified different sub-factors of these non-visual factors and tried to obtain the relationships between these sub-factors.

Current Status of the Automobile Sector in India: The Indian automobile sector is developing very fast and currently is the fifth largest manufacturer in the world, after having been in seventh place in 2017. Presently, the automobile industry contributes more than 7.1% to India's gross domestic product (GDP). For the first three quarters of 2020, auto companies in India manufactured approximately 2.16 million vehicles, down 38.4% compared to the 3.5 million vehicles manufactured during the first three quarters of 2019 (K.-C. Liu & Racherla, 2019). Indian automotive industries directly or indirectly generate employment for 35 million people. The 118-billion-dollar automotive sector is estimated to reach a market of approximately 300-billion-dollar by the end of 2026. India's annual production was 30.91 million vehicles in 2019 against 29.08 million in 2018, registering a healthy growth of 6.26%. Such a drastic growth has created concern for consumer emotional perception and their expected needs from automobile manufacturers (A et al., 2020). These concerns are not only limited to the designer's perception at the time of designing a new car but also spread across the consumers' emotions and their perception at the time of purchase of a new car, or when planning the purchase of a new car. This difficulty was dealt with by using simple multi-criteria decision-making techniques for finding the top sub-factors for non-visual factors in our previous study (J. Singh & Sarkar, in communication).

As we have seen in previous studies, numerous visual factors affect the consumers' cognitive perception. Apart from these visual factors that lead to the failure/success of any segment of automobiles (Crilly et al., 2004a), there are some other factors, such as ergonomics, warranty/quality, past experiences, etc. In some experimental studies, it was observed that the customers had a higher preference for some designs compared to others designs (D. Norman, 2002; Orth & Malkewitz, 2008), but little seems to be known about how consumers understand product designs and how they can translate them into insights of value (Veryzer, Jr. & Hutchinson, 1998b). Whereas Orth and Malkewitz (2008) concluded in their study that numerous factors affect the consumer's cognitive appeal at the time of purchase. These factors may be visual or non-visual. The judgment may vary from person to person or from product to product, but it is based on visual information and is also often based on the functionality, elegance, and social significance of the product (Bloch, 1995a). These decisions often show a connection between the perceived characteristics of the product, and they frequently point towards the consumers' desires rather than their needs (G_Monö, 1997). Generally, car buyers expect a car to have a variety of accessories. If these accessories are available, then buyers consider it as a good-quality car. Quality is the perceived performance of a service or product (Angelova & Zekiri, 2011). However, quality itself alone is not enough; whether the product is reliable enough is also important. A product's reliability is usually explained as a reason for consumers to repurchase a specific product or service in the upcoming period (Angelova & Zekiri, 2011; G_Monö, 1997; Johnston, 1995; Manu, 2011; Seth et al., 2005; Veryzer, Jr. & Hutchinson, 1998b). Other non-visual factors, apart from quality and reliability, eventually lead to the success or failure of any vehicle in the market. This article focuses only on the automobile industry and especially on passenger cars. However, we identified various non-visual factors in our previous research that affect consumer perception while buying a new car (J. Singh & Sarkar, in communication). The list of non-visual factors is given in Table 5.3.1.

Table 5.3.1. List of non-visual factors that influence the purchase of cars (J. Singh & Sarkar, 2023)

Status/feeling of prestige	Reliability	New technology/features
Ergonomics	Quality/warranty	Past experience
Safety features	Design/unique form	Mileage/fuel-efficiency

5.3.2. Research Objective

According to Blessing and Chakrabarti (Blessing & Chakrabarti, 2009a), the general idea of design research is to make product design 'more efficient and effective' and make products more successful. The objective of this study was threefold: (1) to identify the major non-visual factors related to cars that affect the consumer's purchase behavior and the designer's thinking at the time of designing a new car through previous works; (2) to identify the various sub-factors of the non-visual factors identified through a literature search; (3) to establish and examine the causal relationships between the finalized sub-factors and the top non-visual factors to identify the most significant sub-factors. First, we conducted an extensive literature search to find the top non-visual factors, and then we conducted a survey to find the various sub-factors related to the non-visual factors of cars. After that, the DEMATEL method was used to obtain the causal relationships between sub-factors, which show the type of influence that one sub-factor has on another sub-factor. A causal relationship is normally validated with the support of a causal diagram that distributes the factors under study into cause-and-effect factors. A cause factor commands some influence on the arrangement and an effect factor receives this command. The Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique was used to develop an interaction matrix that expresses the inter-relationships between the sub-factors of the top non-visual factors. Sub-factors that are cause factors and have an interrelationship with most of the other sub-factors will have a greater possibility to improve the non-visual factors, which will fulfill the consumer's emotional, practical desires.

The rest of this article is organized as follows: In Section 5.3.2, we discuss previous research associated with the factors of cars and consumers' and designers' thinking on these factors. The proposed framework was based on an open-ended survey and the DEMATEL method (this work's main methodology) is explained in Section 5.3.4. In Section 5.3.5, the collection of data for this study is explained. An application of the proposed work is provided in Section 5.3.6, which is followed by the conclusions and limitations of this work in the last section.

5.3.3. Research Gap

The factors that were found are related to the automobile sector, especially for cars and there is a need to explore the sub-factors of each main factor that is mentioned in section 2. Some researchers have attempted to find out the relations between two or three factors, such as ergonomics and product quality (Falck et al., 2010; Shin et al., 2015), studying the relation of consumer willingness and their preferences to pay for new vehicle technology. We found few relationships between these factors and to date no study has been conducted on what type of sub-factors affect the main non-factors mentioned in section 2. Therefore, a study should be carried out that does not only show the connection between different sub-factors but can also show the ability of each sub-factor to affect the other sub-factors for the enhancement of main non-visual factors and fulfilling the consumers' needs and desires.

5.3.4. Aim and Methodology

This research aimed to find the most prominent set of sub-factors associated with each top non-visual factor, as found in the existing literature (J. Singh & Sarkar, in communication). The list of non-visual factors is given in Section 2 (Table 5.3.1). To achieve the above aim, we used the following methodology: (i) first, we reviewed the literature to find out the non-visual factors related to passenger cars, (ii) then we identified the various sub-factors that affect the non-visual factors of a car. For finding the sub-factors, we conducted an open-ended survey among car buyers and prospective car buyers. Among these sub-factors, we found the most prominent factors and their relationships with each other and the non-visual factors. To find the most prominent sub-factors, we used the DEMATEL approach.

Even though there are other useful decision-making methods, for example Interpretive Structural Modeling (ISM), Elimination and Choice Expressing Reality (ELECTRE), Analytical Network Process (ANP), etc., these techniques/approaches are only able to prioritize sub-factors/criteria and are unsuccessful in detecting cause-and-effect factors. An understanding of the cause-and-effect factors helps professionals/experts in comprehensive decision-making. A detailed description of the Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique is given below.

5.3.5. The DEMATEL Technique

From 1972 to 1976, the Battelle Memorial Institute of Geneva ran a science and human affairs program for solving interconnected and complex problems and proposed a Decision-Making Trial and Evaluation Laboratory (DEMATEL) (Rajput & Singh, 2019). For comprehensive decision-making, the DEMATEL technique is beneficial for experts from all industries. It is based on digraphs and is used not only to find the inter-relationships between sub-factors/criteria, but also helps in finding the direction of these relationships (Sharma et al., 2018; P. K. Singh & Sarkar, 2020; W.-C. Wang et al., 2012). The key points of the DEMATEL approach are: (a) it is based on graph theory and simplifies the analysis of challenging problems with the help of visualization; (b) it helps to develop the cause-and-effect relationships among different sub-factors/criteria, which makes it easy to understand the mutual impact of these factors/sub-factors/criteria, and (c) with this method, we can find out the strength of the relationships among different factors, which is impossible with other multi-criteria decision-making techniques (C.-Y. Huang et al., 2007). This method has broadly been applied in different areas, such as online reputation management (A. Kumar & Dash, 2017), identification of critical factors for green supply chain management (Wu & Chang, 2015), sustainable supply chain (S. Mangla et al., 2014), sustainable food supply chain (Sharma et al., 2018), and logistics management implementation (S. K. Mangla et al., 2018). This approach/technique does not require large amounts of data.

In some situations, the DEMATEL (Decision-Making Trial and Evaluation Laboratory) technique is appreciated and chosen over alternative methods for several reasons (Lahane & Kant, 2022; Singh & Sarkar, 2020).

- DEMATEL offers an organized, systematic method for examining difficult decision-making circumstances. It enables a thorough grasp of how different aspects or variables involved in the decision-making process interact.
- The DEMATEL approach makes it possible to identify and assess the causal connections between various components. It provides deeper insights into the choice problem by going beyond simple correlation analysis and assisting in determining the cause-and-effect linkages between parts.
- Using a visual matrix, DEMATEL provides a graphical description of the cause-and-effect interactions. This representation makes the relationships between the elements easier to grasp and analyze, making explaining the findings to interested parties more straightforward.
- The DEMATEL method takes a quantitative approach, which minimizes any biases resulting from subjective evaluations. By quantifying the connections and relative impacts of the components, it offers a more impartial study, boosting the integrity and dependability of the findings.
- DEMATEL adopts a holistic viewpoint by considering direct and indirect linkages between various components. Choice-makers can better understand the general structure and dynamics of the choice problem because it captures the interdependencies and feedback loops within the system.

- In several industries, including business, engineering, healthcare, and environmental management, DEMATEL has been successfully used. It is a preferred tool for decision analysis and evaluation across various fields due to its usefulness and adaptability.

This method offer a systemic analysis of complex decision problems, pinpoint causal relationships, graphically display the outcomes, provide objective research, adopt a holistic viewpoint, and show practical applicability across various domains. These benefits result from its significance and desirability over alternative procedures in particular decision-making contexts.

The steps of the DEMATEL technique are:

1. Construction of an initial relational matrix. In the first step, an initial relational matrix is constructed for the sub-factors with professionals/experts' help. The views of the experts/professionals are collected using the linguistic rating scale shown in Table 5.3.5.
2. Construction of a direct-relation (average) matrix. The average direct-relation matrix is generated from the initial relation matrix. We asked the experts to score each sub-factor, according to which they believe a sub-factor i influences sub-factor j using a comparison scale. The notion $x_{i,j}^{k}$ specifies the extent to which according to expert's k judgment sub-factor i influences sub-factor j. The experts use the non-negative numbers in Table 5. The variables $X^1, X^2, X^3, \cdots, X^L$ are the inputs of each expert that create a $n \times n$-sized non-negative matrix $X^k = \left[x_{i,j}^{k}\right]_{n\times n}$ for $k \in [1, L]$. There is no influence from the sub-factors, so each matrix's diagonal element is zero. To integrate all opinions from L experts, the average matrix $A = \left[a_{i,j}\right]$ can be constructed as follows:

$$\left[a_{i,j}\right] = \frac{1}{L}\sum_{k=1}^{L} \quad [x_{i,j}^{k}] \tag{5.3.1}$$

3. Construct a normalized direct-relation matrix. Based on the average direct-relation matrix (A), a normalized initial direct relation matrix (N) can be obtained by $N = AP$, with

$$P = \left\{\frac{1}{i\sum_{i=1}^{n} \quad a_{i,j}}, \frac{1}{j\sum_{j=1}^{n} \quad a_{i,j}}\right\} \tag{5.3.2}$$

   where $0 < n_{i,j} < 1$. Similarly, a positive scalar P takes the largest of the two factors, and the matrix N is calculated by dividing each element of matrix A with the positive scalar P.

4. Calculate a total-relation matrix (T). Once the normalized direct relation matrix (N) has been obtained, the total relationship matrix $T_{n\times n}$ is obtained as follows:

$$T = N(I - N)^{-1} \tag{5.3.3}$$

   Where I is the identity matrix.

5. Formation of a causal diagram. The sum of rows and the sum of columns are separately denoted as vectors r and c within the total relation matrix T, respectively. In the total relation matrix, the sums of rows r and columns c are computed as r and c, $n \times 1$, and $1 \times n$ vector, as shown below:

$$r = \left(\sum_{j=1}^{n} t_{i,j} \right)_{n \times 1} \quad (5.3.4)$$

$$c = \left(\sum_{i=1}^{n} t_{i,j} \right)_{1 \times n} \quad (5.3.5)$$

The casual diagram is prepared by mapping prominence $r + c$ and relation $r - c$data, marked horizontally and vertically in the graph. Then the categorization of sub-factors into a cause or effect group is done. If the $r - c$ value is positive, sub-factors come in the cause group, and if the $r - c$ value is negative, they come in the effect group. The $r + c$ value indicates the importance level of the factor and $r – c$ indicates a cause-and-effect factor.

6. Construction of an interaction matrix of sub-factors. The average of the elements in the total relation matrix T gives the threshold value, since matrix T provides instances of how one sub-factor affects another. Thus, the threshold value assists in filtering out some insignificant/negligible effects in this context. Further, the results that are greater than the threshold value will be selected, as shown in the interaction matrix of sub-factors.

5.3.5.1.Finding Sub-factors for non-visual Factors

At least five experts should be involved in a study that is based on decision-making (Gardas et al., 2019). For the collection of sub-factors, we conducted an open-ended survey. We made a questionnaire related to non-visual factors of cars, which can be found in Appendix 5.3.A. During the open-ended survey, we asked eighteen experienced car owners to provide their responses to each question. All the participants were male, their average age was thirty-two years, and they had different social, economic, and cultural backgrounds. Despite having eighteen respondents, we only received a response from fifteen respondents; the other three left the survey in the middle due to time and work constraints. Therefore, we eliminated these three incomplete replies from the final cumulative collection. Out of fifteen car owners, six worked in different multinational companies, and the rest worked as senior research associates. All of them had two to four years of industrial experience, and all of them had more than six to seven years of car driving experience.

Each respondent took approximately forty-five minutes to complete the survey. Each respondent mentioned a respective sub-factor for each non-visual factor on a priority basis; the entire list is presented in Appendix 5.3.B. In Table 5.3.B of Appendix 5.3.B, the first respondent listed ‘safety’ as the first priority as a sub-factor of reliability; the second respondent listed ‘airbag, brand values, seat locking system, and brake system’ as the first priority under the same factor. In the next step, we listed all the sub-factors for each non-visual factor mentioned by all respondents, and then added all of them.

5.3.5.2.Grouping of Sub-factors

We obtained various sub-factors from the respondents for every non-visual factor. Next, we used the English dictionary, blogs (websites), and technical books related to car/vehicles to find out synonyms for each sub-factor. Then all words with a similar meaning were grouped together and one representative name was selected. As we saw in Appendix 5.3.B, the sub-factors other than the top five (six, seventh, and so on) got the same level of priority. Then, we took the top five sub-factors for each non-visual factor, which are listed in Table 5.3.2.

Table 5.3.2. List of sub-factors according to their respective non-visual factors (frequency of occurrence in brackets)

Unique form/design	Feeling of prestige/status	Quality	Ergonomics	Reliability	Safety	Mileage/ fuel-efficient	New technology/ features	Past experience
Design of head/ taillights (6)	Brand value (6)	Car build quality (9)	Adjustable seat, steering & mirror (8)	Good engine performance (6)	Airbags (10)	Weight of the car (6)	Cost (8)	Engine performance / mileage (6)
Design & looks of the car (4)	Design & looks of the car (6)	Safety (3)	Leg/inside space (8)	Regular car servicing (5)	ABS (7)	Eco-mode feature (5)	New features improving safety (6)	Car servicing (6)
Aerodynamic look (3)	Comfort (4)	New accessories/ features (3)	Comfortable seat size & design (6)	Safety (4)	Car build quality (7)	Engine performance (5)	New technology enhancing engine performance (3)	Comfort (4)
Height & ground clearance (2)	High-end features & interior (4)	Reliability (3)	Height & ground clearance (4)	Brand value (4)	Height & ground clearance (5)	Aerodynamics of the car (4)	New smart features (2)	Brand value (3)
Inside space (2)	Good engine performance (3)	Good engine performance (3)	Cost (2)	Car build quality (4)	Cost (2)	Proper car servicing (2)	New features increase comfort level (2)	Sitting space (3)

In Table 5.3.2, we present the various sub-factors under each category (main non-visual factors) in descending order of frequency. For instance, we can see that the main non-visual factor 'reliability' is affected by the sub-factors 'good engine performance (6)', 'brand value (4)', 'build quality (4)', 'proper car servicing (5)', and 'safety (4)' in decreasing order, and so on for the other non-visual factors. The numeric value represents the different respondents who chose one particular sub-factor for that particular rank/preference during the open-ended survey.

After collection of the different sub-factors we wanted to find the relationships between the sub-factors and the main factors, since the number of sub-factors was very high. The reason was that there was repetition of sub-factors, as we can see in Table 5.3.2. The respondents considered 'safety of the car' as a sub-factor for the main factors 'quality', 'reliability' as well as 'new technology/features', as shown in Figure 5.3.1.

Figure 5.3.**1.** Relationship between the main factors and their sub-factors

Similarly, there were other factors too, which were considered sub-factors for other main non-visual factors. Figure 5.3.1., shows how one sub-factor is linked with different main non-visual factors. With the help of Figure 5.3.1., we could identify 20 sub-factors that affect the top nine non-visual factors. After finding the twenty different sub-factors, it was necessary to identify the most prominent sub-factors among them, which are given in Table 5.3.3.

Table 5.3.3. List of all sub-factors obtained after finding the similarity between them

No.	Sub-factor	No.	Sub-factor	No.	Sub-factor	No.	Sub-factor
F_1	Adjustable driving equipment	F_6	After-sale services	F_{11}	Design of front grill & bonnet	F_{16}	Car inside space
F_2	Aerodynamic design	F_7	Car build quality	F_{12}	Design of headlights	F_{17}	New accessories/featur e
F_3	Air-bags	F_8	Comfortable seat design	F_{13}	Eco-mode feature	F_{18}	Reliability
F_4	ABS	F_9	Car cost	F_{14}	Engine performance	F_{19}	Safety of the car
F_5	Brand value	F_{10}	Design/looks of the car	F_{15}	Ground clearance	F_{20}	Weight of the car

Note: F1 denotes the sub-factor 'adjustable driving equipment,' F2 denotes the sub-factor 'aerodynamic design', and so on until F20.

5.3.6. Data Collection and Results Analysis

We conducted an open-ended survey to find out the sub-factors of each non-visual factor among prospective car buyers, i.e., people who are thinking of purchasing a car in the coming year. Next, we used a decision-making technique for prioritization, i.e., the DEMATEL technique, and to identify the influence of each sub-factor on the main non-visual factors. The DEMATEL approach was used to understand the inter-relationships between the sub-factors and also to recognize the cause-and-effect factors by developing a causal diagram.

After the collection of the sub-factors, they were arranged in matrix form, as depicted in Appendix 7.C. We approached six automobile designers/professionals to obtain their views on each sub-factor with respect to the others and requested them to give their response by using the comparison scale in Table 5.3.4. All six designers had at least eight years of industrial experience, and currently worked in multinational automobile companies. During this study, experienced people played an important role. As mentioned in section 5.3.2, the minimum number of experienced professionals required is five (Gardas et al., 2019).

Table 5.3.4. Linguistic approach for the DEMATEL method

Numeral	Definition
0	No influence
1	Low influence
2	Medium influence
3	High influence
4	Very high influence

The expert input is presented in the form of an initial relation-matrix, provided in Table 5.3.D, Appendix 5.3.D. After that, by using Equation (5.3.1), the inputs of all six experts were aggregated, as shown in Table 5.3.5.

Table 5.3.5., was obtained by averaging the inputs of the six experts. For instance, in the third row and the fifth column of Table 7.5., the value 0.17 shows an average input of $D_1 = 0, D_2 = 1, D_3 = 0, D_4 = 0, D_5 = 0, D_6 = 0$, where D denotes 'experts/professional designers'.

Table 5.3.5. Linguistic approach for the DEMATEL method

*	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}
F_1	0.00	0.33	1.67	0.17	3.33	0.67	1.17	3.33	2.83	2.67	0.00	0.00	0.33	0.00	0.00	2.00	1.50	2.00	2.83	1.00
F_2	0.00	0.00	0.00	0.17	1.00	0.17	2.17	1.83	1.50	3.00	3.00	2.00	0.33	1.33	1.83	0.50	0.50	0.67	1.67	1.17
F_3	2.00	0.50	0.00	0.00	3.50	0.67	1.00	1.00	2.83	1.00	0.00	0.00	0.00	0.00	0.00	0.67	1.33	2.00	3.67	0.67
F_4	0.50	0.33	0.00	0.00	2.83	1.67	1.17	2.00	2.83	0.00	0.00	0.00	0.17	0.67	0.17	0.00	1.00	2.33	3.67	0.50
F_5	2.33	1.83	3.00	2.67	0.00	2.00	2.67	2.50	2.67	2.50	1.83	2.17	2.00	1.50	1.00	1.33	2.50	2.67	3.00	1.50
F_6	1.00	0.17	0.67	1.17	2.33	0.00	0.67	1.50	2.67	0.33	0.33	0.00	0.83	2.00	0.00	0.17	0.17	1.83	2.50	0.50
F_7	0.83	0.83	0.50	0.67	2.67	0.67	0.00	2.67	2.83	2.33	1.67	1.50	1.33	0.50	0.50	0.83	0.83	2.67	3.50	2.17
F_8	3.00	1.00	0.83	2.00	2.83	1.83	2.67	0.00	2.83	1.00	0.50	0.33	2.00	1.33	0.83	1.50	1.00	2.17	2.33	1.67
F_9	2.17	1.67	2.33	2.33	2.33	2.00	3.00	2.83	0.00	2.67	2.50	2.67	2.33	2.00	0.67	1.50	2.50	2.83	3.33	1.33
F_{10}	1.50	2.33	0.33	0.00	2.33	0.67	2.17	1.50	3.17	0.00	3.50	3.33	0.00	0.00	2.33	1.83	2.00	1.67	1.67	2.00
F_{11}	0.00	2.67	0.00	0.00	1.67	0.00	1.17	0.17	2.50	3.67	0.00	1.00	0.00	0.33	0.50	0.00	0.33	1.83	1.00	1.00
F_{12}	0.00	2.00	0.00	0.33	1.50	0.00	1.17	0.17	2.50	3.00	1.17	0.00	0.00	0.00	0.50	0.00	0.00	0.83	1.00	0.50

F13	0.00	1.00	0.33	0.50	2.00	0.50	4.00	1.50	2.17	0.67	0.00	0.00	0.00	3.17	0.00	0.00	1.50	1.67	1.17	0.33
F14	0.00	1.50	0.00	0.33	2.33	2.50	1.50	1.33	2.50	0.33	0.83	0.00	2.83	0.00	0.17	0.00	0.33	2.33	2.17	1.33
F15	0.00	2.33	0.00	0.17	1.17	0.33	1.00	1.00	0.67	1.83	0.67	0.50	0.00	0.17	0.00	0.50	0.17	1.83	2.33	1.67
F16	1.83	1.00	0.67	0.00	0.83	0.50	1.17	2.17	2.50	2.33	0.33	0.00	0.00	0.00	0.67	0.00	1.83	1.00	1.50	1.17
F17	1.67	0.50	1.17	1.00	1.83	1.17	1.00	1.67	3.00	2.50	1.67	0.67	2.00	0.33	0.17	1.83	0.00	1.00	2.33	1.00
F18	2.50	0.83	2.50	2.67	2.83	1.50	2.83	2.67	2.33	1.83	1.33	1.33	1.67	2.00	1.33	2.17	2.17	0.00	2.83	1.00
F19	2.67	1.50	3.67	3.50	2.50	2.33	3.00	2.33	3.33	1.00	1.67	1.00	0.17	1.67	1.00	1.00	1.17	2.50	0.00	2.00
F20	0.83	1.17	0.50	0.67	1.50	0.17	1.67	1.17	2.33	2.00	1.50	0.50	0.33	1.17	0.83	0.67	1.17	1.67	2.17	0.00

Note: F_1 (Adjustable driving equipment), F_2 (Aerodynamic design), F_3 (ABS), F_4 (Air-bags), F_5 (Brand value), F_6 (After-sale services), F_7 (Car's build quality), F_8 (Comfortable seat design), F_9 (Car cost), F_{10} (Design/looks of the car), F_{11} (Design of front grill & bonnet), F_{12} (Design of headlights), F_{13} (Eco-mode feature), F_{14} (Engine performance), F_{15} (Ground clearance), F_{16} (Car inside space), F_{17} (New accessories/feature), F_{18} (Reliability), F_{19} (Safety of the car), F_{20} (Weight of the car).

The table shows different visual factors (F_1 to F_{20}) are ranked according to their connections or interdependencies. The relationships between these variables are examined, and their respective causal relationships are established using the DEMATEL (Decision Making Trial and Evaluation Laboratory) method.

The provided table's numerical values allow us to interpret it as follows:

From F_1 to F_{20}, each row and column represents a visual factor. The numerical values in the table's cells show how strongly or how much a particular factor affects the other factors. As an illustration, a value of "0.33" indicates that Factor A has a moderately positive effect on Factor B, and a value of "3.00" shows that Factor A has a significant positive impact on Factor B. A value of "0.00" typically indicates that there is no relationship or influence between the two variables.

After calculating the direct relation average matrix, the normalized direct relation matrix was developed for the twenty sub-factors by using Equation (5.3.2), as provided in Table 5.3.6.

First, we calculated scalar value P using Equation (5.3.2):

$$P = \left\{ \frac{1}{i \ \sum_{i=1}^{n} \quad a_{i,j}}, \frac{1}{j \ \sum_{j=1}^{n} \quad a_{i,j}} \right\} = \left\{ \frac{1}{48}, \frac{1}{43} \right\} = 0.0208333$$

Next, $P = 0.0208333$ was multiplied with each element of the average relations matrix (A) in Table 5.3.5 to obtain the normalized relation matrix (N) of Table 5.3.6.

Table 5.3.6. Normalized Direct-Relation matrix for sub-factors

*	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}
F1	0.00	0.01	0.03	0.00	0.07	0.01	0.02	0.07	0.06	0.06	0.00	0.00	0.01	0.00	0.00	0.04	0.03	0.04	0.06	0.02
F2	0.00	0.00	0.00	0.00	0.02	0.00	0.05	0.04	0.03	0.06	0.06	0.04	0.01	0.03	0.04	0.01	0.01	0.01	0.03	0.02
F3	0.04	0.01	0.00	0.00	0.07	0.01	0.02	0.02	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.04	0.08	0.01

F_4	0.01	0.01	0.00	0.00	0.06	0.03	0.02	0.04	0.06	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.05	0.08	0.01
F_5	0.05	0.04	0.06	0.06	0.00	0.04	0.06	0.05	0.06	0.05	0.04	0.05	0.04	0.03	0.02	0.03	0.05	0.06	0.06	0.03
F_6	0.02	0.00	0.01	0.02	0.05	0.00	0.01	0.03	0.06	0.01	0.01	0.00	0.02	0.04	0.00	0.00	0.00	0.04	0.05	0.01
F_7	0.02	0.02	0.01	0.01	0.06	0.01	0.00	0.06	0.06	0.05	0.03	0.03	0.03	0.01	0.01	0.02	0.02	0.06	0.07	0.05
F_8	0.06	0.02	0.02	0.04	0.06	0.04	0.06	0.00	0.06	0.02	0.01	0.01	0.04	0.03	0.02	0.03	0.02	0.05	0.05	0.03
F_9	0.05	0.03	0.05	0.05	0.05	0.04	0.06	0.06	0.00	0.06	0.05	0.06	0.05	0.04	0.01	0.03	0.05	0.06	0.07	0.03
F_{10}	0.03	0.05	0.01	0.00	0.05	0.01	0.05	0.03	0.07	0.00	0.07	0.07	0.00	0.00	0.05	0.04	0.04	0.03	0.03	0.04
F_{11}	0.00	0.06	0.00	0.00	0.03	0.00	0.02	0.00	0.05	0.08	0.00	0.02	0.00	0.01	0.01	0.00	0.01	0.04	0.02	0.02
F_{12}	0.00	0.04	0.00	0.01	0.03	0.00	0.02	0.00	0.05	0.06	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.02	0.01
F_{13}	0.00	0.02	0.01	0.01	0.04	0.01	0.08	0.03	0.05	0.01	0.00	0.00	0.00	0.07	0.00	0.00	0.03	0.03	0.02	0.01
F_{14}	0.00	0.03	0.00	0.01	0.05	0.05	0.03	0.03	0.05	0.01	0.02	0.00	0.06	0.00	0.00	0.00	0.01	0.05	0.05	0.03
F_{15}	0.00	0.05	0.00	0.00	0.02	0.01	0.02	0.02	0.01	0.04	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.04	0.05	0.03
F_{16}	0.04	0.02	0.01	0.00	0.02	0.01	0.02	0.05	0.05	0.05	0.01	0.00	0.00	0.00	0.01	0.00	0.04	0.02	0.03	0.02
F_{17}	0.03	0.01	0.02	0.02	0.04	0.02	0.02	0.03	0.06	0.05	0.03	0.01	0.04	0.01	0.00	0.04	0.00	0.02	0.05	0.02
F_{18}	0.05	0.02	0.05	0.06	0.06	0.03	0.06	0.06	0.05	0.04	0.03	0.03	0.03	0.04	0.03	0.05	0.05	0.00	0.06	0.02
F_{19}	0.06	0.03	0.08	0.07	0.05	0.05	0.06	0.05	0.07	0.02	0.03	0.02	0.00	0.03	0.02	0.02	0.02	0.05	0.00	0.04
F_{20}	0.02	0.02	0.01	0.01	0.03	0.00	0.03	0.02	0.05	0.04	0.03	0.01	0.01	0.02	0.02	0.01	0.02	0.03	0.05	0.00

As can be seen, the sum of each column of the normalized relation matrix was greater than zero and less than one. This proves the feasibility of the DEMATEL technique for this study. After calculating the normalized matrix (N), we computed the total relationship matrix in Table 5.3.7 by using Equation (5.3.3).

Table 5.3.7. Total relationship matrix

*	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}
F_1	0.05	0.04	0.07	0.04	0.13	0.05	0.08	0.12	0.13	0.11	0.04	0.03	0.04	0.03	0.02	0.07	0.07	0.10	0.13	0.06
F_2	0.03	0.03	0.02	0.03	0.07	0.03	0.09	0.08	0.09	0.11	0.09	0.07	0.03	0.05	0.06	0.03	0.04	0.06	0.09	0.05
F_3	0.08	0.04	0.04	0.04	0.12	0.04	0.07	0.07	0.12	0.07	0.03	0.03	0.03	0.03	0.02	0.04	0.06	0.09	0.13	0.05
F_4	0.05	0.03	0.03	0.04	0.11	0.07	0.07	0.09	0.12	0.04	0.03	0.03	0.03	0.04	0.02	0.02	0.05	0.09	0.13	0.04
F_5	0.11	0.09	0.11	0.10	0.09	0.09	0.14	0.13	0.16	0.13	0.09	0.09	0.08	0.07	0.05	0.07	0.10	0.13	0.16	0.08
F_6	0.05	0.03	0.04	0.05	0.10	0.03	0.06	0.07	0.11	0.04	0.03	0.02	0.04	0.07	0.02	0.03	0.03	0.08	0.10	0.04
F_7	0.06	0.06	0.05	0.06	0.12	0.05	0.07	0.11	0.14	0.11	0.08	0.07	0.06	0.05	0.04	0.05	0.06	0.12	0.14	0.08

F8	0.11	0.06	0.06	0.08	0.13	0.08	0.12	0.07	0.14	0.08	0.05	0.04	0.07	0.06	0.04	0.06	0.07	0.11	0.13	0.08
F9	0.10	0.09	0.10	0.10	0.14	0.09	0.14	0.14	0.11	0.13	0.11	0.10	0.09	0.08	0.05	0.07	0.10	0.14	0.17	0.08
F10	0.07	0.09	0.04	0.04	0.11	0.05	0.11	0.09	0.14	0.07	0.12	0.11	0.03	0.03	0.07	0.07	0.08	0.09	0.11	0.08
F11	0.03	0.08	0.02	0.02	0.08	0.02	0.06	0.04	0.10	0.11	0.03	0.05	0.02	0.03	0.03	0.02	0.03	0.07	0.07	0.05
F12	0.02	0.06	0.02	0.03	0.06	0.02	0.06	0.03	0.09	0.09	0.05	0.02	0.02	0.02	0.03	0.02	0.02	0.05	0.06	0.03
F13	0.03	0.05	0.03	0.04	0.09	0.04	0.13	0.07	0.10	0.05	0.03	0.03	0.03	0.09	0.02	0.02	0.06	0.08	0.08	0.04
F14	0.03	0.06	0.03	0.04	0.10	0.08	0.08	0.07	0.11	0.05	0.05	0.03	0.08	0.03	0.02	0.02	0.04	0.09	0.10	0.06
F15	0.03	0.07	0.02	0.03	0.06	0.03	0.06	0.05	0.06	0.07	0.04	0.03	0.02	0.02	0.02	0.03	0.03	0.07	0.09	0.06
F16	0.07	0.05	0.04	0.03	0.06	0.03	0.07	0.08	0.10	0.09	0.04	0.03	0.02	0.02	0.03	0.02	0.07	0.06	0.08	0.05
F17	0.07	0.05	0.06	0.05	0.10	0.06	0.08	0.09	0.13	0.10	0.07	0.04	0.07	0.04	0.02	0.07	0.04	0.08	0.11	0.06
F18	0.11	0.07	0.10	0.10	0.14	0.08	0.13	0.13	0.15	0.11	0.08	0.07	0.07	0.08	0.05	0.08	0.09	0.08	0.15	0.07
F19	0.11	0.08	0.12	0.12	0.14	0.09	0.13	0.12	0.16	0.09	0.08	0.06	0.04	0.07	0.05	0.06	0.07	0.13	0.10	0.09
F20	0.05	0.05	0.04	0.04	0.08	0.03	0.08	0.07	0.11	0.09	0.06	0.04	0.03	0.05	0.04	0.04	0.05	0.08	0.10	0.03

The table shows a total relation matrix derived from numerical pairwise comparisons of 20 visual factors (F1 to F20). Each element in the matrix represents the strength of the relationship between any two factors. The table makes it easier to comprehend how the visual elements are connected regarding their influence or impact. How to interpret the total relation matrix is as follows:

Each row and column in the matrix represents a different visual factor (ranging from F1 to F20). The numerical values in the matrix's cells indicate the degree to which the corresponding factors are related.

Numbers: The numbers in the cells represent the strength or degree of the relationship between the two factors. Higher values denote a more substantial influence, while lower values denote a weaker effect.

Value Scope: The matrix typically has values between 0 and 1. A value of 0 indicates no relationship or influence between the two factors, whereas a value of 1 indicates a significant impact or direct connection.

Focus on the connections between the visual factors when interpreting the matrix. For instance, if the correlation coefficient between F1 and F2 is 0.04, F1 likely has little effect on F2 and vice versa. The value of 0.12, on the other hand, denotes a stronger relationship between the two factors.

The overall relationship matrix is typically symmetric, meaning the relationships are reciprocal. F2 to F1 would have the same value, or 0.04 if F1 to F2 were 0.04 as well.

Complete analysis: The visual factors' patterns of influence and connectivity can be discovered by looking at the entire matrix. Prioritizing them in decision-making or design processes can be aided by identifying the factors with a strong influence.

Meanwhile, from the matrix $T_{n \times n}$, we could see how each sub-factor affects other sub-factors. In Equation (5.3.3), 'I' denotes an identity matrix. In the next step, with the help of Equations (5.3.4) and 5.3.5), we computed the sum of rows $[r_i]_{n \times 1}$ as well as the sum of columns $[c_i]_{n \times 1}$ of the total inter-relation matrix $T_{n \times n}$ to find the 'prominence' and ‘relation’ value of each sub-factor. The sum of every row and column is given in Table 7.8. In the meantime, during the calculation of the sum of rows ($[r_i]_{n\times1}$) and columns ($[c_i]_{n\times1}$), we also computed the values of $(r_i - c_j)$ and $(r_i - c_j)$ as shown in Table 5.3.8.

Table 5.3.8. Direct and indirect influence

Sub-factors	R	c	$r-c$	$r+c$
F_1	1.430	1.267	0.163	2.697
F_2	1.141	1.183	-0.042	2.325
F_3	1.194	1.065	0.128	2.259
F_4	1.132	1.071	0.061	2.202
F_5	2.076	2.060	0.016	4.136
F_6	1.044	1.046	-0.003	2.090
F_7	1.565	1.820	-0.255	3.385
F_8	1.642	1.724	-0.082	3.366
F_9	2.136	2.367	-0.232	4.503
F_{10}	1.608	1.728	-0.120	3.336
F_{11}	0.966	1.220	-0.254	2.186
F_{12}	0.799	0.974	-0.175	1.774
F_{13}	1.112	0.887	0.225	1.999
F_{14}	1.189	0.958	0.231	2.147
F_{15}	0.864	0.678	0.187	1.542
F_{16}	1.049	0.906	0.143	1.956
F_{17}	1.378	1.180	0.198	2.557
F_{18}	1.930	1.805	0.125	3.735
F_{19}	1.916	2.222	-0.306	4.139
F_{20}	1.164	1.174	-0.009	2.338

Note: adjustable driving equipment, aerodynamic design, airbags, ABS, weight of the car are sub-factors.

In Table 5.3.8, ‘r’ and ‘c’ represent the sum of rows and columns, respectively, while ‘$(r_i + c_j)$’ shows the degree of significance the factor i has in the system. Also, $r_i - c_j$ shows the gross effect that factor i has on the system. With the help of mapping the values of $r + c$ as well as $r - c$, a cause-and-effect diagram was constructed, which is shown below in Figure 5.3.2. The horizontal line shows the value of $r + c$ and the line in the vertical direction shows $r - c$.

Sub-factors (F_1 to F_{20}): Each row corresponds to a particular sub-factor associated with the characteristics or features of a car, such as the weight of the vehicle, airbags, ABS, and adjustable driving equipment.

R: The value of R, which stands for each sub-factors direct influence, is displayed in this column. It expresses the degree of a specific sub-factors direct impact on other sub-factors.

C: The value of C, which denotes the indirect impact of each sub-factor, is represented in the column with the label "C." It demonstrates the magnitude of an indirect influence on other sub-factors caused by intermediary factors on a given sub-factor.

R-C: This column displays the difference between each sub-factors direct (R) and indirect (C) influences. If this column's value is positive, the direct influence is stronger than the indirect influence; if it's negative, the indirect influence is more substantial.

R+C: The direct influence (R) and indirect influence (C) of each sub-factor are combined in the R+C column. It shows the overall impact of a specific sub-factor, considering its direct and indirect effects.

Overall, the table offers a quantitative understanding of the connections between the sub-factors and how they, directly and indirectly, affect one another. Researchers or decision-makers can learn which sub-factors influence the overall system or choice under consideration by examining the values of R, C, R-C, and R+C. This type of analysis can be helpful in various fields, such as product development, car design, or decision-making procedures where it is necessary to assess complex interactions between multiple factors to make decisions or improvements.

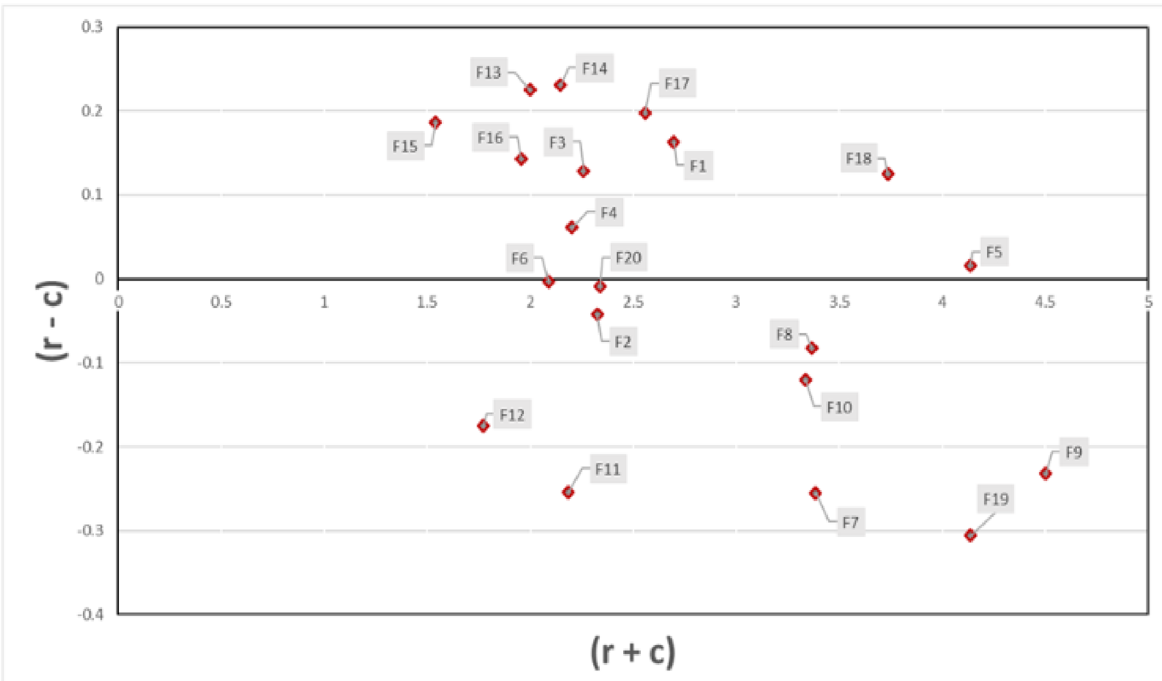


Figure 5.3.2. Digraph showing causal relations among the twenty criteria (sub-factors)

After finding the $r + c$ and $r - c$ values, it was necessary to filter out some insignificant/negligible effects. For this, decision-makers have to set up a threshold value by using the r and c values. The interaction matrix was constructed based on a calculated threshold value to give the mutual degree of interaction among the considered sub-factors, as shown in Table 5.3.9. The threshold value (i.e., $a = 0.0683$) was obtained by calculating the average of the elements of the Total relation matrix T. By using this value, we chose only values that were greater than the threshold value. When $(i = j)$, the sum of $r_i - c_j$ is known as 'prominence', which indicates the total effects both received and given by factor i. Similarly, the digraph can be attained by using the dataset of $r + c$ and $r - c$.

Table 5.3.9. Interaction matrix of enablers ($a = 0.068$)

*	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}
F_1			*		*		*	*	*	*						*	*	*	*	
F_2					*		*	*	*	*	*	*							*	
F_3	*				*		*	*	*									*	*	
F_4					*		*	*	*									*	*	
F_5	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*
F_6					*			*	*									*	*	

F_7					*			*	*	*	*							*	*	*
F_8	*			*	*	*	*		*	*			*					*	*	*
F_9	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*	*
F_{10}	*	*			*		*	*	*		*	*			*	*	*	*	*	*
F_{11}		*			*				*	*								*		
F_{12}									*	*										
F_{13}					*		*	*	*					*				*	*	
F_{14}					*	*	*	*	*				*					*	*	
F_{15}		*								*								*	*	
F_{16}	*							*	*	*									*	
F_{17}	*				*		*	*	*	*	*							*	*	
F_{18}	*		*	*	*	*	*	*	*	*	*		*	*		*	*	*	*	*
F_{19}	*	*	*	*	*	*	*	*	*	*	*			*			*	*	*	*
F_{20}					*		*	*	*	*								*	*	*

The analysis of the sub-factors with the DEMATEL technique provided the prominence (i.e., importance) of each sub-factor affecting the cognitive appeal of a car design for consumers. The sub-factors in descending order of prominence were: F9 > F19 > F5 > F18 > F7 > F8 > F10 > F1 > F17 > F20 > F2 > F3 > F4 > F11 > F14 > F6 > F13 > F16 > F12 > F15. Further, these sub-factors were divided into a cause group and an effect group based on their positive and negative values of (r – c), respectively, where the sub-factors of the cause group influence the sub-factors of the effect group. Thus, the sub-factors in the cause group are the key factors because of their direct influence on the whole model. Therefore, it was essential to focus on these cause group sub-factors to achieve the best results.

Out of the 20 sub-factors, there were 12 cause factors and 8 effect factors, as can be seen in Figure 5.3.2. The sub-factor Car cost (F9) had the highest prominence among all sub-factors, as shown in the digraph (Figure 5.3.2). In the cause group, the sub-factors Engine performance (F14) and Eco-mode feature (F13) had very high $r - c$ scores, which indicates that the sub-factors Engine performance (F14) and Eco-mode feature (F13) had a significant influence on the other sub-factors. It is interesting to note that two sub-factors, viz. Brand value (F5) and Reliability (F18) were not only cause factors but also had a high prominence among all sub-factors, which indicates that these two sub-factors must be given high importance by designers when conceptualizing a car design. Another key observation is that the sub-factor After-sale services (F6) lies on the neutral line of the digraph (see Figure 5.3.2), which signifies that it is neither a cause factor nor an effect factor and therefore After-sale services (F6) is an independent factor. This can be attributed to the fact that after-sale services are part of company policy, which is solely dependent on the top management of the company. The top 10 key relationships between the cause-and-effect factors are presented in Figure 5.3.3. Each relationship is presented along with its relational strength, which is derived from the Total relationship matrix provided in Table 5.3.7.

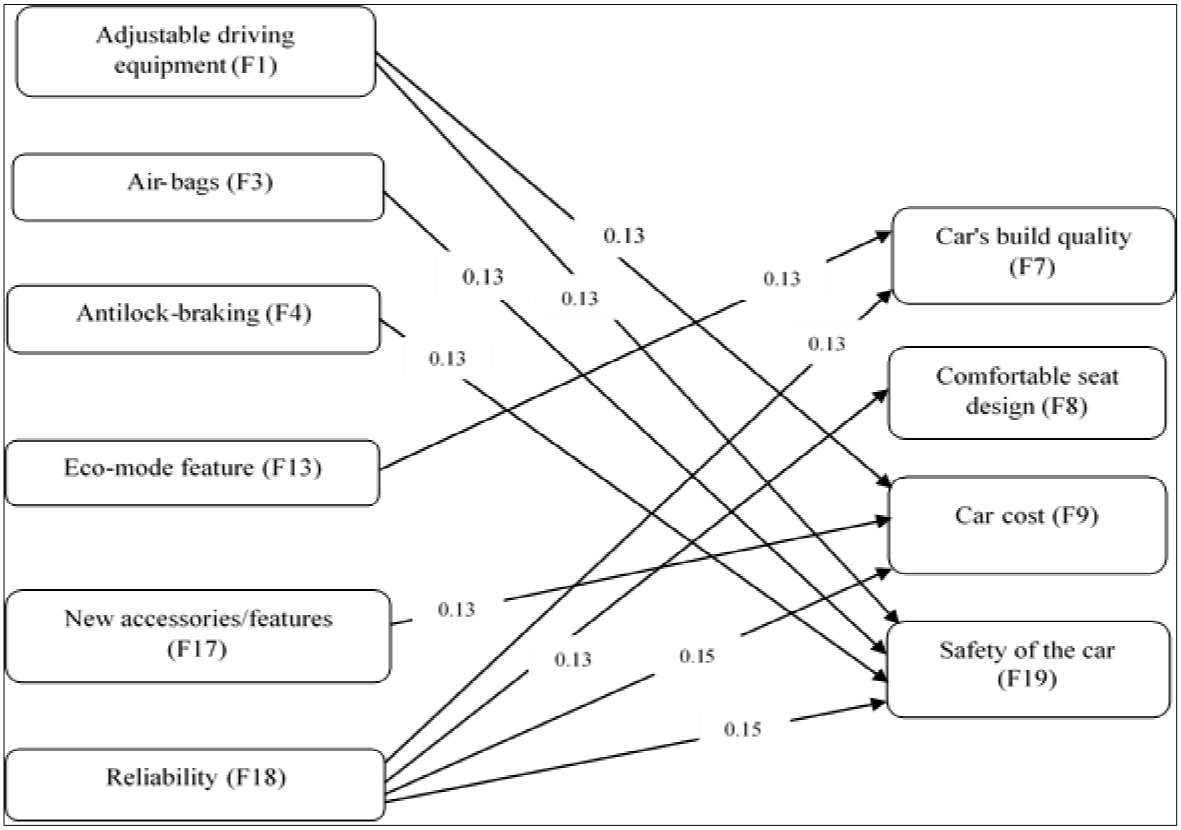


Figure 5.3.3. Cause-and-effect relationships

As we have seen in Figure 5.3.3, the sub-factor ‘reliability’ showed a strong relationship with the sub-factors ‘safety of the car’ and ‘cost of the car’, each having a relational strength of 0.15. Other key relationships were obtained between the sub-factors ‘reliability’ and ‘cars build quality’ (0.13), as well as between ‘reliability’ and ‘comfortable seat design’ (0.13)’. The result of the above analysis provides valuable insight to designers and higher management people. From Figure 5.3.3, it can be understood that key concerns of consumers, such as ‘Car cost’ and ‘Safety of the car’, can be managed by the designers by focusing on cause factors such as ‘Adjustable driving equipment’, ‘Airbags’ and ‘Antilock-braking’. If these features are considered properly in the design of a car, then such a car will have cognitive appeal for consumers and influence their purchasing behavior.

5.3.7. Summary for chapter 5.3

In Chapter 5.3, the main focus is to help the car manufacturing companies understand the psychology of consumers during the car buying process. Cars are an integral part of many people’s lives, whose number is expected to keep increasing in the future. Also, the psychology and purchasing behavior of consumers of cars has been changing over the years. Thus, it is important for car manufacturing companies to understand the psychology of consumers when they buy a car. In this research, various non-visual factors of cars that affect the cognitive behavior of consumers were studied. The non-visual factors were identified through a literature search as well as through a survey of consumers who owned a car or were planning to buy one. Then, the identified factors were analyzed by using the DEMATEL technique to obtain the key factors that affect the cognitive behavior of consumers.

The outcomes of this research indicate that ‘Car cost’ is the main factor that affects the psychology of car buyers. Consumers perceive that a car with higher cost will grab the attention of people very easily. ‘Car cost’ is also a key factor in deciding the purchasing capability of consumers. The ‘brand value’ of a car is another crucial factor that affects the cognitive appeal of consumers. This happens because once a consumer receives information regarding the product through his senses, it remains in their memory, which further drives the purchasing decision. The ‘reliability’ of the car is another key factor that must be emphasized by car companies to grab the attention of consumers. A car that is perceived as reliable becomes an unbiased choice of consumers in the long term. Some of the factors, such as ‘Engine performance’ and ‘Eco-mode feature’, are also important because of their ability to influence most of the other non-visual factors of a car. A car with good engine performance will not only bring a feeling of reliability but also justifies the cost of the car. Thus, the factors mentioned above must be emphasized by the designers while conceptualizing a car. This will help car companies grab the attention of consumers, which will ultimately lead to better sales and increased market share. The research conducted in this study can be further extended by involving more consumers for a more comprehensive understanding of the non-visual factors of cars that affect the cognitive behavior of consumers. Also, the cognitive behavior of consumers can be better understood by utilizing cognition-based experiments such as eye tracking experiments.

5.3.8. Overall summary of Chapter 5

This research presents an approach for identifying the various potential factors and sub-factors of an engineered product (car). Further, we quantify and analyze these factors' and their effect on the consumer's and designers' cognitive thinking while purchasing a new product and designing a new product. Further, we also analyse the relationship among the top factors and their sub-factors. During this study, we used different multi criteria decision making (MCDM) techniques to identify and analyze these factors such as Fuzzy-AHP and DEMATEL Technique. In this study an open-ended survey, Pareto principle and rank values method is also used to quantifying these factors. Outcomes of this study can be utilized by designers and top management people to understand the most influential factors affecting the cognitive behavior of consumers when purchasing a car. This understanding will help companies to design cars as per the requirements of consumers, which will ultimately lead to better profitability of these companies. Additionally, cognition-based experiments such as eye tracking could provide deeper insights into consumer cognitive behavior.

CHAPTER 6.1.

Understand and Quantify the Consumers' Cognitive Behavior for the Appropriateness Features of Product Aesthetics through the Eye-Tracking Technique

In Chapter 6, we thoroughly did an understanding and factual analysis of the key contributing factors which impact the product aesthetics and affect the perception of consumers and designers. This study is conducted into section: Chapter 6.1 and Chapter 6.2. In Chapter 6.1, we focus to quantify and understand and the feature of product aesthetics associated to the (appropriateness) perception of function.

6.1.1. Introduction

In general, customers have limited interaction with product designers, who incorporate various attributes like functionality, taste, use, and social importance to communicate with users through the product (Berkowitz, 1987; Demirbilek & Sener, 2003). Considering the physical appearance of a product as a communication medium during the design process becomes essential in product design, and viewing products as symbols draws attention to their ability to represent ideas (Crilly et al., 2004; Chandrasegaran et al., 2013). Therefore, research becomes crucial to understanding users' emotional desires during product design by incorporating consumer behavior and human-product interaction (Moulson & Sproles, 2000; Peighambari et al., 2016; Fenko & van Rompay, 2018). For that reason, there is a need to understand human-product interaction and emotional design through various theories and models to help identify subjective impressions of a product (P. M. A. Desmet et al., 2007). Hence, with technological advancements, product design is moving towards a user-centered approach to satisfy emotional and cognitive needs rather than just functional and physical ones (Lai et al., 2006). The relationship between product innovation, social cognition, and human psychology needs to be studied to understand consumer requirements and tastes (Veryzer & Borja de Mozota, 2005; Krishna & Morrin, 2008). Integrating consumer research with product aesthetics design requires a connection between multiple fields, such as psychology, engineering, aesthetics, marketing, and cognition, to decipher emotional responses and cognitive perceptions (Simmonds & Spence, 2017; Singh & Sarkar, 2018). Product designers often rely on intuition rather than a systematic approach to the visual qualities of products (Yun et al., 2003; You et al., 2006). Product aesthetics, influenced by human cognitive feelings, functionality, and other factors, have roots in philosophical thought and theory of beauty dating back to the 18th century (Wessell, 1972; Agost & Vergara, 2014; Singh & Sarkar, 2019). Aesthetic values are associated with consumer emotional behaviors (Beardsley, 1981). Aesthetics play a vital role in product design and consumer consumption (Hirschman & Holbrook, 1982; Kieran, 1997; Veryzer, Jr. & Hutchinson, 1998; Page & Herr, 2002; Charters, 2006). Understanding and identifying primary factors related to product aesthetics are crucial (Hsiao & Chen, 1997; Pham, 1999; Chuang et al., 2001; Cawthon, 2007; Zain et al., 2008; Yadav et al., 2013).

In this study, the term "aesthetic" relates to the physical appearance of a product, while "customer" refers to the user and their purchase decision-making (Smets & Overbeeke, 1995; MacDonald, 2001; Singh & Sarkar, 2018, 2019). Design elements like functionality, emotional appeal, outward appearance, and quality significantly influence customers' beliefs and emotional responses toward a product, which can vary based on cultural, background, age, and gender differences (Crilly et al., 2004). Functionality in product design is linked to "appropriateness," which represents suitable and pleasing design elements recognized by most individuals (H.-C. Chang et al., 2006, 2007). Appropriateness is a key quality of attractiveness in a product (Baxter, 1995; Christiaans, 2002). In the captivating world of product design, where form and function intertwine harmoniously, there exists a concept that seamlessly melds the two - the concept of "appropriateness." Appropriateness in product design is the art of harmonizing design elements, aesthetics, and features with the intricate tapestry of the expectations and preferences of the target audience (Khalid & Helander, 2006). It transcends the mere practicality of a product, ensuring that it is not only functional but also resonates as suitable and pleasing to the broad spectrum of individuals who will interact with it. Within the context of appropriateness, the user takes center stage as the central figure. It places the user's needs, cultural context, and personal inclinations at the heart of design decisions. It's an empathetic approach that seeks to create a product that feels right to the user, mirroring their sensibilities. The significance of appropriateness extends beyond functionality; it shapes the user's entire journey with a product. Moreover, appropriateness is not just about meeting the expectations of the user; it's about evoking positive emotions (Khalid & Helander, 2006; H.-C. Chang et al., 2007). This concept aims to create an emotional connection between the user and the product, a bond that goes beyond mere practicality. Users should not only find the product useful but should also feel that it aligns with their values, aspirations, and cultural context. This emotional resonance can lead to increased user satisfaction, brand loyalty, and enthusiastic word-of-mouth recommendations. Universality is a key feature of appropriateness. While it may not cater to the idiosyncrasies of each individual's preferences, it steers clear of extreme or niche design choices that might exclude a smaller subset of users. By upholding a broader, more inclusive appeal, it expands the product's outreach to a more extensive and diverse audience. Appropriateness is attuned to the subtleties of cultural sensitivity. It acknowledges that what is deemed fitting in one culture may not be so in another. A design that is culturally sensitive ensures that the product avoids unintentionally alienating or causing offense to users from diverse backgrounds, thus promoting inclusivity. Now, why is the study of appropriateness or perception of function important? It's because appropriateness is the bridge that transforms a product from being merely utilitarian to emotionally and aesthetically pleasing. By aligning design with user expectations and cultural contexts, it becomes a key driver of attractiveness in product design. This concept can be a defining factor in a product's success in the market. It's the secret sauce that shapes not just how a product performs, but also how it's perceived and embraced by its users. In a world where users seek products that resonate with their values and emotions, the study of perception of function becomes crucial. It's an acknowledgment that a product is not just a tool but an integral part of a user's journey and identity. Perception of function is the magic that turns a well-designed product into a beloved one, and in doing so, it enriches both the user's life and the product's place in the market.

The study aims to address two questions:

RQ1: What product features affect the attractiveness of aesthetic product design?

RQ2: How can we understand and quantify the appropriateness of product design?

The rest of the manuscript is organized as follows: a brief review of related work is presented in the next section, followed by the aim and methodology in the third section. The fourth section provides results and discussion, and the last section contains the conclusion and limitations of the study.

Based on the above questions, the current study is organized in a systematic manner. It starts with an introduction that briefly overviews the fundamental traits and attributes of aesthetics and design elements. The following part (8.2) focuses on the study's purpose and methodology, establishing the research objectives and detailing the data collection and analysis method employed. The details of the data-gathering process are addressed in section 8.3, highlighting the methods and procedures used to gather essential information. Finally, section 8.4 presents the findings and engages in a whole discussion that interprets the findings and provides insights and implications based on the research findings.

The physical shape and structure of a product play a central role in its functional specifications. While users have a solid grasp of a product's functional aspects, modern trends highlight the importance of additional factors, including product aesthetics and addressing the physical and psychological requirements of consumers (Coates, 2003). Beyond functionality, there are other elements that contribute to a product's success, notably product aesthetics and economic considerations. In our study, our primary focus centered on product aesthetics, specifically examining a key factor: attractiveness, and how it influences the success rate of both the product and its aesthetics. A product's attractiveness possesses the remarkable ability to elicit emotional reactions, whether they lean towards the positive or negative spectrum. This phenomenon occurs because it resonates deeply within the consumer's mind (G_Monö, 1997). According to Khalid (2006) and Verma (2001), the allure of a product stands out as the primary determinant of its success. The need to delve into the significance and intricate relationship between product attractiveness, aesthetics, and human cognitive perception becomes evident.

In the world of product design, it's crucial to recognize that the notion of attractiveness is a dynamic and ever-changing one. It can shift depending on the product's form and can evolve over time, a concept well-explored by authors (Bloch, 1995; Coates, 2003; Crilly et al., 2004). As pointed out by Chang (2006; 2007), the appropriateness of product aesthetics, closely tied to how we perceive a product's function, stands as a cornerstone of its overall appeal. This appropriateness is closely interwoven with the factors that contribute to a product's attractiveness. Now, measuring attractiveness in an objective manner poses a formidable challenge. Designers navigate this challenge by relying on a palette of design elements that offer insights into gauging it effectively. These design elements are essential in the endeavor to craft products that strike a harmonious balance between attractiveness and functionality, a concept aptly referred to as appropriateness (Coates, 2003; Pham, 1999). In essence, appropriateness signals the kind of design elements that are universally recognized as suitable and pleasing for a particular product by a majority of individuals (Baxter, 1995). Furthermore, it's vital to consider the ever-evolving nature of consumer preferences. Over time, consumers may lose interest in a product, and this is precisely where appropriateness becomes a critical quality within the broader realm of attractiveness (Christiaans, 2002). The way things look, how well they fit their purpose, and how people's preferences change over time all come together to create an exciting world of product design and how people connect with what they use.

Appropriateness (perception of function): Previous studies generally specify appropriate-ness (perception of function) as a feature or characteristic of the object's attractiveness, which is usually associated with consumer interpretation (1999; 1994). Consumer preferences for the physical appearance of a product can vary significantly based on personal opinions, resulting in diverse tastes within the public. For widely popular products, certain design elements tend to be preferred by companies for specific functions, leading consumers to highly appreciate these products for their appropriateness in terms of aesthetics. As Baxter (1995) and Hekkert (2006) have noted, appropriateness specifies the design elements that people favor for particular tasks, whether they are emotional, utilitarian, social, or cognitive. This concept gives rise to a well-established set of design expectations for various categories of products (Veryzer, Jr. & Hutchinson, 1998; Hekkert et al., 2003; Hung & Chen, 2009). For example, an individual might perceive the tall and rugged design of cars with ample ground clearance, often found in off-road vehicles or SUVs, as suitable for their intended purpose. This perception is shaped by typical design elements such as large grilles, big headlights, and sharp angles. Such typicality is considered appropriate and is a result of the constraints associated with achieving the product's goal (Barsalou & Sewell, 1985). However, prior research has not explored the alignment between the insights that product designers intend to convey and the actual perceptions of customers regarding product aesthetics. A lingering question in the domain of product aesthetics is identifying the specific shapes or silhouettes of products that consistently evoke emotions in customers, as envisioned by product designers. Therefore, there's a pressing need to comprehensively evaluate the perceived quality of a product's aesthetics by considering both consumer and product design perspectives. Consumers form judgments about products by utilizing their senses, which lead to cognitive responses. These judgments are integral to the assessment of an object's aesthetic qualities (Lynch, Jr. et al., 1991; Crilly et al., 2004). Hence, a quantitative and cognition-based approach is employed in this type of study to gain a clear understanding of both consumer and designer perceptions. This study aims to delve into the visual and cognitive perceptions of consumers regarding a product's aesthetic quality. Through a perceptual comparison, we seek to understand customer affective, visual, and cognitive responses to a product's aesthetic quality.

Perceptual comparison (PC): During this work, an approach known as perceptual comparison is considered to calculate the perceived abilities of the object. This approach is mainly derived from previous psychological areas. It is primarily considered for defining the strength of the interrelationship among an observable fact or event and the induced response of human beings towards it. There are different ways to conduct a perceptual comparison in order to find the relationship between consumer insight and a product for study. The frequency match ratio study and the correlation examination are used to calculate the utility of an object's visual and emotional collation (Purcell & Gero, 1998; Wagemans et al., 2012). For these collations/matching, an open-ended survey and eye-tracking technique are used to map the customer perception of the product.

Customer domain: The customer domain is a collection of users' cognitive thinking aroused by the product design. It is based on attaining an understanding or awareness of sensual figures/facts in psychology (Creusen, 2015). Further, Psychological and phenomenal (any physical and observable incidence) are two types of responsiveness that are taken care of at the time of perception. These can be demonstrated in two very simple manners. In psychology, human observation can be distinguished into two statements; the first is effective, and the second is visual. It can help in understanding the way customers assess any product.

Customer affective perception: Customer personality is one that affects their decision during any product purchase. Before buying any product, consumers try to know about the object based on the external shape of the product. However, Zhang (2021) explains that customers recognize the products present in a surrounding environment using their senses controlled by their neural system. Desmet and Fokkinga (2020) uses Maslow's theory in their study, and they described that human moves to a higher level of emotional desires with the technology change. In addition, these emotional desires progressively become the critical element that affects customers' purchase behavior.

Customer visual and cognitive insight: It is essential to understand the customer's affective (emotional) desire in the initial stage of product development (Khalid & Helander, 2006; Norman, 2010). While understanding any product/object with the help of visual insight, humans memorize their previous experiences about the product and are preserved in their conscious and unconscious minds in terms of feeling. Thus, their perception of the product quality depends on the outlook of the objects. Therefore, based on the behaviors of intellectual understanding, customers are habitual in identifying and separating products into groups. This group is formerly developed through cognitive representations of human beings' thinking (Crilly et al., 2004). Especially these product categories are determined by the visual perception of human beings (Romeo-Arroyo et al., 2023). For instance, if the consumer is asked for a carbonated drink, a swift thought in most consumers' minds images "Coca-Cola/Pepsi." It confirms the consumer's cognitive philosophy about their perception of the first visual information from an object and their judgment.

Comparison relationships: The comparison is separated into aspects of visual and perceptual/affective comparison, as discussed below.

Visual comparison (VC): Visual comparison/collation is an immensely famous and fascinating field of research in the area of consumer perception. In this study, the discussion is conducted on the visual collation/comparison with the help of correlation examinations among consumer and product design areas related to visual cognition. The strength of correlation demonstrates the competence of the product and determines the extent to which the product exactly shows its features. This allows the present and future consumers to easily identify the products in a physical manner (Danneels & Kleinschmidtb, 2001). As an estimation technique, the visual comparison assesses the correctness of the product and classifies to what extent the user finds a product is similar to their actual or primary class. If customers/buyers interpret the object incorrectly, this means the comparison strength is low, and it can lead to confusion. For instance, we recognized a silhouette of the Lamborghini/Porsche car represents a symbol of power, youthfulness, craziness, uniqueness, richness, and low ground clearance represents its speediness. Similarly, a Bacardi bottle shape/silhouette looks well balanced at the time of pour. It is leaner, taller, and perfectly cylinder-shaped, with v-type shoulders that force you to recall something/somebody. Thus, their shape is more linked with craziness and youthfulness, and because of this, it is more famous among the young generation because of their design and shape. If the shape of the Bacardi bottle is changed to curvy, and if we make some sharp curve at the neck area and present it to the original Bacardi beverage to consumers. At first stance, regular consumers may not accept that shape or even they did not take any shots from that bottle too. Similarly, it may have happened with other categories, and it indicates that the appropriateness feature of product aesthetics acts as an essential part of product design (Baxter, 1995; Hekkert, 2006). Thus, a vital feature of the design element known as the perception of function has come into the picture. Therefore, from a comprehensive and obvious design of the product, consumers take valuable insight and understand their function (Chandrasegaran et al., 2013). This helps build a great brand by reaching each consumer by knowing the name and memories of the product's shape.

Perceptual/Affective comparison (PC or AC): The term affective is related to feelings or emotions; in psychological means, the affective is the emotion where attitude is evoked or drawn out through stimulus. The affective reactions are evoked when the customers are interacting with a stimulus or environment (Schreuder et al., 2016). Customers act to do window shopping prior to any plan where they invest after perceiving positive emotional reactions, such as desires, appetencies, and excitement (Kimiagari & Asadi Malafe, 2021). Affective comparison is the relationship between psychological conditions and events that induce specific functional responses in a human body. However, in this study, the effective collation/comparison describes the relation-ship between the consumer area and the product field in relation to affective cognition. Specifically, in this work, we are taking the help of perceptual matching to define the interaction among the opinions that industrial designers propose to convey with product design in any product and customer insight. In other words, this type of work is used to examine visual product recognition (Graf, 2006; Lamberts & Kent, 2008; Lawson, 2010; Graf, 2012), categorization, relational perception learning (Goldstone, 1998; Blaisdell & Cook, 2005), and perceptual learning (Goldstone, 1998). In this work, perceptual comparison/matching is utilized to define the interface among the opinion that industrial designers propose to convey with the help of product design and relate it to the customer insight aroused by visualizing the product (Adaval et al., 2018). We majorly study the product aesthetics design area (design area/field) and customer cognitive perception (consumer sentiment/feeling/emotion) for the product shape. We try to show this relation in Figure 1 in terms of a flow chart. In this study, we investigate the role of aesthetic features in product design. For that, first, we understand and then quantify them with the help of consumer cognitive perception.

Hekkert (2006) states that before purchasing any new product, consumers always recollect (memorize) their previous purchase experience with that product category (category of product). The purchase is initiated based on product functionality, maintaining social status, and seeking emotional pleasure. In literature, we already discussed product aesthetics, consumer emotional psychology, and visual and effective comparison. We conclude that appropriateness is one of the critical features of aesthetic product design, as the product's appearance impacts the consumer's decision-making during the purchase of a new product. Bloch (1995) states that appearance and aesthetic features are essential for every tangible and intangible product in present society, irrespective of their purpose. Previous research found that appropriateness features play a crucial role in product design in earlier research work (Pham, 1999; W. Chang & Wu, 2007). Also, appropriateness has a strong relationship with the attractiveness of the product aesthetic (Baxter, 1995). Therefore, it is important to understand and quantify this relationship. In order to do that, one needs to capture the cognitive preferences of consumers. For a better understanding of consumers' cognitive preferences, we focused on various aspects of the product, such as black-and-white images of the product silhouette/forms. Also, the perspective of male, as well as female participants, was used to avoid any kind of gender biases (Chiu et al., 2005; Hung & Chen, 2009). The black-and-white image of products generates a different kind of sensory information related to the appropriateness feature of product aesthetics compared to an actual image. Other than their related information, such as type of product category, color, brand name/company, their actual shape, etc., are kept hidden. It instigates the study of consumers' perceptions related to various product shapes. As we can see, Figure 8.1 shows that consumers' visual and affective thinking plays an essential role in analyzing the relationship between appropriateness features and product aesthetics.

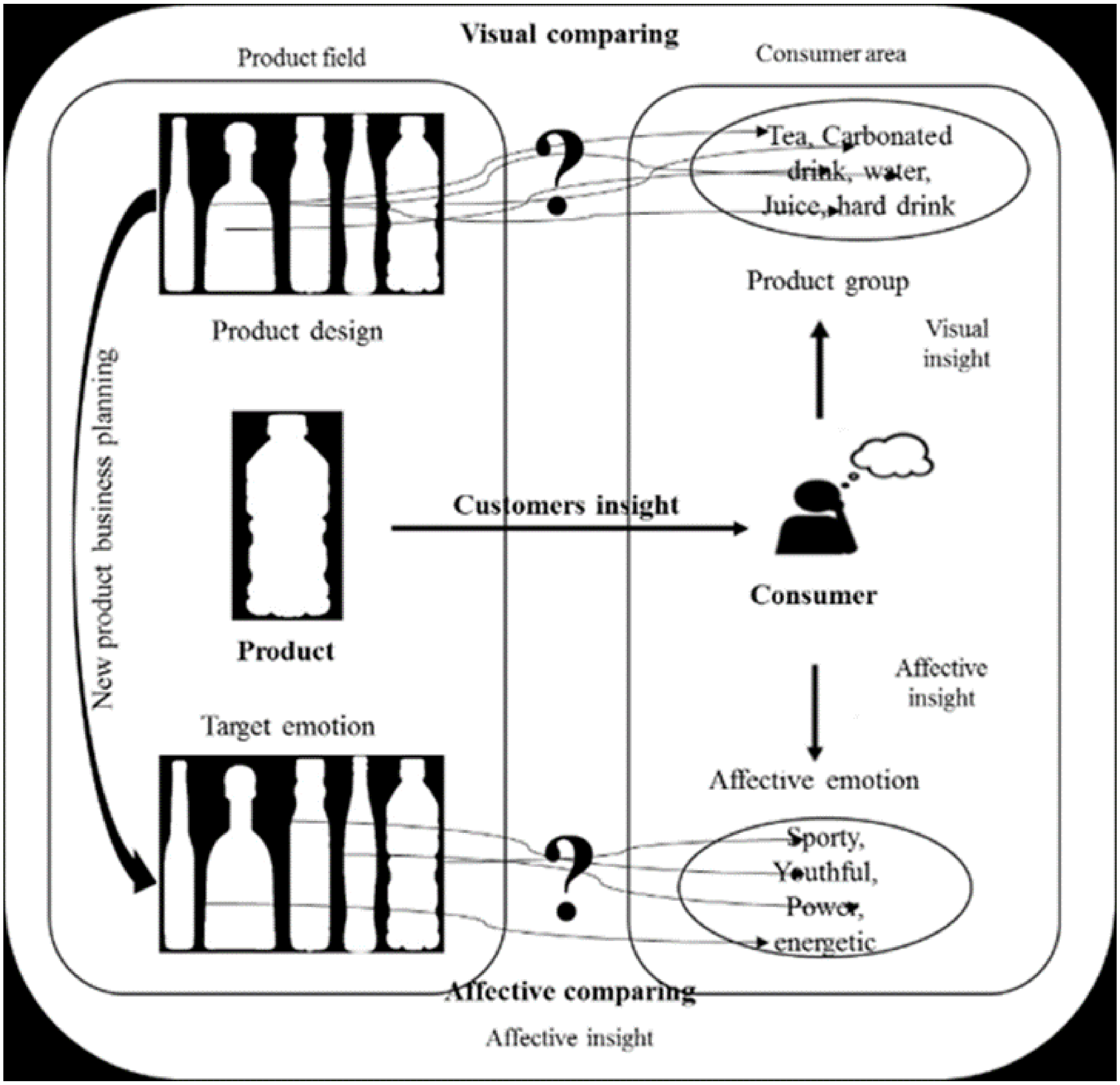


Figure 6.1.1 Comparing relations among the customer area and product field.

In the preceding part, we looked at product aesthetics, consumer emotional psychology, and visual and affective comparison. Based on this debate, a product's suitability is essential in its aesthetic design, as it influences consumers' decision-making when acquiring new products. Bloch (1995) emphasizes the importance of appearance and aesthetic qualities in today's culture for tangible and intangible items, regardless of their purpose. Previous research has also underlined the relevance of appropriateness in product design (Pham, 1999; W. Chang & Wu, 2007). Furthermore, suitability has been proven to be substantially related to the attractiveness of the product's aesthetics (Baxter, 1995). As a result, it is critical to comprehend and measure this link. Our research focuses on numerous product characteristics, such as black-and-white photographs representing its silhouette or form, to acquire insights into consumers' cognitive preferences. To prevent gender biases, we also evaluate the viewpoints of both male and female participants (Chiu et al., 2005; X. Lin et al., 2019). Compared to actual photos, using black-and-white images generates unique sensory information on the suitability element of product aesthetics. To investigate consumers' impressions of diverse product shapes, we purposefully conceal other associated information such as product category, color, brand name/company, and real shape. As depicted in Figure 8.1, it is evident that consumers' visual and affective thinking plays a crucial role in analyzing the relationship between appropriateness features and product aesthetics.

The study aims to investigate how consumers' perceptions of a product's appropriateness in terms of aesthetic design relate to the product's form. The researchers believe that consumers' perceptions of a product's suitability or appropriateness in terms of design are influenced by its visual appearance, which is represented through black-and-white images of its silhouette or form. Therefore, the researchers are interested in learning how consumers' cognitive preferences regarding a product's appropriateness are influenced by its visual attributes.

Hypothesis 1: The form of the products generates sensory information for the appropriateness feature of product aesthetics in the consumer's minds.

Further, investigations into the potential impact of gender biases on consumers' perceptions of the appropriateness of product aesthetics are also necessary. The study's participants, both men and women, were evaluated for their perspectives to ascertain whether there are any notable differences between how men and women view the appropriateness of product designs. If there is no discernible difference, it suggests that both genders have similar perceptions of the appropriateness feature in product aesthetics, strengthening the findings. In the context of beverage bottle design, the reference to "gender bias as a variable" suggests an exploration of how certain design elements, such as the silhouette of the bottle, may evoke gender-related associations or perceptions. The mention of "shape and form of human being nature" hints at the idea that consumers may subconsciously link the bottle's silhouette to gender-specific characteristics or attributes. For instance, the design of a beverage bottle may unintentionally convey cues that are traditionally associated with masculine or feminine qualities. This could include elements like curves, angles, or overall shapes that individuals may unconsciously interpret as having gendered connotations. The reference to consumers using their "connotation skills" implies that people may draw on societal or cultural associations related to gender when evaluating or choosing a beverage based on its bottle design. The introduction of gender bias as a variable suggests a consideration of whether certain design features influence consumer preferences differently based on gender-related perceptions. It's important to approach this topic with sensitivity and awareness of the potential impact that design choices can have on diverse consumer groups, recognizing that individuals may interpret and respond to design elements in unique ways influenced by their personal experiences and cultural backgrounds.

Hypothesis 2: There is no difference in the appropriateness feature of product aesthetics among male and female respondents.

6.1.2. Aim and Methodology

Aim: According to Bloch (1995) study, the shape/form of any product induces a psychological affection or stirs the users' minds. Further, it is a fusion of emotional and cognitive perception that ultimately leads to consumers' behavioral responses to the product's aesthetic. Experts from different industries are looking towards aesthetics as a crucial instrument for competitive differentiation and the success of their products as well as services (Cox & Cox, 2002). In this study, we understand and quantify the appropriateness "(perception of function)" feature of product aesthetics and how product aesthetics will impact the consumer's visual insights and cognitive perception (Ward, 2006). This instigates the study of the perception of consumers related to various product shapes. While entreating with the cognitive appeal of prospective consumers for the appropriateness feature of product aesthetics survey is insufficient. Thus, it is good to consider some other tool/method/equipment besides survey or interview to study the in-depth consumer cognitive appeal regarding the product.

Methodology: Figure 6.1.2 shows the flowchart that demonstrates the approach used in this study. The various steps used in this approach are described below. This study started in the month in January and finished at the end in April 2022. In this case, the assessment process occurred in two phases, as mentioned in Figure 6.1.2. The appropriateness feature, considered as a variable of attractiveness, presents a challenge in quantification, as revealed in the literature search. The impossibility of straightforwardly quantifying the attractiveness feature of aesthetics has been summarized. It's worth noting that aesthetics, as discussed in the literature, comprises two main features: attractiveness and beauty. This distinction further complicates the task of developing a quantitative measure for the appropriateness feature within the realm of product aesthetics. In this study, we focuses on the appropriateness feature of aesthetics of the product design. Therefore, we consider the fast-moving consumer goods (FMCG) sector, specifically examining beverage products represented by their bottle silhouettes. The research is structured into two concurrent phases, allowing for a comprehensive exploration of the chosen product category. Initially, the investigation centered on the analysis of original products, and both phases were conducted simultaneously to gather diverse insights into consumer perceptions related to product aesthetics in the FMCG sector.

The research involved a two-phase approach. In Phase-I, data was collected through open-ended surveys from a diverse group of participants, including postgraduate students, senior research scholars, and undergraduate students. The participants were asked to provide their perceptions related to the appropriateness feature of product aesthetics by analyzing silhouette images of beverage bottles. In Phase-II, an eye-tracking experiment was conducted with a different set of respondents to delve deeper into cognitive perceptions. Grey silhouette images were utilized to assess emotional and psychological responses, employing eye-tracking parameters like pupil diameter, fixation count, and total fixation duration. The study addressed the cognitive aspect of consumer behavior and perception, particularly in the context of product aesthetics. The chosen FMCG sector, represented by beverage products, provided a practical and widely consumed product category for analysis. The research employed a multidimensional approach, combining cognitive assessments from surveys with quantitative insights obtained through eye-tracking technology, contributing to a comprehensive understanding of consumer responses to product aesthetics.

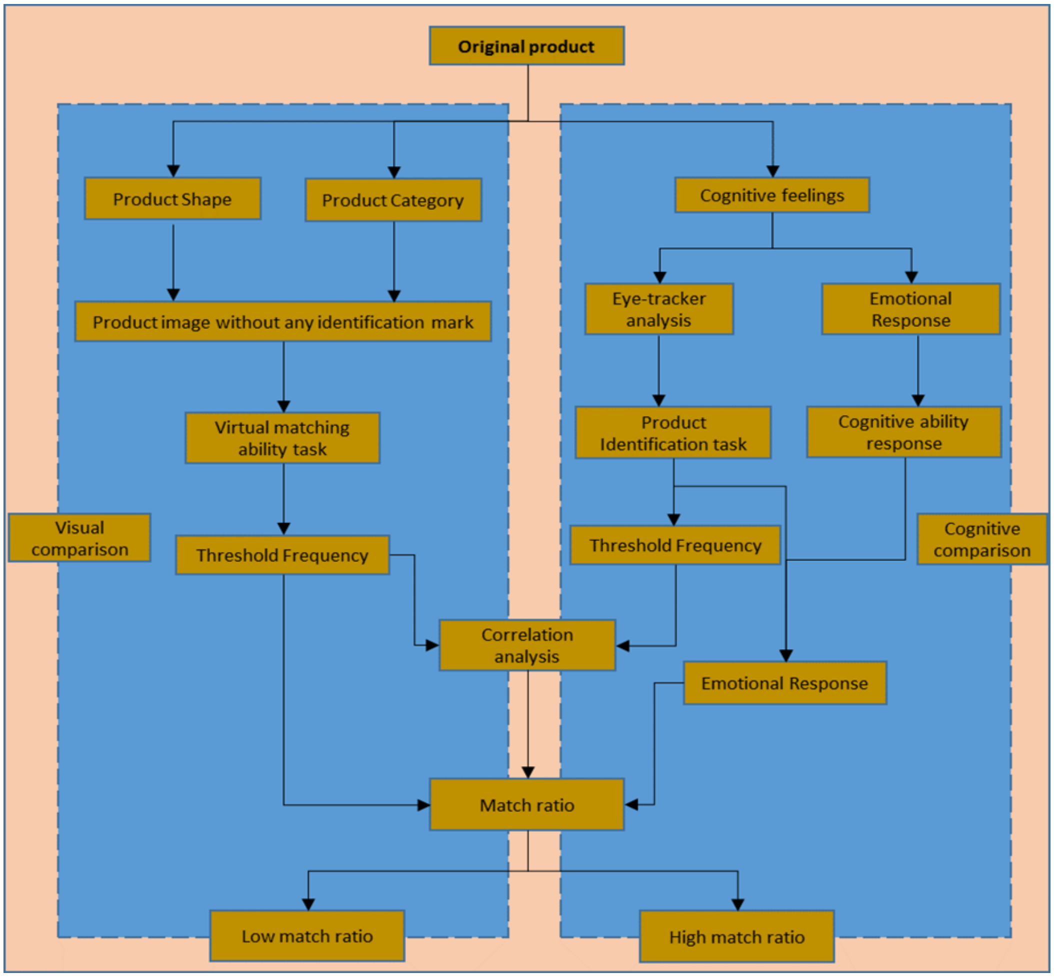


Figure 6.1.2. Structure of cognitive perception ability evaluation procedure

Blessing and Chakrabarti (2009) mentioned that the whole motive of design study is to "make the design more efficient and effective, to allow design exercise develop more effective and popular products." They developed "Design Research Methodology (DRM)" with the intention to anchor a highly rigorous methodology to initiate the design research. Many researchers and de-signers from different fields use this methodology to create new products and succeed in the competitive market, such as; "assessing the design research quality (David summers et al., 2013), and for evaluating the influence of design support in a susceptible rural community (Smits, 2019), and finding the critical sampling difficulties in theory-focused design studies" (Cash et al., 2022). In this research work, a perceptual matching methodology is used to determine the appropriateness features of the product. During the visual comparison, the output of the cognitive ability check task, and the frequency match ratio ($f_{p,b}$ %) of each silhouette are categorized into six different classes. At the same time, we also utilized optimization technique ANOVA and correlation coefficient for the data analysis. These techniques is used in different field to optimizing the data such as improvement of regional industrial ecology (F. Liu et al., 2023), predicting educational opportunity during industrial development (Herrala, 2023), and make strategies for the optimally small carbon emission (Zheng et al., 2023), etc,. In addition, its match ratio is described in Equation 6.1.1, as given in Section 6.1.4.

Select the suitable product category to identify the appropriateness feature of product aesthetics. Collect the data by using the expertise of experienced designers in the selected product categories. Prepare the list of product categories and make a questionnaire on Google form, hardcopy, and LinkedIn for phase–I of the survey (open-ended). Analyze the responses of each prospective consumer separately by using a frequency match ratio. Arrange the list of products for analyzing consumer psychology (cognitive behavior) for the appropriateness feature of product aesthetics by using eye-tracking equipment in the second phase. Verify the match quality and analyze the consumer cognitive appeal related to the appropriateness feature of product aesthetics. Enormous works have been conducted to quantify users'/customers' responses or experiences in theoretical aspects of product aesthetics. In product aesthetics, the attractiveness feature (Schnurr et al., 2017) and marketing (Gardas et al., 2019) are critical in the mating hierarchy considering the product aesthetics design area. Attractiveness is one of the key features that play a substantial role in the product's success, which impacts consumer behavior at the time or before the time of purchase of the new product (Masuda et al., 2022).

In this study, we considered a fast-moving consumer goods (FMCG) sector for testing the above hypothesis. In the FMCG sector, a beverage product (beverage bottle silhouette) is considered study material for understanding and quantifying the appropriateness features of the product aesthetics. "In the experimental design, a grey silhouette presented in black and white was chosen deliberately as a stimulus. This decision was made to minimize potential biases associated with color perception and focus on evaluating the impact of form and shape independent of color. The use of black and white stimuli helps eliminate any influence that color may have on participants' preconceived notions, allowing us to specifically isolate and analyze the effects of form and silhouette. This approach enhances the reliability of our findings by ensuring that participants' responses are primarily driven by the visual characteristics of the shape rather than color-related associations. The goal is to obtain insights into the intrinsic impact of form and gender bias without potential confounding factors introduced by color perception." The product material considered has few dissimilarities, but in the case of taste and brand value, they may differ or be the same from each other. Although, in terms of their shape/form, they create a significant impression on human thinking. The main motive for considering these products is that they are easily available and consumed by almost everyone in their day-to-day lives. Almost all categories considered in this study are primarily available in Asian, European, and American markets. The participant's information and the procedure used for gathering and investigating information are explained below.

Table 8.1. Details of experts that participates in this study

Designer Category	Number of Designer	Designation	Experience Years
Hard drink	One designers	Senior Manager	7.5
Soft drink	Three designers	Manager	5.5
Other	Two designers	Product Manager	7.5

Consumer perception related to the product stimuli is independent of the appropriateness feature of the product aesthetic. After seeing the grey silhouette of the product (black and white image), consumers may estimate or forecast the product's functionality. Hence, appropriateness is ultimately associated with the attractiveness factors of product aesthetics. Therefore, in this study, various beverage categories (different beverage bottles) are considered to understand the role of appropriateness in product aesthetics. The selection of product categories, i.e., beverage and the types of beverage bottles, are completed with the help of experts; the description of experts is given in Table 6.1.1.

6.1.3. Collection of Data

This study gathers and analyzes information in two phases to validate the above hypothesis. Both semi-structured and structured surveys and experiments are used, as dis-cussed below. In phase-I, the cognitive ability task is conducted to collect consumers' perceptions related to the appropriateness feature of product aesthetics. In phase-II, the eye-tracking experiment is performed to collect the cognitive perception of customers. Initially, the survey is conducted with different product images collected from various beverage categories. After completing the phase-I study, the frequency match ratio (using Equation (6.1.1)) values for each silhouette with respect to the consumer input are calculated as mentioned in section 6.1.4. In phase-II, an eye-tracking experiment is conducted with different respondents, apart from the phase-I respondents. Next, an open-ended survey is undertaken to note the consumer behavior of the participants involved in the eye-tracking investigation. In this phase, emotional and sensory responses were analyzed by considering a different group of variables mapped from an eye-tracker experiment performed for more in-depth analysis.

Phase-I subject details: An open-ended survey is conducted with prospective respondents through phone calls, Google forms, and e-mails from postgraduate students, senior research scholars, and undergraduate students. The undergraduate students enrolled in three different courses work; Manufacturing Technology-1 (ME206), Advanced solid mechanics course (ME517), and Experimental Methods (PH422) are also participants in this survey. The details of all the prospective respondents are provided in Table 6.1.2. A survey was conducted among 220 prospective participants, and out-off 220 participants, a total of 200 correct responses, we get during open-ended survey. Furthermore, these respondents represent a younger generation of various beverage product categories consumers. Considering this population can help us know the market trend for the next couple of years. In addition, a detailed description of the respondents is given in Table 6.1.2 below.

Table 6.1.2. List of the participants in an open-ended experiment

Gender		Occupation	Number of participants	Average Age	Living Place	
Male	134	Engineering Undergraduate	20	21	Metro city	112
		Graduate	31	22	Town	57
Female	66	Postgraduate	86	29		
		Design Undergraduate	23	21	Village	31
		In Job	40	30		
Total	200		200	200		200

Also, before conducting a survey, a detailed discussion is conducted with experts from various beverage industries related to the consumption habits of the common customer beverages, and the details of all the experts are mentioned in Section 6.1.2, Table 6.1.1. After discussion, experts suggested (with the expert's input) six different drinks categories, and the product examples, category descriptions, and category identification (ID), which is majorly consumed by a large population, are listed in Table 6.1.3.

Table 6.1.3. Beverage drink categories in the present scenario of the marketplace

Category Identification (CI)	Explanation	Products Example
Q_1	Alcohol (AL)	Vodka, Beer, Wine, Black dog, Johnny walker
Q_2	Coffee & Milk (C/M)	Amul, Verka, Starbucks, Shatto milk, Twix & Snickers flavored
Q_3	Juice (Ju)	Carelumina juice, Pineapple juice, Lemon juice, Apple juice, Orange juice,
Q_4	Sports/energy drink (SD/ED)	Hydra-Flex, Getorade Tiger, Gatorade lemon lime 20 oz
Q_5	Water (W)	Biseleri, Aquafina, Kingfisher, Evian mineral water, Kinley
Q_6	Carbonated drink (CD)	Pepsi, Limca, Mountain Dew, Coca-Cola

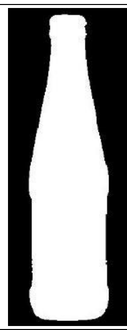
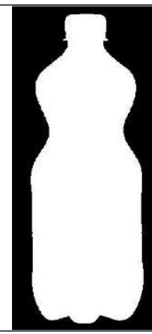
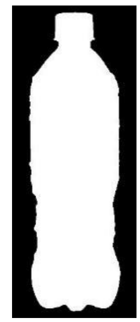
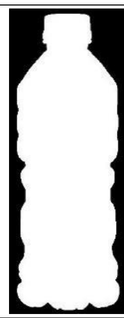
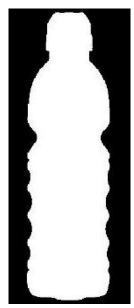
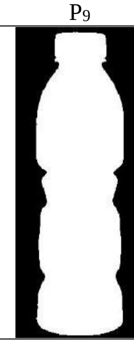
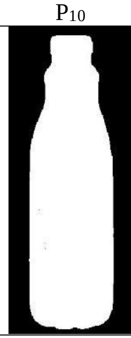
To ensure impartiality among participants, we took several steps after finalizing the six beverage categories and downloading bottle images from the "PNGWING" website (https://www.pngwing.com/ - Accessed on 20 November 2021). All downloaded images were standardized to have the same pixel size and a consistent background. Initially, images were obtained in color. To further remove potential biases, we applied a uniform white or black background to all images using the "remove background from image" tool (https://www.remove.bg/). Subsequently, we transformed these color images into silhouettes, creating uniform white and black representations. This conversion was achieved using a custom code in Matlab, detailed in Figure 6.1.3. The resulting set of converted silhouette images is listed in Appendices 6.1.B, Table 6.1.A2.

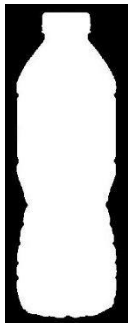
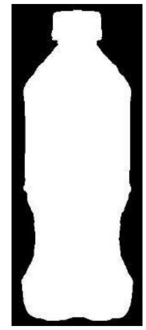
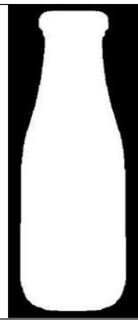
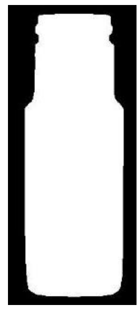
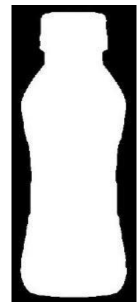
```
cdata=  imread('pngwing.com__31_-removebg-preview.png');
aa = cdata;
BW1 = rgb2gray(aa)>0;
se1 = strel('disk',10);
im1=imdilate(BW1,se1);
im2=imerode(im1,se1);
%ab = imBinary222 - BW1;
imshow(im2, [])
```

Figure 6.1.3. Matlab code for the colored images to convert into silhouette/grayscale

After converting all images into silhouettes, we faced the challenge of selecting the right number of images for the experiment. To address this, we sought the guidance of experts who provided recommendations on the ideal number of images required to represent each beverage category comprehensively. Subsequently, we engaged experts and professionals to suggest three distinct images from each beverage category, ensuring broad coverage of the product range within each category. This process resulted in a selection of eighteen images for Phase-I. In Phase-I, an open-ended survey was conducted using these eighteen images to assess consumer cognitive abilities. Each image in Table 6.1.4 is associated with a unique product identification ID (P1, P2...P17, and P18) to prevent any potential survey-related misconceptions.

Table 6.1.4. List of product Identification ID and their silhouette image from different categories

<table>
<tr><td rowspan="11">Images of different beverage product silhouette</td><td colspan="3">Product Identification (ID)</td></tr>
<tr><td>P_1</td><td>P_2</td><td>P_3</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>P_4</td><td>P_5</td><td>P_6</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>P_7</td><td>P_8</td><td>P_9</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>P_{10}</td><td>P_{11}</td><td>P_{12}</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>P_{13}</td><td>P_{14}</td><td>P_{15}</td></tr>
</table>

			
	P_{16}	P_{17}	P_{18}
			

Note; P1, P2, P3… up to P18 specify the product identity.

During the phase-I survey, each bottle silhouette is shared on Google form with a questionnaire, and a printed hard copy of the survey is also taken to perform the in-person survey. All six drink categories are mentioned in the questionnaire for each bottle silhouette, as options are given. In addition, the sample of the questionnaire is provided in Appendix 6.1.C. While performing the survey, each consumer is asked to list down or choose the options or the product category they perceive from the bottle silhouette, i.e., observing through their cognitive thinking. Meanwhile, to avoid the biased behaviour of the respondents, the survey was presented in that way; the options are given in a random order for every upcoming/next question. Also, the silhouette of each product category is presented in an unexpected way to avoid the chance of biased behaviour or confusion with upcoming silhouettes. In this way, the human cognitive ability check is performed, where they were not aware of the real categories of the beverage bottles. For easy understanding and quantification of data, eighteen silhouette bottles are divided into three groups, and each group considered six different product categories with varying silhouettes of beverages.

6.1.4. Results and discussion

6.1.4.1.Results of phase-I

In the cognitive ability check task, the "frequency match ratio" is a metric used to evaluate how well a product silhouette (Xp) matches with a particular beverage category (Qb). This measure assesses how closely the product's visual form, represented by the shape, resembles that of the beverage category to which it belongs.

Visual comparison; the output of the cognitive ability check task, the frequency match ratio ($f_{p,b}$ %) of each silhouette is categorized into six different classes, and its match ratio is described in equation 8.1, as given below.

The researchers count the number of elements shared by the beverage category and the product silhouette (X_p Q_b) to determine the frequency match ratio ($f_{p,b}$%). A percentage is calculated by dividing this number by the overall number of elements in the beverage category and the product silhouette (C_t).

$$Frequency\ match\ ratio = \frac{Count\ ((Product\ silhouette)\ \cap\ (Beverage\ category))}{Total\ count}$$

$$f_{p,b}\% = \frac{(Xp)\ \cap\ (Q_b)}{C_t} \tag{6.1.1}$$

- The FMR measures how well the product silhouette matches the features or traits typically connected to a particular beverage category.
- A higher frequency match ratio denotes a more substantial visual similarity between the product and the anticipated appearance of goods in that beverage category. A lower FMR, on the other hand, denotes a potential misalignment between the product silhouette and the typical characteristics of that beverage category.
- The researchers can analyze and compare how various product silhouettes relate to their respective beverage categories regarding visual resemblance by categorizing the FMR into six classes.
- This analysis aids in comprehending how consumers judge a product's design's suitability for the intended product category based on its visual attributes.
- The FMR values indicate the strength of the relation between a product category of beverage bottles and the consumer’s cognitive ability, as shown below in Table 6.1.5.

Table 6.1.5. Demonstrated the values of frequency match ratio of a consumer during cognitive ability check the task on six beverage categories

Group (G1)						
Product Identity (PI)	Category identification					
	AL (Q1)	C/M (Q2)	Ju (Q3)	SD (Q4)	W (Q5)	CD (Q6)
Al (P_2)	94.710%	1.770%	1.770%	0.000%	0.588%	1.176%
M/C (P_{17})	0.588%	49.410%	12.940%	27.650%	8.820%	0.588%
Ju (P_{10})	0.588%	38.240%	23.500%	18.240%	17.650%	1.765%
SD (P_8)	0.000%	1.764%	22.350%	38.200%	31.760%	5.882%
W (P_{15})	0.000%	2.940%	8.820%	8.230%	15.290%	64.700%
CD (P_5)	0.000%	0.588%	4.710%	0.588%	8.240%	85.880%
Group (G2)						
Product Identity (PI)	Category identification					
	AL (Q1)	C/M (Q2)	Ju (Q3)	SD (Q4)	W (Q5)	CD (Q6)
AL (P_1)	72.900%	1.760%	1.760%	7.060%	0.588%	15.880%
C/M (P_{18})	0.000%	36.470%	16.470%	30.000%	14.710%	2.350%
Ju (P_{11})	0.588%	73.530%	17.060%	3.530%	4.710%	0.588%
SD (P_7)	0.588%	0.000%	21.170%	25.290%	37.640%	15.290%
W (P_{14})	0.000%	3.520%	6.470%	2.350%	82.350%	5.290%
CD (P_6)	0.000%	0.000%	1.760%	2.940%	21.180%	74.120%
Group (G3)						
Product Identity (PI)	Category identification					
	AL (Q1)	C/M (Q2)	Ju (Q3)	SD (Q4)	W (Q5)	CD (Q6)
AL (P_3)	78.820%	2.940%	8.820%	5.880%	3.529%	0.000%
C/M (P_{16})	2.350%	81.760%	8.230%	4.117%	0.588%	2.940%

Ju (P_{12})	0.588%	34.110%	20.580%	30.580%	10.580%	3.520%
SD (P_9)	1.176%	3.529%	35.880%	27.050%	17.050%	15.290%
W (P_{13})	0.588%	1.170%	11.760%	6.470%	60.580%	19.410%
CD (P_4)	5.880%	8.820%	2.940%	1.760%	0.588%	80.000%

Note: As shown in Table 6.1.5, each consumer's frequency match ratio (FMR) values during the cognitive ability check the task on six beverage categories, group (G1). As shown in Figure 6.1.1, in phase-I of the study, a visual comparison was calculated using Equation (6.1.1). In addition, it was defined in terms of the percentage of a silhouette appropriately matched with its original category. The accuracy of every bottle silhouette is rep-resented in the bold letter with respect to their specific category.

Note: As shown in Table 6.1.5, each consumer's frequency match ratio (FMR) values during the cognitive ability check the task on six beverage categories, group (G1). As shown in Figure 6.1.1, in phase-I of the study, a visual comparison was calculated using Equation (6.1.1). In addition, it was defined in terms of the percentage of a silhouette appropriately matched with its original category. The accuracy of every bottle silhouette is represented in the bold letter with respect to their specific category.

6.1.4.2.Results of phase-II

Eye-tracking technique:

In Phase-II, an affective matching experiment was conducted to gauge and quantify respondents' cognitive perceptions. This experiment involved the use of eye-tracking equipment to collect data on psychological and emotional responses through the tracking of participants' eye movements. Grey silhouette images were employed to elicit and quantify emotional insights, utilizing key eye-tracking parameters like pupil diameter, fixation count, and total fixation duration. The study delved into respondents' emotional, psychological, and physiological reactions, with a strong focus on human cognition and perception. The use of eye-tracking technology in this experiment combined cognitive approaches with quantitative techniques, offering a dominant method for understanding scene viewing. While the study of eye activities has a long history, it has gained significant momentum and relevance, especially in areas related to human-computer interaction (HCI) and consumer behavior. According to Jacob and Karn (2003), human eye activities provide a piece of evitable information during search strategies, mental imagery (Matsas & Vosniakos, 2017), problem-solving (J. J. H. Lin & Lin, 2018), measure/assess the users behavior towards product shapes (Bell et al., 2018; Singh & Sarkar, 2022a; Castiblanco Jimenez et al., 2023) , and reasoning (Chen et al., 2023; Fu et al., 2023).

Research in the area of psychological and consumer behavior human eye activities during the visual search unveils objective information or figures on how a human being interprets a product through a physical look. An eye-tracking experiment is performed on different stimuli, such as an alphanumeric stimuli (Duchowski, 2002), pictorial images in a natural environment and with complex objects (Wang & Sparks, 2016), and textual stimuli (Mangla et al., 2018). It can also be used in measuring a wide variety of experimental contexts and in real-time situations. Researchers can obtain reliable and unobtrusive online and real-time information on eye movements through wearable ET technologies. According to Corbetta (2002), visual understanding is a transmission of thoughts/information processes of the bottom-up approach and top-down approach. In visual cognition studies mainly, elements that affect consumers' visual cognition can be "distinguished by the bottom-up process," "stimulus-driven or top-down process," and objective-inclined attention (Corbetta & Shulman, 2002; Singh & Sarkar, 2022b). Voluntary attention allocated to a certain object is referred to as the “Top-down process,” and it is convened by humans' recent tasks/goals. Further, the bottom-up process is triggered by the visual saliency of a product, including contrast, color, screen size, and many more (Do et al., 2003). In this study, we use the bottom-up process to assess consumer thoughts, as sensory information affects cognitive in-sides.

Measurement of eye-tracking data:

To analyze the human eye activities/movements, the researchers first defined the area of interest (AOIs) for each silhouette just before the eye-tracking experiment to ease the analysis of the results. For each AOIs, essential parameters are determined using Tobii Studio-3.4.8 (Tobii Eye-tracker - https://www.tobii.com/), such as; pupil diameter, fixation count, and total fixation duration. Tobii Studio exports the eye-tracker data-3.4.8 in SPSS 18.0., or in Excel, and eye-tracker data are first refined and separated into individual measures. Below, we detail the methodology encompassing data collection, calibration protocols, and preprocessing steps:

The eye-tracking tool used in this study was the Tobii Studio 3.4.8 (Tobii Eye-tracker - https://www.tobii.com/). This system utilizes infrared light to monitor and record eye movements with a high degree of accuracy. It is equipped with a remote eye tracker, ensuring non-invasive data collection. The Tobii Studio software provides a user-friendly interface for experiment design, data capture, and analysis.

Calibration Protocol:

Participant Setup: Participants were seated comfortably in front of a computer monitor that integrated the Tobii eye-tracking system. They were briefed on the study objectives and the eye-tracking procedure (M. Liu & Zhu, 2012; Singh & Sarkar, 2022a).

Calibration Phase: Prior to data collection, a calibration process was initiated. Participants were instructed to focus on a series of predefined calibration points displayed on the screen. The system used participants' gaze data during this phase to create a mapping between their gaze positions and on-screen coordinates (Ahonniska-Assa et al., 2018; Bell et al., 2018; Castiblanco Jimenez et al., 2023).

Validation: After calibration, a validation process was executed to ensure the accuracy of the eye-tracking system. Participants' gaze points were compared to predefined validation points. Recalibration was performed if necessary to maintain data accuracy (Cuve et al., 2022).

Data Collection:

Area of Interest (AOI) Definition: Before conducting the eye-tracking experiments, we established Areas of Interest (AOIs) for each silhouette presented to the participants. These AOIs served as the regions of the screen that were analyzed in terms of eye movements and gaze behavior (Dogan et al., 2018).

Eye-Tracking Experiment: During the experiment, participants were presented with silhouettes or visual stimuli on the computer monitor. The Tobii eye-tracking system recorded their eye movements and gaze data while they observed the stimuli (Babić et al., 2020).

The Tobii Studio 3.4.8 software captured various eye-related parameters for each AOI, including:

Pupil Diameter: This parameter indicates variations in pupil size, which can reflect changes in cognitive load or emotional responses (Jang et al., 2014).

Fixation Count: It represents the number of times a participant's gaze remains stable within an AOI. Higher fixation counts often indicate areas of particular interest (Rojas et al., 2015).

Total Fixation Duration: This parameter measures the cumulative time a participant's gaze remains within an AOI. It reflects the relative importance or engagement with specific areas of the stimuli (Wass et al., 2014).

Preprocessing Steps: The recorded eye-tracking data were exported from Tobii Studio 3.4.8 in commonly used formats such as SPSS 18.0 or Excel for further analysis. Prior to in-depth analysis, several preprocessing steps were performed, including:

Noise Reduction: Raw gaze data may contain noise due to blinks, head movements, or other artifacts. Noise reduction techniques were applied to filter out unreliable data points (Wass et al., 2013).

AOI-Based Data Segmentation: The data were separated into individual measures for each AOI. This segmentation allowed us to focus our analysis on specific regions of interest (Blascheck et al., 2017).

The use of Tobii Studio 3.4.8, with its rigorous calibration process and data analysis capabilities, enabled us to collect and process eye-tracking data effectively. This methodology is recognized for its ability to provide valuable insights into human gaze behavior, facilitating the understanding of participants' responses to visual stimuli. Authors from various domains employ a diverse range of optimization techniques, as seen in the work of Mehmet (2023), (2022), who apply these techniques to optimize parameters in MIG and TIG welding processes, as well as in the domain of software development, where Sharafi et al. (2020) utilize them for bug localization. We thoroughly analyze the eye-tracking data we have collected, utilizing a wide range of optimization techniques, each suited to a particular objective. We use data cleaning to improve data integrity, normalization to standardize for comparison, filtering to concentrate on relevant information, and segmentation to isolate specific areas of interest as part of our toolkit of optimization techniques. Furthermore, machine learning algorithms unearth hidden insights; statistical analyses highlight trends, and feature extraction extracts essential data points. Graphs and heat maps are two visualization techniques that offer user-friendly data representations; combining eye-tracking data with user surveys furthers our comprehension of the user experience. We use optimization techniques even in the reporting process to ensure clear and valuable outcomes. These diverse optimization strategies enhance the value of eye-tracking data by enabling researchers and designers to understand better user behavior, cognitive processes, and attention patterns. The particular technique will vary depending on the study's objectives and the particulars of the eye-tracking data under investigation. The collected eye-tracker data are examined by means of a one-way analysis of variance (ANOVA) within-subject. This study uses the bottom-up process to assess consumer thoughts. Therefore, a total of 55 respondents are requested for the eye-tracker experiment, which includes both pilot and final experiment respondents. A pilot experiment is conducted to understand how a lab environment, the type of distraction, and the type of light affect the respondent’s emotions, mood, or cognitive ability during the experiment. This pilot experiment was performed with five respondents, and a detailed experimental procedure is provided below.

Experimental procedure: A total of 50 respondents participated in the final eye-track-ing experiments. Out of 50 respondents, only 45 participants' inputs were considered, and the rest of the five participants' inputs were discarded because of an incomplete survey. A detail of participants is given below in Table 6.1.6.

Table 6.1.6. Detail of participants involved in Eye-tracking experiments, the misconception at the time

Gender	No. of Participants	Education Qualification	Place	Average Age
Female	2	Graduate	Town	25 years
	6	Undergraduate	Metro city	
	4	Post-graduate	Town	
Male	22	Post-graduate	Metro city	30.5 years
	6	Undergraduate	Village	
	5	Graduate	Town	
Total	45			

The respondents gave informed approval/consent, and a 50 rupees gift voucher was given to each participant. In section 6.1.3, six different beverage categories are finalized with the help of experts' input, and three different beverage products with different silhouettes are chosen from each category. Thus, with 18 different product silhouettes, an eye-tracking experiment is accomplished to analyze human eye activities (where AOIs were already defined). Experiments are conducted in the "Design Studio Lab" of the "Indian Institute Of Technology, Ropar." And the environment of the laboratory is noise-free, equipped with good light, and air-conditioning (air ventilation). All the protocols/guidelines are followed at the time of an eye-tracking experiment. It is necessary that, before the Eyetracking experiment, the respondents are not to take any caffeinated products or smoke cigarettes for 3–4 hours before conducting the experiment. In addition, none reported any eye surgery, diseases, or injuries and have eyesight 6/6 or normal vision. Before experimenting, the human eye is calibrated using a calibration test, and the calibration test is conducted for every respondent. An eye-tracking experiment is carried out with 45 respondents for the beverage silhouettes. Further, human cognition is analyzed with the help of different variables of eye-tracker. A pupil diameter/dilation is first observed to assess human cognitive under-standing. In section 6.1.3, the discussion is conducted on the selection of different types of beverage bottle silhouettes, product categories, and product identification. In this section, both hypotheses are tested; firstly, we tested that the consumers did not recognize the product based on the product silhouette. In addition, there is no difference in the perception of function among the other product categories based on their silhouette. Second, based on gender (male and female), there is no difference in consumer thinking related to the perception of function. For this, the data generated from the eye-tracker experiment for the silhouettes of alcohol (three types of silhouettes from the same product category) are com-pared with the rest of the five beverage categories (carbonated drink, energy drink, juice, water, and milk/coffee). Then, carbonated bottle silhouettes (three different types) are compared with the rest of the four product categories. In the end, the water bottle silhouette comparison is performed with the milk/coffee bottle silhouettes with the help of ANOVA. Our studies proved the hypothesis mentioned above by considering a different variable used to analyze the consumer's cognitive approach. The results of eye-tracking experiments are presented in terms of three variables that represent human cognitive behavior with the help of eye movement. It is given in Tables 6.1.D, E, F (Pupil diameter, Fixation count, and Total fixation duration) in Appendixes 6.1.D, E, and F. The results are calculated for whole populations, the male population and the female population.

After completing the eye-tracking experiment, we asked each participant to list their honest response to the silhouette/grey images considered at the time of the experiment. The responses are taken using the open-ended survey, and the questionnaire is provided in Appendix 6.1.C. Each participant's responses are analyzed with the same equation (Equation (6.1.1)) used in the phase-I study (Frequency Match Ratio-FMR). In addition, the response of respondents is given in Table 6.1.7, as shown below.

Table 6.1.7, frequency match ratio of the consumer during the cognitive ability check task on six beverage categories

	Group (G1)					
Product Identity (PI)	Category identification					
	Alcohol Drink (Q1)	Cold coffee/Milk Drink (Q2)	Juice Drink (Q3)	Sports/Energy Drink (Q4)	Water (Q5)	Carbonated drink (Q6)
AL (P2)	94.00%	0.00%	4.00%	0.00%	2.00%	0.00%
C/M (P17)	2.00%	40.00%	16.00%	28.00%	10.00%	4.00%
Ju (P10)	6.00%	34.00%	28.00%	16.00%	14.00%	2.00%
SD (P8)	4.00%	4.00%	22.00%	48.00%	16.00%	6.00%
W (P15)	0.00%	8.00%	6.00%	10.00%	26.00%	50.00%
CD (P5)	6.00%	4.00%	4.00%	0.00%	12.00%	74.00%
	Group (G2)					
Product Identity (PI)	Category identification					
	Alcohol Drink (Q1)	Cold coffee/Milk Drink (Q2)	Juice Drink (Q3)	Sports/Energy Drink (Q4)	Water (Q5)	Carbonated drink (Q6)
AL (P_1)	78.00%	0.00%	4.00%	6.00%	4.00%	8.00%
C/M (P_{18})	2.00%	40.00%	12.00%	24.00%	20.00%	2.00%
Ju (P_{11})	0.00%	42.00%	28.00%	18.00%	10.00%	2.00%
SD (P_7)	2.00%	0.00%	26.00%	12.00%	32.00%	28.00%
W (P_{14})	2.00%	4.00%	4.00%	8.00%	74.00%	8.00%
CD (P_6)	0.00%	6.00%	2.00%	8.00%	34.00%	50.00%
	Group (G3)					
Product Identity (PI)	Category identification					
	Alcohol Drink (Q1)	Cold coffee/Milk Drink (Q2)	Juice Drink (Q3)	Sports/Energy Drink (Q4)	Water (Q5)	Carbonated drink (Q6)
AL (P_3)	68.00%	10.00%	8.00%	4.00%	4.00%	6.00%
C/M (P_{16})	0.00%	84.00%	6.00%	2.00%	8.00%	0.00%
Ju (P_{12})	4.00%	14.00%	44.00%	26.00%	6.00%	6.00%
SD (P_9)	4.00%	0.00%	30.00%	34.00%	24.00%	8.00%
W (P_{13})	2.00%	0.00%	6.00%	6.00%	48.00%	38.00%
CD (P_4)	14.00%	18.00%	6.00%	2.00%	6.00%	56.00%

Note: As shown in Table 6.1.7, each consumer's frequency match ratio (FMR) values during the cognitive ability check the task on six beverage categories, group (G1). As shown in Figure 6.1.1, in phase-I of the study, a visual comparison was calculated using Equation (6.1.1). In addition, it was defined in terms of the percentage of a silhouette appropriately matched with its original category. The accuracy of every bottle silhouette is rep-resented in the bold letter with respect to their specific category.

Pupil diameter: Human pupil diameter provides a practical explanation of sentimental arousal. Studies have shown that there is a significant change in pupil sizes when humans/users are involved with emotionally arousing images or products, whether they are pleasurable or non-pleasurable (Bradley et al., 2008). Our studies are first conducted with all the respondents, and at the same time, we also understand and quantify the males' and females' cognitive and visual thinking for each silhouette. This study is performed to determine the difference in the perception of function for product aesthetics design by quantifying the variation of human pupil diameter. For pupil diameter, the results of ANOVA revealed a significant effect of an appropriateness (perception of function) feature of product aesthetics on the consumer pupil size. When silhouettes of alcohol are compared with the rest of the four product categories of silhouette, we obtain [F (1, 4) = 37.258, p = 0.003] (alcohol and carbonated drink), [F (1, 4) = 68.158, p = 0.001] (Alcohol and energy drink), [F (1, 4) = 38.152, p = 0.003] (Alcohol and juice), [F (1, 4) = 395.61, p = 0.00004] (alcohol and water), and [F (1, 4) = 189.24, p = 0.0002] (alcohol and milk/coffee). Similarly, the results of ANOVA explained a significant effect of an appropriateness (perception of function) feature of product aesthetics on the consumer pupil size. When silhouettes of carbonated drinks are compared with water and milk/coffee silhouettes, we obtain [F (1, 4) = 10.0009, p = 0.034], [F (1, 4) = 9.6870, p = 0.035], and there is no significant effect of an appropriate-ness (perception of function) feature of product aesthetics on the human pupil size in carbonated drink silhouettes with energy drink, and juice bottle, with p > 0.05 (0.145 and 0.160) respectively. However, the silhouettes of energy drinks bottles are compared with juices, water, and milk/coffee silhouettes, which gives p > 0.05 (0.779, 0.577, and 0.434), respectively. The ANOVA results explained that when silhouettes of juice bottles are compared with water and milk/coffee silhouettes, the p values obtained are p = 0.957, p = 0.577, and p = 0.7830, respectively, and no significant effect is observed. Similarly, no significant effect on the appropriateness (perception of function) features of product aesthetics on the human pupil size is observed when silhouettes of water bottles are compared with milk/coffee silhouettes with p > 0.05 (0.56).

Male and Female comparison: In the case of males and females, there were no significant main effects on the appropriateness (perception of function) feature of product aesthetics on gender with [F (1, 34) = 3.15182, p = 0.084] on pupil size. There is no significant difference in the perception of function in males and females, which is indicated by pupil diameter. In the case of female respondents, ANOVA results revealed that there is a significant effect of appropriateness feature (perception of function) on the human pupil size when silhouettes of alcohol are compared with energy drinks, juice, water, and milk/coffee, with [F (1, 4) = 16.2804, p = 0.01567], [F (1, 4) = 8.7728, p = 0.04147], [F (1, 4) = 11.56282, p = 0.027267], [F (1, 4) = 32.52432, p = 0.004], and except Carbonated drink, with [F (1, 4) = 4.3085, p = 0.106]. Further, the results of ANOVA explained there is no significant effect of the appropriateness feature (perception of function) on the human pupil size, with p > 0.05. When the carbonated drink silhouettes are compared with the other four product categories; energy drink silhouettes are compared with the other three product categories; juice drink silhouettes are compared with the rest of the two product categories, and water silhouettes are compared with milk/coffee. However, for male respondents, the ANOVA results explained that there is a significant effect of appropriateness feature on the size of the human pupil when silhouettes of alcohol are compared with all five beverage bottles product silhouettes, with [F (1, 4) = 12.21, p = 0.02], [F (1, 4) = 101.68, p = 0.0005], [F (1, 4) = 92.10, p = 0.0007], [F (1, 4) = 271.15, p = 0.00005], [F (1, 4) = 115.1, p = 0.0004], respectively. Meanwhile, the ANOVA results revealed that there is a significant effect of appropriate-ness feature on the size of the human pupil when we compared carbonated drink bottle silhouettes with water and milk/coffee bottles with [F (1, 4) = 8.96, p = 0.04], [F (1, 4) = 8.86, p = 0.04]; energy drink bottle silhouettes with water bottle silhouettes and milk/coffee bottles silhouettes; [F (1, 4) = 14.28, p = 0.01], [F (1, 4) = 8.63, p = 0.04]; except other comparisons in which they are having a p-value > 0.05.

Fixation count (FC): The results of ANOVA revealed that there is a significant effect of the appropriateness feature of product aesthetics on the fixation count (FC). When silhouettes of alcohol are compared with energy drink bottle silhouettes, carbonated drink bottle silhouettes with energy drink bottle silhouettes, similarly, energy drink bottle silhouettes compared with water bottle silhouettes, and energy drink bottle silhouettes with milk/coffee bottle silhouettes, we obtain [F (1, 4) = 71.3145, p = 0.001], [F (1, 4) = 13.788, p = 0.020], [F (1, 4) = 23.015, p = 0.008], and [F (1, 4) = 8.966, p = 0.040]. For other combinations, the p-value > 0.05, and there is no significant effect of the apparentness feature on consumer cognitive thinking. For fixation count, there is no significant effect of gender (males and females) and an appropriateness feature of product aesthetics on the fixation count with [F (1, 34) = 2.382092, p = 0.131]. Even during the product category-wise, there is still no significant effect of gender on an appropriateness feature on the fixation count (a measure of human behavior through human-eye activity).

Male and Female comparison: In the case of the female respondents, the result of ANOVA for fixation count revealed that there is a significant effect of appropriateness feature of product aesthetics. When alcohol bottle silhouettes are compared with ED bottle and water bottle, we obtain [F (1, 4) = 17.4633, p = 0.01] and [F (1, 4) = 37.665, p = 0.003]. Similarly, the ANOVA results explained that there is a significant effect of appropriateness feature of product aesthetics when CD bottle silhouettes are compared with energy drink bottles and water bottles with [F (1, 4) = 20.384, p = 0.01], [F (1, 4) = 20.716, p = 0.01], when energy drinks bottle silhouettes are compared with water bottle and milk/coffee bottle with [F (1, 4) = 20.384, p = 0.01], [F (1, 4) = 20.716, p = 0.01]. However, for other product categories, the results of ANOVA revealed that there are no significant effects of the appropriateness feature of product aesthetics on fixation count with p > 0.05, such as Al-juice = 0.78; Al-juice = 0.14; CD-Juice = 0.51; CD-M/C = 0.31; ED-Juice = 0.12; Juice-M/C = 0.21; and Water-M/C = 0.097. However, for male respondents, the result of ANOVA explained that there is a significant effect of appropriateness feature on the fixation count on human eye activity. When alcohol bottle silhouettes are compared with silhouettes of juice bottles and water bottles, we obtain [F (1, 4) = 47.109, p = 0.002], [F (1, 4) = 13.99, p = 0.02], and [F (1, 4) = 12.96, p = 0.02]. Similarly, the ANOVA results revealed that there is no significant effect of appropriateness feature on product aesthetics when cold drink bottles' silhouettes are compared with the rest of the four beverage bottles' silhouettes, energy drink bottles are compared with the rest of the three beverage bottles, juice bottles silhouette is compared with last two beverage bottles and water bottles silhouette are compared with milk/coffee bottles we obtain p > 0.05.

Total fixation duration (TFD): The ANOVA results revealed that there is a significant effect of gender and appropriateness feature (perception of function) of product aesthetics on the total fixation duration for respective silhouettes with [F (1, 10) = 7.187, p = 0.011]. In product category wise, there is no significant effect of the appropriateness feature of product aesthetics on the human cognitive thinking for the first (G1) and second (G2) group products categories except the third (G3) group with [F (1, 10) = 11.713, p = 0.006].

Male and Female comparison: In the case of female respondents, in product category wise, the results of ANOVA revealed a significant effect of appropriateness feature (perception of function) of product aesthetics on the human cognitive thinking we obtain [$F(1, 4) = 52.145$, $p = 0.002$] for alcohol and milk/coffee, [$F(1, 4) = 24.252$, $p = 0.008$] for alcohol and energy drink [$F(1, 4) = 17.596$, $p = 0.013$] for alcohol and water, except comparison with juice bottles drink and carbonated drink bottles silhouette. In addition to this, the results of ANOVA for other product categories revealed there is a significant effect of the appropriateness feature of product aesthetics on human cognitive emotions we obtain [$F(1, 4) = 34.175$, $p = 0.004$] for a carbonated drink and milk/Coffee, with [$F(1, 4) = 26.64$, $p = 0.006$] for an energy drink and milk/coffee, with [$F(1, 4) = 37.62$, $p = 0.003$] for water bottles and milk/coffee for total fixation duration, and except other product comparison having a $p > 0.05$, such as carbonated drink bottle silhouettes with energy drink, juice, and water bottle; energy drink bottle silhouettes with juice, and water bottle silhouettes; juice bottle silhouettes with water, and milk/coffee bottle silhouettes; respectively. However, for male participants, product category-wise, the results of ANOVA revealed a significant effect of appropriateness feature (perception of function) on human cognitive emotion. When silhouettes of alcohol are compared with a juice bottle, water bottle, and milk/coffee bottle silhouettes, we obtain [$F(1, 4) = 13.19$, $p = 0.02$], [$F(1, 4) = 41.97$, $p = 0.002$], and [$F(1, 4) = 8.475$, $p = 0.04$], respectively, except comparison with carbonated drink and energy drink bottles silhouette. Similarly, the ANOVA results explained no significant effect of the appropriateness feature (perception of function) on product aesthetics. When the cold drink bottles' silhouettes are compared with the rest of the four beverage bottles' silhouette, juice bottles' silhouettes are compared with the rest of the three beverage bottles' silhouette, and energy drink bottles' silhouette is compared with water and milk/coffee bottles, and water bottles silhouette is compared with milk/coffee; with a $p > 0.05$. However, in the case of the whole population in product category-wise, the results of ANOVA revealed a significant effect of perception of function on human cognitive emotion, with [$F(1, 4) = 19.27$, $p = 0.011$] for alcohol bottle silhouettes and juice bottle, [$F(1, 4) = 53.76$, $p = 0.0018$] for alcohol bottle silhouettes and water bottle, [$F(1, 4) = 22.03$, $p = 0.009$] for alcohol bottle silhouettes and milk/coffee bottles, except comparison with energy drink and carbonated drink bottles silhouette. Similarly, for other product categories, the ANOVA results explained a significant effect of the appropriateness feature (perception of function) of product aesthetics on human cognitive feeling. When the carbonated drink bottles silhouettes are compared with milk/coffee bottles; and energy drink bottle silhouettes with milk/coffee bottles, we obtain [$F(1, 4) = 8.81$, $p = 0.041$], [$F(1, 4) = 10.33$, $p = 0.032$], and except other products comparison having a $p > 0.05$, such as carbonated drink bottle silhouettes is compared with energy drink, juice, and water bottle silhouettes; energy drink bottle silhouettes are compared with juice and water bottle silhouettes; juice bottle silhouettes are compared with water, and milk/coffee bottle silhouettes; water bottle silhouettes with milk/coffee bottle, respectively.

The product identity and product categories are mentioned in Table 6.1.3 and 6.1.A2, respectively. Table 6.1.7 shows the results of the cognitive ability task after the ET-experiment in phase-II of this work. Eighteen beverage bottle silhouettes are used, and these silhouettes are segregated into three groups. In the first group

(G1), the product identity P2 (alcohol drink silhouette) has a very high match ratio with the Q1 (alcohol drink category); the product identity P15 (carbonated drink silhouette) has a low match ratio with the Q5 (water category), and the product identity P5 (carbonated drink silhouette) has an average match ratio with the Q6 (carbonated rink category). Further, in the second group (G2), product identification P18 has a low match ratio with Q2 (Sports drink category), and product identification P6 (carbonated drink silhouette) has a medium match ratio with Q6 (Carbonated drink category). Similarly, in the 3rd group (G3), the product identification P3 (alcohol drink silhouette) has a low match ratio with the Q4 (sports drink category) and Q5 (water category); P16 (coffee/milk drink silhouette) has a high match ratio with the Q2 (coffee/milk category), and product identity P4 (carbonated drink silhouette) has a low match ratio with the Q6 (sports drink category). Similarly, in the case of correlation analysis, the threshold value defined by field experts, such as (Corbetta & Shulman, 2002), a score which is greater than 0.8 is considered a stronger correlation, 0.3-0.7 is considered a moderate correlation, and < 0.3 are considered as weak correlation. The correlation coefficient in Table 6.1.A4 is given in Appendices 6.1.D.

6.1.5. Analysis of Phase I and Phase II results

This research work investigates the effects of appropriateness features of aesthetics in product design, and it helps to understand and quantify the consumer's expectations related to them. Further prior research focuses only on industrial product designers' emotional and gut feelings (Goldstone, 1998; Helander et al., 2013). However, over time, some researchers have been working on consumer desire to create the most acceptable product using different techniques, such as the semantic differential, survey-based experiments, and Kansei engineering (Jindo & Hirasago, 1997; Macak et al., 2014; Gilal et al., 2018), but have ignored that consumer cognitive perception in relation with the product aesthetics, which can also suggest other signals for making decisions about evident usability.

Phase-I Analysis:

The consumer input is analyzed using Equation 6.1.1, and the output is presented as a percentage value/score. A higher percentage value/score indicates a stronger interrelationship between the sample (silhouette) and product class, signifying a closer match to the product category. This facilitates the assessment of matching accuracy, following the approach of Do et al. (2003). The FMR score, expressed as a percentage, quantifies the extent to which a match assesses the product accuracy. To determine the quality of the match, a threshold value is considered based on Liao & Vemuri's article (2002). The suggested thresholds are as follows: 80% or above is considered higher precision, 50% to 80% is medium to high precision, and below 50% is low precision. Similarly, for correlation analysis, the threshold values established by field experts, such as Cohen (2014), are employed. A correlation coefficient greater than 0.8 is considered a stronger correlation, a range from 0.3 to 0.7 is moderate, and below 0.3 is weaker.

With these studies in mind, silhouette designs are categorized based on their matching features from each group. Silhouettes with a matching feature of 80% or higher and a correlation coefficient exceeding 0.8 are considered high-quality designs. Silhouettes with a matching feature between 0.5 and 0.8 are classified as medium-quality designs, while those with less than 50% precision and a correlation value below 0.5 are regarded as low-quality designs. The product categories and product identities are listed in Table 6.1.3 and 6.1.6. In the results of the cognitive ability task from the phase-I study, Table 6.1.7 provides a visual comparison using Equation 6.1.1. Eighteen beverage bottle silhouettes are divided into three groups. In Group 1, products P2 and P5 exhibit a very high FMR with Q1 and Q6 categories. In Group 2, P18 shows a low match ratio with Q2, P11 has a low match ratio with Q3 and a moderate match ratio with Q2, P7 has a low match ratio with Q4, P14 has a very high match ratio with Q5, and P6 has a medium match ratio with Q6. In Group 3, P11 demonstrates a high match ratio with Q2, P12 has a low match ratio with the Q3 category, and P4 has a high match ratio with the Q6 category. Among all the alcohol classes, the product P2 silhouette achieves the highest match score. In the milk/coffee class, product P11 achieves the highest match score. In the water class, P14 obtains the highest score, while P4 and P5 achieve the highest match score in the carbonated drink class. The correlation coefficient of the open-ended survey is provided in Table 6.1.A3, Appendices 6.1.C.

An eye-tracking experiment involving 45 respondents and beverage silhouettes is conducted to analyze human cognition. Pupil diameter/dilation is initially observed to assess cognitive understanding. In section 8.3, the discussion focuses on the selection of different types of beverage bottle silhouettes, product categories, and product identification. The section tests two hypotheses. First, it examines whether consumers can recognize the product based on the product silhouette, and if there is no difference in the perception of function among different product categories based on their silhouettes. Second, it explores whether there is a difference in consumer thinking related to the perception of function based on gender (male and female). To test these hypotheses, data from the eye-tracker experiment on alcohol bottle silhouettes (three types of silhouettes from the same product category) are compared with the silhouettes from the other five beverage categories (carbonated drink, energy drink, juice, water, and milk/coffee). Subsequently, comparisons are made between carbonated bottle silhouettes (three different types) and the silhouettes from the remaining four product categories. Finally, a comparison is made between water bottle silhouettes and milk/coffee bottle silhouettes using ANOVA. These analyses confirm the hypotheses, considering different variables used to analyze consumer cognitive approaches. The results of the eye-tracking experiments, representing human cognitive behavior through eye movement with the help of three variables (Pupil diameter, Fixation count, and Total fixation duration), are provided in Tables 6.1.12 (Appendices 6.1.E). These results are calculated for the entire population, male participants, and female participants. Following the eye-tracking experiment, participants were asked to provide their honest responses to the silhouette/grey images used during the experiment. The responses were collected using an open-ended survey, and the questionnaire can be found in Appendices 6.1.H. The participants' responses are analyzed using the same equation (Equation 6.1.1) employed in the phase-I study (FMR). The responses of the participants are presented in Table 6.1.7.

Phase-II study analysis:

The results from the study indicated that variables such as pupil diameter, fixation count, and total fixation duration effectively reveal the appropriateness feature (perception of function) of products among both existing users and prospective consumers when presented with product silhouettes. The study is divided into two phases: phase-I focuses on visual comparison, while phase-II delves into the affective and cognitive responses of individuals. In phase-I, participants engaged in the physical matching of products, employing various design elements like symbolic features, curves, lines, points, and textures. These elements played a crucial role in enhancing the visual matching quality of products, drawing from both conscious and non-conscious memories. These design elements serve as a means to assess the appropriateness feature related to product aesthetics and perception of function. The composition of these design elements could form a specific shape that closely aligns with the object's characteristics, facilitating users' recognition of the product. As a result, consumers associated silhouettes with sharp angles, blunt corners, and a dumbbell shape with energy or sports drink products. Phase-II, on the other hand, utilizes variables like pupil diameter, fixation count, and total fixation duration to gauge the impact of appropriateness features related to product aesthetics on both existing and potential consumers' cognitive processes when exposed to product silhouettes. These findings shed light on how individuals perceive and emotionally respond to product silhouettes, highlighting the role of various design elements and visual cues in shaping consumer perceptions.

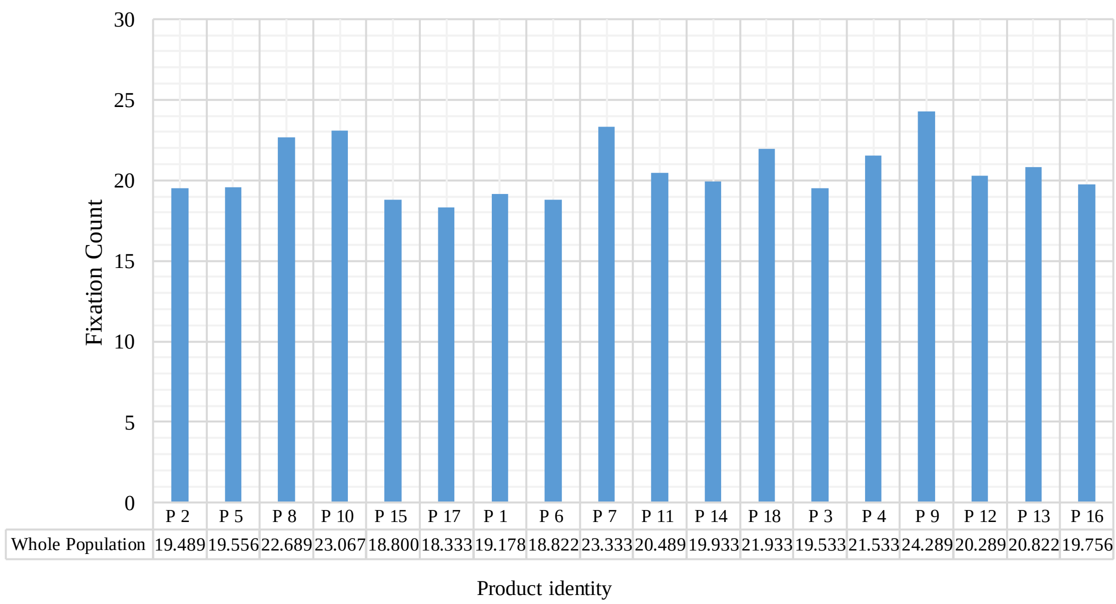
Further, the silhouette of the juice bottle is strongly associated with a spherical shape. In addition, consumers easily associate the relationship between a silhouette of juice bottles with the shape of the orange, mango, and other fruits. Similarly, the silhouette of the alcohol bottle is strongly associated with a straight shape, and the shape of the alcohol bottle silhouette looks more rigid and composed than other categories of beverage silhouette, according to consumers. Young generation male consumers try to relate these shapes to their personality or status, such as toughness and power (to show their strength). However, the silhouette of the coffee/milk bottle is strongly associated with a smooth shape and, such as a droplet of milk, and it is easier for consumers to link the relationship of a silhouette of milk/coffee bottles with the shape of the cold coffee and milk bottles. Therefore, suitable design elements can delicately connect the form of an object and its characteristics/qualities, and it can help enhance the quality of physical comparison.

Pupil diameter: The results obtained from the eye-tracking experiment, analyzed using ANOVA, offer valuable insights into predicting the cognitive thinking of both male and female participants. These results shed light on the differences in pupil diameter during independent testing of male and female subjects. Significant differences in pupil diameter were observed among male participants when comparing alcohol bottle silhouettes with those from the four other product categories. The prominent reason behind these variations could be attributed to the distinct outer shapes of alcohol bottles, characterized by their rigidity and masculinity. This feature reflects a sense of youthfulness, which is particularly appealing and easily recognizable to male consumers. Whether or not consumers have prior interactions with such products seems to influence their level of interest. As a result, when consumers are more interested in a particular product, their pupil dilation tends to be larger compared to products that pique less interest. Moreover, among male participants, differences in pupil diameter also emerged when comparing carbonated drink silhouettes with those of water and milk/coffee bottles. In contrast, female participants displayed differences in pupil diameter primarily when comparing alcohol bottle silhouettes with those of the remaining four beverage categories. However, for other comparisons between different beverage product categories, female respondents faced challenges in identifying the product categories based on the appropriateness feature (perception of function) of product aesthetics. They seemed more familiar with alcohol categories compared to the others. The main reason is; that the outlines/shapes of alcohol beverage categories are quite different from others. As Hess (1964) also found out in their study, the human pupil diameter increases when dealing/being involved with complex tasks or trying to find out some relationships. As the complexity increases, the size pupil increases significantly, as shown in Table 6.1.A5 in Appendices 6.1.E. However, the maximum time hard drink bottle silhouette is quite different from other beverage categories such as; Jack Dalian, XXX rum, Coca-Cola bottle shapes, Pepsi bottle shapes, Juice, milk/coffee bottle shapes, etc. Previous studies have demonstrated that emotionally charged images or objects cause a significant change in pupil size. To test whether there were any gender differences in the participants' cognitive and visual processing of various product silhouettes, the researchers ran experiments with both male and female respondents. The appropriateness feature of a product's aesthetics significantly impacted consumer pupil size, according to the ANOVA results for pupil diameter. Significant differences in pupil size were found when comparing various beverage categories, including alcohol, carbonated drinks, energy drinks, juice, water, and milk/coffee. This suggests that the perception of the function for each product silhouette influenced consumers' visual and cognitive reactions.

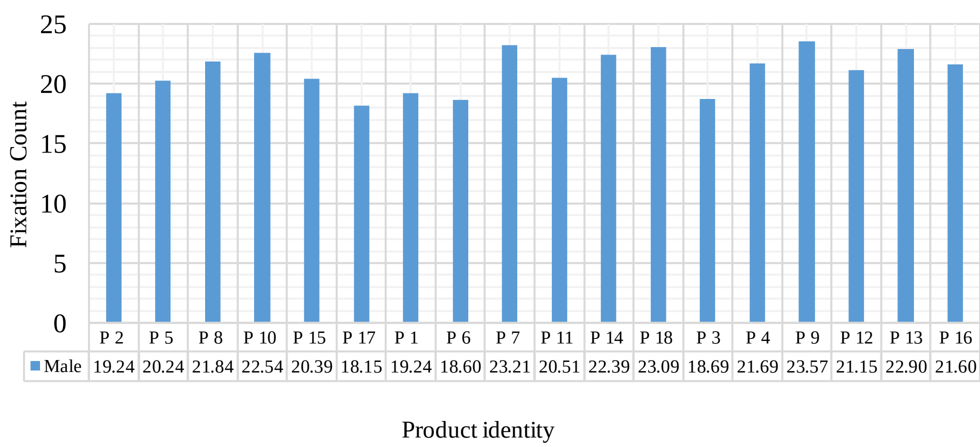
Comparing gender differences, there were no discernible main effects of the appropriateness feature of product aesthetics on either gender's pupil size. This suggests that regardless of pupil diameter, males and females have no real differences in their perception of function. The appropriateness feature significantly impacted pupil size among female respondents, though, when comparing alcohol with energy drinks, juice, water, and milk/coffee. When comparing alcohol with all beverage bottle silhouettes for male respondents, as well as carbonated drinks with water and milk/coffee bottle silhouettes, significant effects were seen.

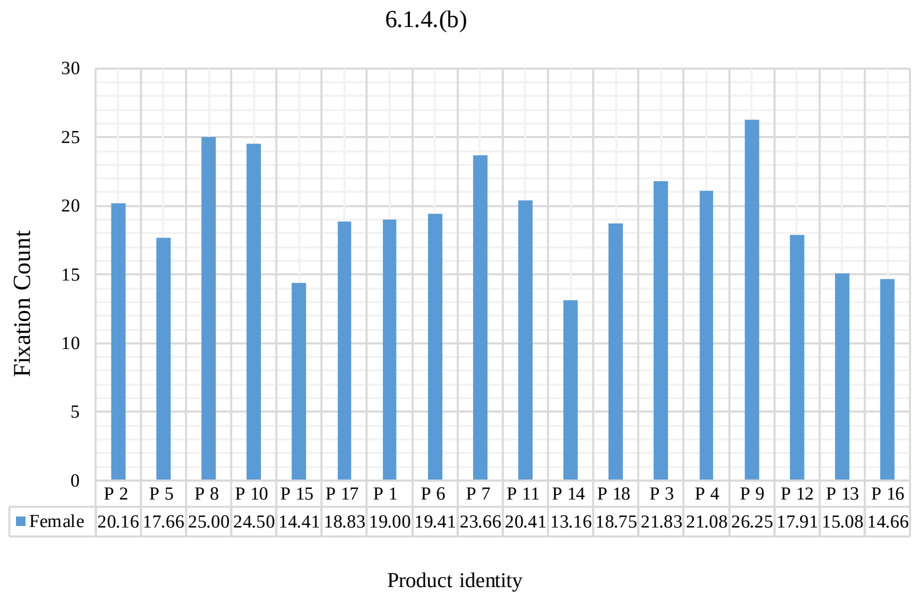
Fixation count: As the eye is comparatively still, it is considered a fixation, and it is used to determine where human beings look as they complete the experiment. We can identify or measure the portion of the image/page produced less or high curiosity by using fixation tallies. The curiosity level also depends on the size/form of the image, different textures, and various splines/curvatures, which sometimes also leads to a higher fixation count. With the help of fixation count, we can easily estimate how human beings look at various objects/features. It is presented in numbered form (numeric form) how the human being's eye processes different images/objects, as shown in Figure 6.1.2. According to Rahal and Fiedler (2019), the number of fixations acts as a powerful gauge for studying the human cognitive processing system. In addition, it is defined with the help of a number of fixations that occurs inside the area of interest. This study uses different beverage silhouettes as an experimental material or product. From this, we can understand human cognitive thinking by considering the appropriateness features (perception of function) of product aesthetics for the different beverage bottle categories with the help of an eye-tracking experiment, and data are given in Table 6.1.12, Appendices 6.1.E. The fixation for each product silhouette is presented for the whole population, female and male respondents, and is provided in Figures 6.1.4 a–c below.

As we can see, Figures 6.1.4 a–c, tell us about the fixation count on the product silhouettes for the whole population, male participants and female participants, respectively. From Figure 6.1.4, we identify that the silhouette of products P1, P4, P7, P11, and P17 have approximately the same fixation count for all three of them, i.e., total population, male participants, and female participants. Further, female respondents have a higher fixation count on P3, P8, P9, and P10 product silhouettes than male participants and whole populations during eye-tracker experiments. Similarly, for P2 and P6 product silhouettes, the female respondents have a higher fixation count than the total respondents and the male respondents. However, in the case of the P5, P12, P13, P14, P15, P16, and P18 product silhouettes, the fixation count is in descending order from female participants, the total population of participants, and then male participants. The fixation count tells us how many participants focus on which particular portion of the picture/image/silhouettes, as shown in Figure 6.1.4. The fixation count is shown in numeric numbers or terms of the heat map as we were considered; a few examples from this study are shown below.



6.1.4.(a)





6.1.4.(c)

Figure 6.1.4. Fixation count for the whole participants, male participants, Female participants and (a), (b), (c), respectively.

Regarding a gender comparison, the findings revealed that neither gender (men nor women) significantly influenced the fixation count when considering the appropriateness feature of a product's aesthetics. This suggests that when assessing the appropriateness of product silhouettes, both men and women showed comparable cognitive reactions. When comparing alcohol bottle silhouettes with sports/energy drink (ED) bottle and water bottle silhouettes, as well as carbonated drink (CD) bottle silhouettes with energy drink bottles and water bottles, significant effects of the appropriateness feature on fixation count were found for female respondents. On the other hand, there were no appreciable effects on fixation count for different product categories. Comparing the silhouettes of alcohol bottles to those of juice and water bottles revealed significant effects of the appropriateness feature on fixation count for male respondents. The appropriateness feature had no appreciable impact on fixation count for other comparisons. The study examined how fixation count (FC), a measure of eye activity, was affected by the appropriateness of a product's aesthetics. The appropriateness feature significantly impacted fixation count for some comparisons, according to the ANOVA results. Significant effects were found when comparing the silhouettes of alcohol bottles with those of energy drinks, carbonated drinks with energy drinks, water bottles with energy drinks, and milk/coffee bottles with those of energy drinks. However, for other combinations, the appropriateness feature had no discernible impact on consumers' cognitive thinking, as shown by fixation count. Total fixation duration: The appropriateness feature significantly impacted human cognitive thinking for specific product pairs, such as alcohol and milk/coffee, alcohol and energy drink, and alcohol and water, according to the ANOVA results for female respondents. Regarding total fixation duration, comparable significant effects were seen for other product pairs, including carbonated drinks and milk/coffee, energy drinks and milk/coffee, and water bottles and milk/coffee. However, when comparing alcohol with juice, water, and milk/coffee, significant effects were discovered in human cognitive emotion, but not when compared with carbonated drinks and energy drinks. For male participants, there were no noteworthy effects in comparisons across other product categories.

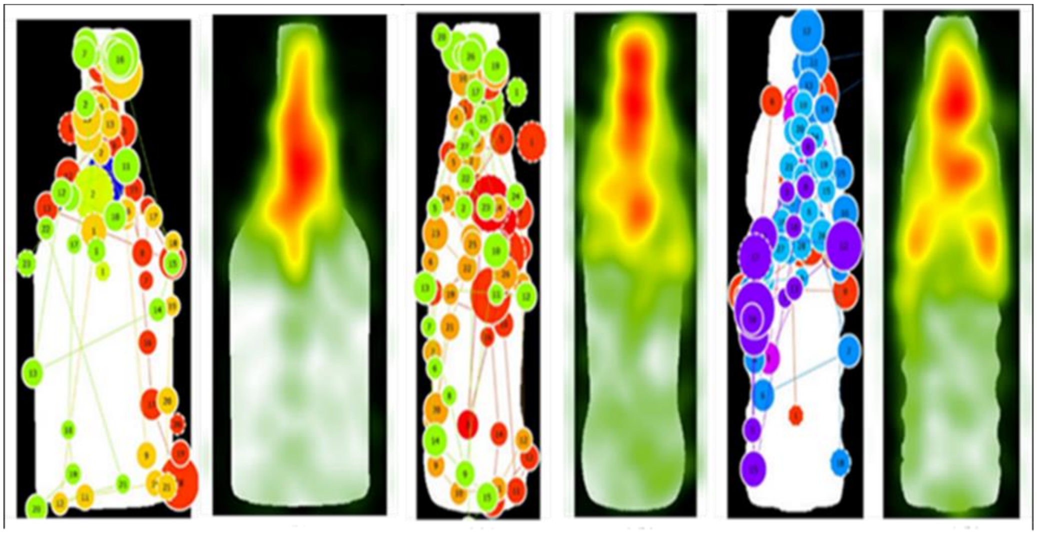


Figure 6.1.5.1.(a) Figure 6.1.5.1.(b) Figure 6.1.5.2.(a) Figure 6.1.5.2.(b) Figure 6.1.5.3.(a) Figure 6.1.5.3.(b)

Figure 6.1.5. A fixation count and heat map for different beverage bottle silhouettes.

In Figure 6.1.5, we examine three distinct beverage bottle categories and present the eye-tracking data of five participants in a detailed manner for illustrative purposes. Using these beverage bottle silhouettes, we can observe the fixation counts for the three different product categories alongside a heat map. In Figure 6.1.5.1 (a–c), the size of the circles represents the amount of time the human eye spent on a particular segment or portion of the silhouette. This indicates that specific portions evoke emotional responses in consumers. For instance, in the mid-left portion of 6.1.5.1(c), all five participants had larger fixation count diameters. This suggests that the angular and deeply curved section of the silhouette triggers greater curiosity in the participants' minds. In terms of human cognitive perception, angular and deep curves tend to evoke negative, rigid, and tough emotions. These emotions are often associated with beverage categories related to sports, energy, or carbonated drinks.

Total fixation duration: Usually, normal measures of visual attention in the area of users/customers study using eye-tracking equipment are the location of the first fixation and total fixation duration (TFD) on an AOI over the whole experiment. It is the total time of all fixations on a particular image or product (Peschel & Orquin, 2013). According to the "form follows function," the outer shape of any product provides an approximate idea of product function. Eye-tracking experiments were carried out using silhouettes of 18 beverage bottles divided into three categories (G1, G2, and G3). The ANOVA results showed a significant relationship between gender and a product aesthetics feature, appropriateness, and the total fixation duration for particular silhouettes. However, the appropriateness feature only significantly affected the third group (G3) of products in the analysis of product categories. The results of the cognitive ability task revealed different match rates between the product silhouettes and the relevant categories in each group. While others had low or medium match ratios, some product silhouettes had extremely high match ratios. Correlation coefficients were also computed to evaluate the strength of the connections between specific product silhouettes and categories. The study, as a whole, offers insightful information about how gender and the appropriateness of a product's aesthetics influence total fixation duration, cognitive thinking, and emotion when comparing product silhouettes visually. These results can help marketers and product designers create goods that better reflect consumer perceptions and feelings while also assisting in understanding consumer behavior and preferences.

The results from the total fixation time analysis indicated that respondents spent an equal and substantial amount of time on images or stimuli with angular shapes and deep curves compared to those with simpler designs or shapes. For instance, when comparing the silhouettes of alcohol bottles with those of energy drinks, milk or coffee bottles, and cold drink bottles with milk or coffee bottle silhouettes, the total fixation duration was higher for alcohol and cold drink bottles compared to the silhouettes of other categories. In experiments involving alcohol, carbonated drinks, and energy drink bottle silhouettes, respondents devoted more time compared to milk or coffee and juice bottle silhouettes. This significant difference in human cognitive thinking was evident when comparing these categories. However, the ANOVA results showed no significant difference when comparing juice silhouettes, milk or coffee, and water silhouettes, as respondents did not perceive frequent differences in shapes or angles. Consequently, the total fixation duration was similar for these categories. Moreover, ANOVA results for female respondents revealed a significant difference in human cognitive thinking regarding the appropriateness feature (perception of function) of product aesthetics and the eye-tracking data when comparing carbonated drink bottle silhouettes with milk or coffee bottles. Higher total fixation duration is indicative of greater preference and attractiveness for a product (van der Laan et al., 2015). Notably, the total fixation duration was more pronounced on the bottle's neck area, slant height area, and angular area for alcohol, carbonated drink, and energy drink bottle silhouettes. For detailed eye-tracking data on the Total fixation duration, please refer to Appendices 6.1.E, Table 6.1.12.

6.1.6. Conclusion

This research work is important as it investigates the impact of appropriateness features (perception of function) in product design on consumer expectations, helps in the enhancement of design strategies and customer desires. This study highlights the crucial role of appropriateness features in shaping consumers' pre-purchase decision-making. It's worth noting that collecting eye-tracking data is a challenging process that requires substantial time and effort, given the pronounced influence of external factors on human eye movements. This study is important because it straddles two essential fields: consumer behavior and product aesthetics. In this study, our research was guided by two hypotheses, which enabled us to measure their significance and produce significant findings. A two-phase study explores the complex and multidimensional domains of human visual and cognitive thinking through the lens of several product categories and functionalities. The intricacy of human cognitive processes and their intrinsic diversity highlight the difficulty in comprehending how customers view a product's functionality. To resolve these two hypothesis, we conducted open-ended survey and use Frequency Match Ratio (FMR) method, eye tracking experiment, and Anova analysis.

In phase-I, through the FMR score and correlation analysis, silhouette designs were rigorously categorized into high-quality, medium-quality, and low-quality designs, providing a valuable framework for assessing their match accuracy. The eye-tracking experiments revealed significant insights into human cognitive behavior, with the assessment of pupil diameter, fixation count, and total fixation duration. These experiments confirmed our hypotheses, demonstrating that consumers can identify products based on silhouettes and revealing gender-based differences in cognitive perception. The outcomes of this research shed light on the importance of aesthetics in consumer decision-making and product design. It underscores the significance of silhouette design in shaping consumer perceptions and preferences, particularly in the beverage industry. This knowledge empowers designers to create products that resonate with consumers and fulfill their aesthetic and functional expectations. Overall, this study contributes to a deeper understanding of the interplay between aesthetics and cognition, offering practical implications for marketing and product development in diverse industries.

In phase-II, a comprehensive approach to analyze consumer cognitive responses to product silhouettes. The examination of variables such as pupil diameter, fixation count, and total fixation duration provided valuable insights into how individuals perceive and interact with product aesthetics, particularly in the context of different beverage categories. Fixation count revealed distinct patterns of attention, influenced by shape, curvature, and other design elements, highlighting the role of aesthetics in eliciting emotional responses. Pupil diameter variations between genders suggested unique perceptions related to product categories, emphasizing the interplay of aesthetics, cognition, and gender. These findings contribute to a deeper understanding of consumer behavior and have practical implications for product design and marketing. The results of this study provide valuable insights into the interplay between gender, product aesthetics, and consumer cognitive responses when evaluating product silhouettes. It was found that neither gender significantly influenced the fixation count when considering the appropriateness feature of product aesthetics. This suggests a common cognitive approach among men and women when assessing product silhouettes. However, the appropriateness feature did impact fixation count for specific product comparisons, particularly for female participants. Significant differences were observed when comparing alcohol bottle silhouettes with sports/energy drink and water bottle silhouettes, as well as carbonated drink bottle silhouettes with energy drinks. Additionally, total fixation duration revealed that consumers spent a substantial amount of time focusing on silhouettes with angular shapes and deep curves. These findings highlight the complex relationship between gender, aesthetics, and cognitive processes in consumer behavior, offering valuable insights for product designers and marketers in understanding consumer perceptions and preferences. In conclusion, this study enhances our understanding of how consumers interact with product aesthetics and emphasizes the significance of design elements such as shape, curves, and texture in shaping cognitive and emotional responses. It also underscores the influence of gender on consumer perception, particularly in the context of different product categories. These insights can be leveraged by marketers and product designers to create products that better align with consumer perceptions, preferences, and emotions, ultimately enhancing the success of their products in the market.

In summary, this study has shed light on the significance of appropriateness features in product design and offered insightful information about consumers' cognitive processes and visual perception. Our study bridges the emotional and cognitive aspects of product aesthetics, which will be helpful for future research and for product designers who want to make functional products that also profoundly resonate with customers and foster a sense of relevance, satisfaction, and connection. A limitation of this study is the sample size, which could be enhanced by recruiting a larger number of participants. This would not only increase the statistical power of the results but also allow for a more diverse range of perspectives and potentially more robust conclusions. Expanding the participant pool would strengthen the generalizability of findings and offer a more comprehensive understanding of the relationship between appropriateness features and consumer decision-making. Although in the future, we will also try to understand and quantify the relationship between the term beauties with product aesthetics. Consumers not only use their visual insights for analysis purpose, but they also use their cognition power for decision-making before they purchase a product. In future work, a combination of electroencephalogram (EEG) and electromyography (EMG) is used in combination with the eye-tracking technique for acquiring more information related to human emotional or cognitive thinking and feeling related o product aesthetics. An EEG technique is used with the deep learning method to learn the human emotional state effectively. Similarly, image processing is also one of the emerging tools that can help recognize consumer emotions at the time of eye-tracking experiments.

6.1.7. Chapter Summary

In this chapter 6.1., the main aim is to understand better consumer expectations about suitable aesthetic characteristics in product design. This study intends to investigate how consumers' cognitive perceptions of product aesthetics differ from previous research, which has primarily focused on industrial product designers' emotional and intuitive perceptions. The study collects consumers' cognitive approaches toward suitable elements of product aesthetics by combining conventional and cutting-edge methodologies, tools, and equipment. This study's significance lies in consumer behavior and product aesthetics. The study uses two phases to explain how human visual and cognitive processing works, using various product categories and functionalities. The results emphasize the importance of the appropriateness feature in consumers' pre-purchase decision-making. The study also uses complicated, subject to outside influences, time-consuming, and labor-intensive eye-tracking tests. The main topics of the two hypotheses are the frequency match ratio (FMR) score, eye-tracking findings, and the relationship between the product silhouette, customer decision-making, and perception of function. The results show how suitability affects consumer decision-making and product aesthetics and cognitive thinking are related.

Chapter 6.2

An artificial neural network tool to support product designers' understanding and quantifying the beauty of 2-D product with the help of eye tracking techniques

The main goal of this study, to get a thorough grasp of product attractiveness and quantify it using qualitative and quantitative methods, is the subject of Chapter 6.2. The fundamental components of product design are categorized and analyzed using a variety of methodologies in this chapter. The result of this investigation is creating a tool that helps designers measure the aesthetic value of their products.

6.2.1. Introduction

"Appearance of a product remains one of the key features that impact the purchasing decisions of customers. In modern times, aesthetics is extensively regarded as a compelling and critical aspect of product design (Kieran, 1997; Page & Herr, 2002; Sarkar, 2018). Various product designers, psychological researchers, and design practitioners have made several attempts to create a robust engineered approach and design tool to enhance the product's quality more objectively (Pham, 1999; Chuang & Ma, 2001; Lai et al., 2005, 2006; Cawthon, 2007; Hsiao & Chen, 2018; Zain et al., 2008; Yadav et al., 2013). Similarly, the finished product, which may not always reflect the preferences of the consumer (Hsu et al., 2000), is nonetheless subjectively processed and heavily influenced by the designer's perceptions (You et al., 2006; Yun et al., 2003)." "Due to the contradictory nature of aesthetics, the proposed methods are not effective, beneficial, or practically relevant in the design process for two reasons. The first reason is the inherent combination of emotive and cognitive elements in aesthetics (Bloch, 1995; Crilly et al., 2004; Khalid & Helander, 2006). The second reason is that evaluating aesthetics requires the integration of fields such as art, engineering, and psychology, which are fundamentally distinct (Khalid & Helander, 2006). It is vital to precisely characterize the driving forces behind aesthetics in order to develop a method that can quantify them (Helander et al., 2013). Coates categorized the characteristics that make a product aesthetically pleasing into four categories: design principles, consumer features, attractiveness, and contrast (Coates, 2003). However, this classification has some shortcomings, including the lack of consideration for product function, the ambiguous intent of "aesthetic design principles," and the absence of consumer features (Khalighy et al., 2014).

With the globalization of competition, the value added to each product is progressively increasing. Consequently, creative product design becomes a crucial element for businesses to gain a competitive edge. Designers traditionally relied on their aesthetic knowledge and experience to create new products (Bloch, 2011; Sarkar, 2018). However, a perceptual consumption form is now emerging in the current market, wherein a product must not only serve a useful purpose and have an appealing appearance but also meet the needs and preferences of its target market (Singh & Sarkar, in communication; Yadav et al., 2013). Designers must understand the high standards that consumers have for their products and provide an optimal form, material, and color to maximize the added value for the product's benefit. Numerous authors have emphasized that the appearance of a product remains one of the key factors influencing consumer purchasing decisions

(Mugge & Schoormans, 2012; Dimitrios & Fang, 2012; Tang et al., 2013; B. Liu, 2021). Consequently, in the current scenario, many companies put effort into enhancing the visual appeal of their products to gain a competitive edge in this volatile market. This holds particularly true for modern consumer goods such as personal computers, smartphones, laptops, and digital cameras. To improve the attractiveness of a product's appearance, several factors must be addressed, each having objective and subjective aspects (refer to Table 6.2.1)."

Table 6.2.1. Shows the objective and subjective features of product design

Product appearance design	
Objective features	Subjective features
Aesthetic aspects	Emotional aspects
Balance	Cute
Contrast	Retro
Proportion	Luxurious
Pureness	Comfort

The characteristics of product design that are both objective and subjective, specifically product appearance design, are shown in Table 6.2.1. Subjective features are more closely related to the emotional and perceptual aspects that consumers perceive, whereas objective features refer to measurable and quantifiable aspects of the product design.

"The expression of design information through product appearance is subjective in nature. It influences how individuals interpret and perceive the shapes of a product and is closely linked to their life experiences and backgrounds, such as culture, personality, social status, age, and gender (Barnes & Lillford, 2009; Crilly et al., 2004; Ding et al., 2017; Gan et al., 2021; Jiang et al., 2018). For example, a bottle with smooth curves may evoke more "feminine" feelings and is primarily designed for female customers. On the other hand, the objective aspect of product appearance relates to the composition and arrangement of design elements, such as form, texture, color, and so on. It contributes to the overall attractiveness of a product's visual aesthetics. According to various authors (Adaval et al., 2018; Kumar & Garg, 2010; Sarkar, 2018; Zarzosa & Huhmann, 2019), the principles of aesthetic design are universally recognized compositional strategies for visual appearance design. They are crucial for effectively creating and organizing visual design elements (Huicong & Wen-Feng, 2020). These principles include organizational theories that guide the combination of visual design components to achieve aesthetic qualities like contrast, balance, proportion, and unity, resulting in aesthetically pleasing designs. Product and industrial designers often employ aesthetic design principles as they play a vital role in product design. Many well-known product designs exemplify the application of aesthetic design principles (Alcaide-Marzal et al., 2020; Kang, 2020). However, applying these principles requires careful consideration of various options to create ideal aesthetic features. For designers new to product design, this approach heavily relies on the experiences and perceptions of designers. Moreover, the utilization of design principles is often challenging to quantify for product designers when evaluating the beauty of existing design artifacts. Additionally, there has been limited emphasis on applying aesthetic design principles in the assessment of product beauty during the product development process. Therefore, this study proposes an approach to assist product designers in incorporating design principles, various factors, and constituents of aesthetics during the development and enhancement of new products, as well as in the assessment and evaluation of product beauty and design aesthetics."

"Visual aesthetics encompasses the subjective and objective significance that can be measured in terms of consumer reactions to the external reality of a product (Kieran, 1997; Crilly et al., 2004; Ulrich, 2006; Khalid & Helander, 2006; Crilly et al., 2009). The objective aspect of product aesthetics is more tangible and intuitive, while the subjective aspect is associated with the emotional responses of consumers or users (Norman, 2004; Khalid & Helander, 2006). In aesthetics, two types of reactions are generated: cognitive reactions (such as remembering, reasoning, or thinking) and affective reactions (emotional responses or activities influenced by emotions) (Crilly et al., 2004). The balance between these contrasting reactions contributes to a favorable perception of aesthetics (Coates, 2003). Moreover, the physical appearance of a product is considered pleasurable when it is capable of satisfying customers/users in both the rational and emotional aspects of aesthetics (Bloch, 1995; Jacobsen et al., 2006). These aspects are closely connected to design principles (Kostellow, 2002), human factors (Jordan, 1998), product harmony (Crilly et al., 2004), product characteristics (Shank & Langmeyer, 1994; van Breemen & Sudijono, 1999), usability (Sonderegger et al., 2012; Tuch et al., 2012), and product functionality (Verma & Wood, 2001; Singh & Sarkar, 2023). Aesthetics involves cognitive reactions to specific elements and shapes and is an integral feature of product design (Veryzer, Jr. & Hutchinson, 1998; Kumar & Garg, 2010; Heitmann et al., 2020). Additionally, visual aesthetics refers to customers' perceptions of a product's beauty and the accompanying feeling of satisfaction it evokes (Moshagen & Thielsch, 2010; Bhandari et al., 2019). Baskerville (2018) explains that from a non-practical perspective, visual aesthetics is objective (as opposed to subjective) and reflects a holistic appreciation (as opposed to the influence of specific design aspects). However, the critical approach to aesthetics (Hassenzahl, 2008) challenges the notion of absolute beauty and acknowledges that "beauty lies in the eye of the beholder," thus considering aesthetics as subjective (Kumar & Garg, 2010; Baskerville et al., 2018). Therefore, it is important to recognize the significance of beauty. Unlike attractiveness, beauty is a timeless and pleasurable experience (Etcoff, 2000) that is instinctive (Norman, 2004)."

"Beauty is always associated with a specific arrangement (Galanter, 2010) in which "design principles" are created based on that arrangement (Kostellow, 2002) and is independent of human perception (Khalid & Helander, 2006). Similarly, Khalid and Helander (2006) found that attractiveness is entirely time-dependent and is influenced by functionality (Mono, 1997; Verma & Wood, 2001; Singh & Sarkar, 2023), varying according to individuals (Huang & Henry, 2009; Singh & Sarkar, 2023). However, cognitive aspects generate 'beauty' (Coates, 2003; Crilly et al., 2004), while behavioral aspects of aesthetics create 'attractiveness' (Desmet, 2003; Norman, 2002), and both are integral elements of aesthetics (Khalighy et al., 2014). Early philosophers suggested that "beauty is an objective property of any product." However, some academics propose that it is more of a personal and subjective experience triggered by products or objects (Hassenzahl, 2004a; Hekkert, 2006; Porteous, 2013). In 1790, Kant described the relationship between beauty, taste, and aesthetic knowledge (Guyer, 2008), while Robert Solomon observed Kant's perception by stating that aesthetic understanding involves a continuous interplay between imagination and cognition, with individuals "enlivening one another" (Solomon, 2002). Philosophical perspectives on beauty often emphasize its quality of orderliness, representing well-planned, well-organized, excellent, or symmetric patterns that evoke pleasantness. Others seek to identify beauty's nature through working characteristics such as regularity, balance, proportion, rhythm, or harmony (Ngo & Byrne, 2001). The term aesthetics refers to the overall pleasure that individuals perceive through the sensory characteristics of objects (Y. Liu et al., 2017) and the observation of object beauty (Hoegg et al., 2010). Studies in aesthetics can be divided into two approaches: those that investigate how the objective and perceptual characteristics of products contribute to beauty (bottom-up), and those that explore how the subjective interpretation of objects contributes to beauty (top-down) (Hassenzahl, 2004a). From this perspective, "beauty is a result of the unique characteristics of the observer, and all attempts to establish laws of beauty are futile." This subjectivist viewpoint, captured in expressions like "beauty is in the eye of the beholder," aligns with the social constructivist emphasis on the historically changing and culturally relative nature of beauty (Kubovy, 2000)."

6.2.2. Relation of beauty with aesthetics

Aesthetic design principles were developed to provide empirical direction for visual arrangement in design, considering both arousing and calming design directions (Kim, 2006; Kumar & Garg, 2010). These principles explain how design elements can be combined to create and communicate beauty. Here is a summary of some commonly used aesthetic design principles: balance, proportion, simplicity, and contrast. Beauty is defined in terms of objective characteristics of a stimulus, for instance; amount of information, cleanness, symmetry, contrast, and shape (Santayana, 1896; Kostellow, 2002; Hekkert, 2006; Scott, 2012). Philosophers of aesthetics have extensively studied contrast as an "objective" factor of beauty (Gombrich, 1995; Solso, 1997). Fluency is often a relationship between two quantitative and objective characteristics, but flow becomes the predictive variable when they are placed side by side. Therefore, alike patterns are rated more favorably when presented with vertical symmetry rather than horizontal symmetry (Palmer, 1991), as vertical balance facilitates processing (Royer, 1981). In the same way, high contrast enhances preference for concise designs, but not for patterns displayed for extended periods (Reber & Schwarz, 2001). Additionally, objectively identical stimuli/images are calculated more positively when their processing is facilitated by priming (Reber et al., 1998; Musch & Klauer, 2003). In conclusion, we recommend considering their impact on processing fluency alongside the influence of objective characteristics. Beauty describes the relationship among the competence of design elements and is physically perceived as pleasing (Kostellow, 2002). Beauty is considered "absolute" (Coates, 2003), "timeless" (Etcoff, 2000), "independent of function" (Norman, 2004), "rational" (Khalid & Helander, 2006), and "absolute" (Coates, 2003). Beauty arises from logical or rational relationships in the physical appearance of design elements (Kostellow, 2002; Khalighy et al., 2012), where a proper stability/balance among these relationships elicits the most favorable sense of pleasantness. The standard of beauty is primarily derived from the critical elements that enable human beings to perceive visual characteristics. To describe powerful and measurable essential aesthetic features, it is necessary to start at the fundamental level. When imagining a completely blank canvas or a new painting, the first visual element that attracts any human being is known as "contrast." Contrast, simplicity, and proportion will be discussed briefly in the following section.

6.2.2.1. Contrast

Kostellow (2002) discusses the relationship between beauty and different design elements, explaining how these elements can be used to create visually delightful products. Visual delight is a crucial aspect that designers consider when creating any product. Visual aesthetics are related to the physical appearance of an object and are directly connected to what is visually perceived by human beings. The eye can perceive an object/product only when there is a distinction amongst the object's properties and the properties of the background (Kostellow, 2002). For example, in the current situation, the difference in color or proportion of the text allows you to understand and recognize the script in this manuscript or chapter. Coates (2003) refers to this phenomenon as "contrast." Contrast is not limited to the product context but is associated with the visual properties of the product. It is created by variations between the visual/physical properties of the design elements and the background. Variations in the length and height of a product, for instance, can produce contrast (Elam, 2001). Moreover, the accumulation of these variations intensifies the contrast (Coates, 2003; Crilly et al., 2004). Therefore, contrast is influenced by the amount and quality of variations created by the elements and an alignment of the design. The higher the variation in elements and composition, the higher the contrast, and the other way round (Khalighy et al., 2014). Contrast refers to the deliberate placement of design elements that are noticeably different from one another in order to attract attention, evoke emotions, and emphasize information. It serves to create visual interest and draw the viewer's focus.

6.2.2.2. Pureness

Simplicity is a key aesthetic principle that plays a significant role in human perception and interpretation. Simple forms are easier for humans to notice and understand compared to ambiguous or complex ones. In design, the aesthetic of simplicity is often employed to enhance the comprehensibility of a design by removing unnecessary components and superfluous design features. Kostellow (2002) describes purity as a measurable aspect of contrast. Coates (2003) also identifies design elements that captivate human beings in their study. Consequently, lower purity corresponds to a higher power of grabbing attention and engaging the mind, while higher purity has the opposite effect (Khalighy et al., 2012). Additionally, as the number of visual or physical elements increases, purity becomes another factor to consider. Purity can be quantified and is an essential characteristic associated with the concept of beauty.

6.2.2.3. Proportion

An essential aspect of aesthetics is proportion, which deals with the relationship and interactions between the various visual components of a design. It is a qualitative aspect of contrast, which means that rather than precise measurements, it relies more on subjective observation and in-the-moment case studies of consumers or users. The visual similarity or dissimilarity of design element properties, such as size, nature, placement, and colour, determines proportion (Papanek, 2022).

A crucial component of proportion is visual stability, achieved by distributing visual weights among the components of a design (Coates, 2003). Lower similarity between elements indicates a lower proportion, while higher similarity suggests a higher proportion. It is crucial to achieve visual balance, which can be divided into three categories: symmetry (formal balance), asymmetry (dynamic balance), and peripheral balance. To correspond to our sense of balance physically, our eyes naturally seek visual balance by wanting the distribution of visual weight to be evenly spread on both sides of an axis (Jordan, 1998; Kostellow, 2002; Abdulhussain et al., 2023). A fundamental design principle in styling, proportion plays a significant role in comparing the scales and sizes of elements and the overall design. Historically, aesthetic procedures have been produced using traditional proportional techniques like root rectangles or the golden ratio (1:1, 1.414, 1.618, 1.732, and 2) (Ngo et al., 2003). The principles of aesthetic design, on the other hand, are typically expressed qualitatively when they are discussed, drawing on the perspectives and expertise of designers. At the same time, some proportional systems offer numerical ratios, and measuring aesthetic design quantitatively or objectively can be difficult. To gain insight into the various components of aesthetic design and how they interact, the study of aesthetic design focuses on comprehending and analyzing its fundamental elements and components. By studying the beauty features of product aesthetics design, designers and researchers can gain a deeper understanding of what makes a design visually appealing and how to apply these principles to create aesthetically pleasing products successfully. This knowledge can improve customer experiences, make products more attractive, and influence customer preference and satisfaction.

6.2.2. Interaction between aesthetic attributes

The relationship between pureness/purity, proportion, and contrast is indeed crucial in understanding the beauty of a product. As you mentioned, based on the literature and previous research, pureness and proportion are functions of contrast, and their relationship is inversely proportional. This means that if the proportion and pureness increase, the contrast decreases, and vice versa. When the proportion/balance and pureness/cleanness are deficient, the contrast is high. By considering this relationship, we can understand why certain design principles, such as the "golden ratio," are highly regarded. The golden ratio represents a specific proportion that maximizes the beauty of a design. It is believed to have the highest proportion of rectangles compared to squares, resulting in rectangles that look similar as they deviate from a square. This similarity in proportions contributes to the aesthetic appeal of the design. Overall, the relationship between proportion, contrast, and pureness plays a significant role in achieving optimal beauty in a product design. By understanding and utilizing these principles effectively, designers can create visually appealing and harmonious compositions.

6.2.3. Research gaps

The study you described aims to overcome the limitations of existing methods for assessing the beauty of a product. These limitations include relying on theoretical analysis, subjective judgments from expert designers, and qualitative assessment techniques. To address these challenges, your study proposes a quantitative approach that combines logical reasoning, mathematical techniques, and eye-tracking technology using Tobii equipment. By using Tobii eye-tracking equipment, you can gather objective data on how individuals visually perceive and interact with a product. This data can provide insights into the visual attention and preferences of users, allowing for a more accurate assessment of product aesthetics. The quantitative approach employed in your study allows for the quantification of the value of product aesthetics over a wide range, providing a more comprehensive understanding of its beauty. The developed tool based on this approach is user-friendly and easy to understand, providing support to designers in assessing the beauty of a product. By incorporating logical reasoning, mathematical techniques, and empirical data, your study aims to provide a more robust and reliable method for evaluating product aesthetics.

Overall, your research approach combines objective data collection through eye-tracking technology with quantitative analysis to address the limitations of existing methods and provide a more comprehensive assessment of product beauty.

- To understand and quantify the beauty of an object by using the essential constituent of product aesthetics.
- To develop an AI-assisted tool that supports industrial designers in improving the aesthetics of products during the product development process and generates a user-friendly graphical user interface.

The development of the tool starts with the identification of constituent factors and design elements that contribute to the beauty of a product. These factors include contrast, proportion/unity/harmony, and purity/pureness, which have been established as essential constituents of beauty (Singh & Sarkar, 2023).

To create the tool, an Artificial Neural Network (ANN) model is employed. The model utilizes different constituents/factors or attributes of beauty as inputs, including design element parameters, fixation count, total fixation duration, standard deviation of fixation duration, pupil diameter, heat maps, cluster maps, and more. The output of the model includes measures of pureness, proportion/unity, contrast, and contrast/total time. In addition, during this study we considers a set of proportions, including ratios such as 1:1, 1.414, 1.618, 1.732, and 2, to comprehensively capture the relationship between proportion and beauty. The Artificial Neural Network (ANN) model is combined with a graphical user interface (GUI) to improve usability, creating a straightforward and efficient tool that helps designers improve the aesthetics of their products. This tool is the first of its type and provides a distinctive method for evaluating the aesthetic appeal of a product. Your study offers designers a valuable and approachable tool for assessing and improving the aesthetics of their goods by fusing the ANN model with a GUI. Incorporating a wide range of input parameters and considering the recognized constituent aspects and design elements, the tool provides objective ratings of beauty based on computational analysis.

6.2.5. Aim and Methodology

6.2.5.1.Aim

In this study, our main focus is to comprehensively understand and quantify the beauty of products both qualitatively and quantitatively. Additionally, we aim to develop an AI tool that can assist industrial designers in enhancing the aesthetics of their products during the product development process. To achieve this, we consider the source of beauty traits as a critical factor that enables the human eye to distinguish the visual features of product aesthetics. We specifically analyze contrast, which is composed of pureness and proportion, as a measure of beauty. Therefore, we incorporate contrast, balance/proportion/harmony, and pureness as crucial factors in our analysis, based on sensory perception. The main concern during the development of this tool is to eliminate the need for manual computations in order to identify the beauty of a product. To address this, we have incorporated consumer cognition data, specifically eye-tracker data, in the backend of the tool. By applying a mathematical relation to this data, we can determine the values of beauty automatically. This approach offers the advantage of quantifying beauty terms in the aesthetics domain with the assistance of engineering principles. The tool operates with a primary GUI that simplifies the process for industrial designers. They can effortlessly select their input parameters (design) through the GUI, and the tool presents the resulting outcomes. Designers have the flexibility to iterate as many times as they desire, with the associated inflows and outcomes saved in a file for future reference. At any point, designers can review the file to observe how changes in input parameters influence the outcome parameters of the product design. This iterative tactic empowers designers to fine-tune the feeding parameters until the preferred outcome is achieved. It encourages the exploration of various potential design options within the scope of the study. It is important to note that such a tool is currently not available in the market. The technology we have developed has shown the capability to deliver outcomes with up to 95% accuracy. This tool significantly supports industrial designers in enhancing the engineering aesthetic of their products, providing them with a valuable resource in the design process.

6.2.5.2.Methodology

In Section 6.2.2.1, it was mentioned that beauty is formed through logical reasoning and visual relationships among the design elements. These relationships contribute to achieving a balanced composition, which in turn generates a sense of harmony and pleasantness. Straight-thinking or logical reasoning refers to the process of analyzing and understanding the visual connections and interactions between different design elements. It involves considering factors such as proportion, contrast, unity, and purity to create a cohesive and aesthetically pleasing composition. The concept of definite balance implies that there is a specific equilibrium or harmony that needs to be achieved among these visual relationships. When the design elements are arranged in a balanced and harmonious manner, it results in an ideal amiability or a pleasing aesthetic experience for the viewer.

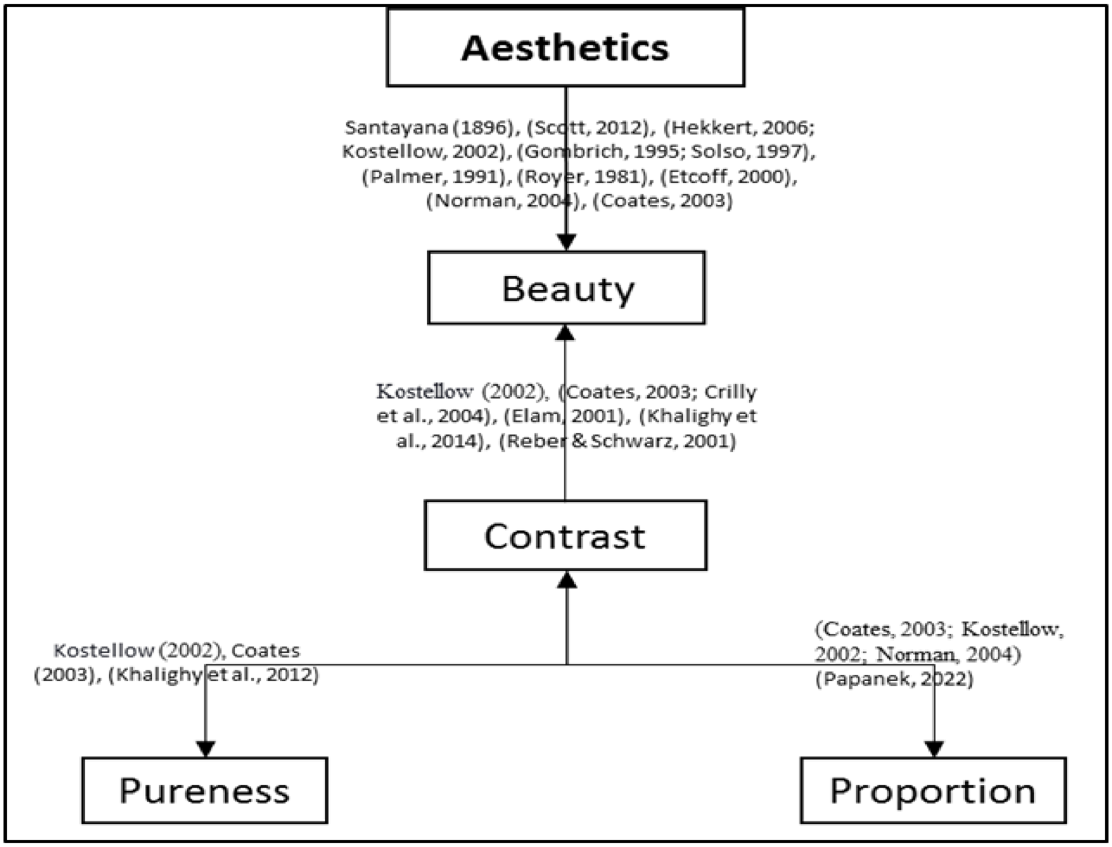


Figure 6.2.1, shows the relationship diagram of beauty with their essential constituents

Therefore, to conduct this study, we follow specific steps which are mentioned in figure 6.2.1. This figure shows the relationship diagram of beauty with their essential constituents.

6.2.6. Experimental setup

- The experiment was conducted in a laboratory with dimensions approximately 10 * 10 square meters.
- To minimize distractions, the windows in the lab were covered with black paper, and only simulated light was used. And all the experiments took place during nighttime. Before starting the experiment, the stimuli were uploaded into the Tobii Pro TX300 software on a laptop. The participants were instructed to sit in front of the "Pro TX300 eye tracker with the supplied screen."
- The eye tracker device had four eye-tracking sensors located underneath it, as depicted in figure 2. A dedicated laptop was used for the experiment, which had the Tobii Pro TX300 software installed. This software was responsible for monitoring the eye-tracking procedure, and the images were displayed on the "Pro TX300 eye tracker with the supplied screen." The eye-tracking software was executed on the laptop.
- Prior to displaying the visuals on the screen, the participants' eye positions needed to be calibrated. This calibration process involved the participants focusing on a red dot displayed on a white background. The red spot moved to various positions on the Tobii monitor, aligning with the position of the participant's pupil. This calibration procedure was repeated to verify its accuracy.

- After successful calibration, the software indicated whether recalibration was necessary or if the calibration was successful. If the calibration was deemed ineffective or unsuccessful, the participant's seating position, including the distance from the supplied screen, height, and angle, needed to be checked before proceeding with the experiment. Once the calibration process was completed successfully, the stimuli were displayed on the screen, and the eye movements of the participants were recorded. These eye movements were recorded for further analysis and assessment, as shown in figure 6.2.2.

6.2.6.1.Experimental structure (measuring device)

To objectively quantify the aesthetic attributes of a product, a measurement device capable of recognizing visual attributes from involuntary stimulation is necessary. This device should be able to track eye behavior since the entire perception process is visual. Eye-tracking equipment refers to technology that can monitor and track eye movements and gazes. This tools has been widely used in design related investigations, including studies on sketchers' eye movements (Sun et al., 2014). Using eye-tracking devices, it is possible to measure the positions on images that viewers focus on and the time of every fixation. It refers to the interval among each eye activity. Additionally, these devices can determines the size and duration of blinks as well as pupil dilation. In the experiments conducted for this study, an advanced eye-tracking device called the "TX 300 eye tracker" from Tobii, a Sweden-based manufacturer, was used. The TX300 eye tracker is capable of accommodating significant head motions and has a high sampling rate, allowing for precise eye movement measurements. You can refer to figure 6.2.2 for an image of the eye tracker device.

Figure 6.2.2, Pro TX300 eye tracker with the supplied screen

6.2.7. Experimental area

The Tobii TX300 Eye Tracker is a discrete eye-tracking device designed for in-depth studies of natural behavior. It is equipped with a detachable 23-inch TFT monitor that has a resolution of 1920 * 1080 pixels, as depicted in figure 6.2.2. For the eye-tracking tests, Tobii Studio software was utilized, providing a comprehensive platform for collecting and analyzing eye gaze data. To ensure accurate measurements and minimize interference, the experiments were conducted in a separate section of the lab during nighttime. This controlled environment helped to eliminate distractions from noise, infrared light, and other participants that could affect the eye-tracking data collection process.

6.2.8. Eye-tracking input and output data

During the eye-tracking research, the Tobii TX300 Eye Tracker was utilized, which includes an integrated user camera to capture participants' responses to stimuli. The eye-tracking experiments were conducted using Tobii Pro Studio software. To begin the experiment, high-resolution images in PDF format (1024 * 768 pixels) were uploaded into the Tobii Pro Studio software. The software recorded various data during the experiment, including timestamp data, gaze event data, recording event data, AOI (Area of Interest) activity information, time duration, fixation duration, visit duration, gaze tracking data, and more. The output data from the Tobii Pro Studio software was saved as an .xlsx or .tsv format file, which can be easily accessed and analyzed. The data can be exported in a text format that is compatible with MS Excel, allowing for convenient data interpretation and analysis.

6.2.9. Measuring formula

A clearly defined process is required to guarantee the accuracy and durability of the methodology for evaluating the visual design features of products. The usage of the eye-tracking apparatus and the assessment tool, as well as the gathering and analysis of the output data, are all included in this procedure. As previously indicated, the output data includes a variety of eye-related metrics, including the number of fixations, where they were made, and how long they lasted overall for each trial. These measurements offer information about participants' visual engagement and attention to the aesthetically pleasing aspects of the product.

Pureness quantification: In terms of design aesthetics, simplicity or minimalism of a design, where fewer features are present, is referred to as pureness. It has nothing to do with the actual number of elements in a design. Instead, the goal is to create an uncluttered visual composition and a sense of clarity. During eye-tracking experiments, the number of fixations observed may not always correspond to the overall number of design elements. Fixations are the areas of a design where viewers tend to concentrate their attention. While viewers may pay attention to every piece in a design, there must be a clear relationship between the number of fixations and the number of elements. Since fewer elements produce higher pureness, pureness is a measure of the number of design elements. Because spectators are probably to focus on every element, the eye-tracking stats/outcomes number of fixations accurately reflects the total number of design elements because the higher fixations, the larger elements there are. Thus, Amount of fixations = NF.

$$\text{Pureness} = 1 / NF \qquad (6.2.1)$$

Proportion quantification: The relative size, spatial relationships, and placement among the elements in a composition are called proportion in design. It is essential for drawing and focusing the viewer's attention.

The balance and visual harmony when elements are positioned in the right proportions can improve the overall aesthetic appeal and help direct the viewer's attention. A design's aesthetic harmony and balance are influenced by proportion. A feeling of equilibrium and coherence is produced when parts are placed in an attractive and balanced manner using proportional placement. This harmony can direct the viewer's focus throughout the composition and have a pleasing visual experience. According to the definition, items in the right proportion draw the eye for the same period of time due to identical visual forces. Hence, a “higher standard deviation” of fixation length denotes a lesser proportion. Thus, standard deviation of fixations of duration = σF.

$$\text{Proportion} = 1 / (\text{Standard deviation of fixations})$$

$$\text{Proportion} = 1/ \sigma F \tag{6.2.2}$$

Measurement of contrast: As mentioned earlier, there is an inverse relationship between proportion/harmony/unity and purity/pureness. While both factors contribute to the overall contrast value, they are combined through multiplication.

$$\text{Contrast} \ \alpha \ 1/ \text{Pureness}, 1/ \text{Proportion} \tag{6.2.3}$$

$$\text{Contrast} = \text{Standard deviation of fixations} * \text{Number of fixations} \tag{6.2.4}$$

Similar formulas were proposed by Eli Peli (1990) and apply the “Std. devi.” of pixels depending on the value of the grey scale to determine the contrast of images (Peli, 1990). Contrast is the percentage of the observational interval during which the eye exhibits unpredictable behaviour, as inferred from the calculation. In this context, the term "whole time" refers to the period of observation before the viewer is able to make a decision.

6.2.10. Artificial neural network (ANN)

A machine learning method called ANN is used to find intricate, nonlinear correlations between several sets of data (Tang et al., 2013; Deumert, 2018; Dou et al., 2019). This method studies from the data labeling some normal phenomena and draws inspiration from the human nervous system (Sharma & Venugopalan, 2014). Other methods include “Support Vector Machine (SVM)”, “Naive Bayes”, and “K-Nearest Neighbors (KNN)”, although these methods depend on intricate mathematical operations to work. Without the requirement for any mathematical representation, ANN has the extraordinary capacity to create empirical relations between dependent and independent variables (Sadiq et al., 2019). When dealing with data that has high noise, ANN models outperform regression-based algorithms. In comparison to traditional methodologies, ANN effectively manages the unpredictability in the incoming data and recognizes the arrangement of data to predict the outcome with a substantial degree of accuracy (Kang et al., 2011; Noble & Tribou, 2007). The wearable payments system (Lee et al., 2020), forecasting faith in online announcement (Leong et al., 2020), user preference investigation (Chen et al., 2020), predication of residential water (Bennett et al., 2013), among many other applications, have all seen extensive use of ANN models. Figure

6.2.2, presents the methods used for the creation of an ANN-based tool. Below, various stages of tool development are discussed in order.

Step 1: Various input parameters pertaining to the product beauty were chosen in the first step. The input parameters include the dimensions of the whole product as well as each element wise, color in RGB scale, number of products and their elements. Based on the knowledge that was accessible. Therefore, these were the only parameters used.

Step2: In this phase, various magnitudes of the input variables were recognized, as presented in Appendix 6.2.B and Table B. These magnitudes of data/values with the span were used to bring out 50 mixtures of the input variables. These 50 mixtures of input variables (product outer dimensions, element dimensions, color in RGB system) are freely available. In such a scenario, different variables of Tobii Eye Tracker for the different sets of combinations should be extracted to find out the proportion, pureness, contrast, and beauty of product aesthetics. This feature is taken care of in 3rd phase, as provided below.

Step 3: In this phase, the output values i.e. fixation count, standard deviation of fixation duration, and fixation duration were quantified to all the 50 cases of the input values position.

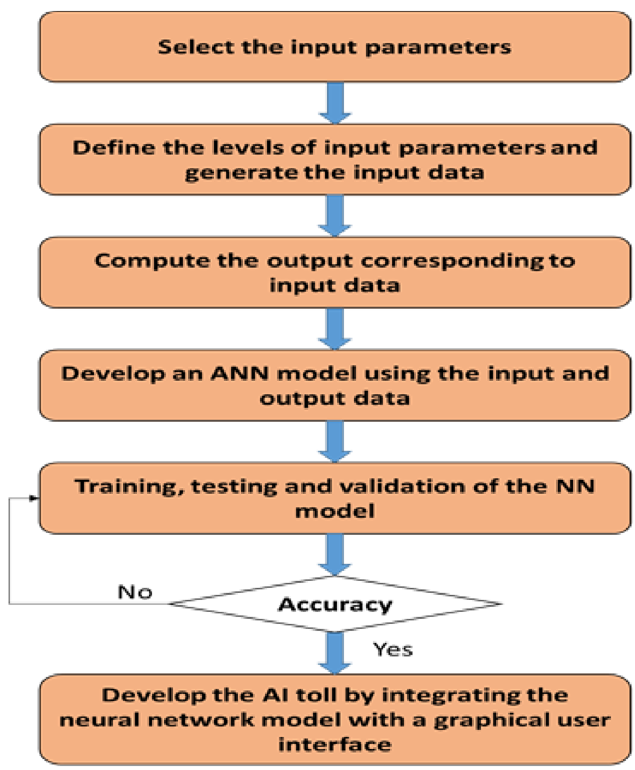


Figure 6.2.3, Shows the structural design of ANN model

These 50 mixtures of input variables i.e. Fixation count, standard deviation of fixation duration, and fixation duration are extracted in sequence of steps. First, the respondents saw the images of different combinations of dimensions, color and different sets of elements. Then, the eye tracker notes down the eye movement of respondents for particular images, and then generates the different set of variables for each image. After getting the values of different set of variables from the eye tracker, the procedure to calculate the proportion, pureness, contrast, and contrast/total time, after that we find out beauty of the product is as follows.

6.2.11. Design of experiment

In this study, two sets of eye-tracking experiments were conducted: the logical experiment and the product base experiment. Each experiment had approximately 89 respondents participating. The objective of the study was to find the essential constituents of beauty in terms of engineering aesthetics and explore their relationship with beauty using eye-tracking equipment and open/closed-ended surveys. Before the final experiment, a pilot experiment was conducted with around 15 participants. However, the results of the trial experiment were not included in the final set of experimental results, and the output data from the pilot experiments were not considered. In the final experiment, a total of 74 respondents participated. Out of these, data from 69 participants were considered for analysis, while the remaining participants' data were discarded due to incomplete experiments or irregularities. In the final experiment, a total of 74 respondents participated. Out of these, data from 69 participants were considered for analysis, while the remaining participants' data were discarded due to incomplete experiments or irregularities.

Design of experiments:

- During the experiment, we examined the camera's aesthetics and the combinations of design elements in the images that served as products. We drew squares with rounded and straight edges, circles, triangles, and stars in various sizes for the design element images. As shown in Table 6.2.4, we considered several real-time parameters for the camera product at multiple levels. We created 50 photos in total using various combinations of factors and levels.
- We utilized Taguchi Orthogonal Arrays L50 ($2^{15} \times 11$) to create partial factorial combinations of the design parameters to identify the camera product's design samples quickly. CAD software was used to create the images, and we also gathered wireframe images for each design that included all colour ratios.
- The eye-tracking experiment and the open-ended experiment made up the two sections of the investigation. We made two Microsoft PowerPoint presentations before the eye-tracking test: one with all 50 camera images and the other with logical pictures of design elements. For the experimental purpose, both sets of images were uploaded as PDF files to the Tobii software.
- The Tobii eyetracker was placed in front of the participants, who were instructed to view the images there. They calibrated their eye positions before each experiment. The images were presented to the participants one at a time during the eyetracking experiment, and they were free to proceed to the next image at their own pace. A white blank screen was displayed on the Tobii screen after every fifth image to relieve any eye strain or fatigue.
- The open-ended experiment was conducted after the eyetracking experiment, and participants in both experiments completed the questionnaire found in Appendix 6.2.D.A and B. Results

from the eyetracking experiment included fixation count, total fixation duration, fixation duration standard deviation, total time spent, and Likert scale-based aesthetic preference.

Eye-tracking metrics such as fixation count, fixation duration, and total fixation duration are used to track and measure participant eye movements as they view objects such as images or products.

Fixation Count: The number of times a participant's gaze is relatively stable on a particular area of interest (AOI) within the visual stimuli is referred to as fixation count. Fixation count can determine which areas or design features of the stimulus draw more attention and are regarded as visually appealing in beauty proportion assessment. If a design element receives a higher fixation rate, it suggests they are essential to the visual stimuli's overall aesthetic appeal and beauty proportion.

Fixation Duration: The length of time a participant's gaze is fixed on an AOI is referred to as fixation duration. Longer fixation periods on particular design elements suggest that participants look at those elements more carefully. Longer fixation durations on clear and uncluttered design elements in assessing visual purity imply that participants find these elements more aesthetically pleasing and visually pure. Similar to this, longer fixation times on areas of high contrast in contrast assessment show that participants are drawn to these areas due to the visual impact produced by the contrast.

Total Fixation Duration: The total time a participant spends fixating on all their areas of interest in the visual stimuli is known as total fixation duration. It gives a general indication of the participants' attention and engagement with the stimuli. In evaluating beauty proportion, purity, and contrast, a higher total fixation duration on particular design elements or areas can suggest that these elements are more aesthetically pleasing and can hold the participants' attention for a longer period.

Standard deviation of fixation duration: The variability or spread of fixation durations within a set of eye-tracking data is quantified statistically by the standard deviation of fixation duration. Each fixation duration in eye-tracking experiments refers to the amount of time the participant's gaze is relatively stable on a single area of interest. Participants' gaze frequently shifts between regions of interest during the experiments. The fixation duration standard deviation offers insightful data on the consistency or variability of participants' gaze behavior. A higher standard deviation suggests that fixation durations are highly variable and that participants' attention is split up among several different areas of interest, each with a different duration. A lower standard deviation, on the other hand, suggests that fixation durations are more constant and comparable across various areas of interest.

Table 6.2.2. Participants detail for the design of experiment

S. N.	Number of participants	Educations	Gender	Average Age	Living locations	Number of candidate
1	49	B.Tech	Male	17-19	Town	21

		M.Tech/M.Sc.		23.5	Village	20
		PHD		28.5	Metro city	8
2	40	B.Tech	Female	19.5	Town	17
		M.Tech/M.Sc.		23.5	Village	15
		PHD		27.5	Metro city	8
Total	89					89

6.2.12. Data collection

During the data collection process, we sought the participants' willingness to participate in the experiments, which were conducted in 2 phases. In phase-I, we present the logical images, which is design with the help of different design elements, while the second phase involved showcasing a commercial product commonly used in daily life. As previously mentioned, we provided participants with comprehensive information regarding the selection procedure for the experimental study. We initiated the experiment by focusing on the logical base stimuli, which encompassed a total of 17 different stimuli generated using a variety of dimensions, categories, shapes, and design elements. The detailed listing of these stimuli can be found in Table 6.2.B and Appendix 6.2.B.

6.2.13. Results and discussion

6.2.13.1. Phase-I study

During the data collection process of the Phase I study, we carefully arranged the stimuli listed in Appendix 6.2.A, and Table 6.2.A to enable us to collect both objective and subjective information from the participants for each stimulus. For every stimulus, we administered an open-ended survey included in Appendix 6.2.B and Table 6.2.B, to gather participants' theoretical aesthetic preferences. In addition to the survey, we conducted an eye-tracking experiment to quantitatively measure the beauty of the stimuli. Each participant took part in a total of 8 experiments, which involved presenting different stimuli and collecting data on participants' subjective preferences through the open-ended survey. Simultaneously, we utilized eye-tracking equipment to capture and analyze participants' eye movements during the experiments. The eye-tracking data provided valuable metrics for quantifying the beauty of the stimuli. Various variables or factors were derived from the eye-tracking data, and these could be calculated using mathematical relations or formulas. Section 6.2.9, of the study briefly describes the mathematical relations or formulas, including equations 1, 2, 3, and 4, which were employed in the analysis. The eye-tracking data provided valuable metrics for quantifying the beauty of the stimuli. Various variables or factors were derived from the eye-tracking data, and these could be calculated using mathematical relations or formulas. Section 5.4 of the study briefly describes the mathematical relations or formulas, including equations 1, 2, 3, and 4, which were employed in the analysis. The outcomes of the eye-tracking test are shown in Table 6.2.3 in the columns "Number of fixations (sum)/Fixation Count," "Standard deviation (Std. devi.) Of fixations in sec/microseconds," and "Total time (sum of fixations) in sec/microseconds."

Table 6.2.3, shows the value of Standard deviation of fixations (sec), Total time/sum of fixation (sec), Contrast, Contrast/Total time, Preference for the different Logical stimuli

Stimuli	Number of fixation/Fixation Count (sum)	Pureness %	Standard deviation of fixations (sec)	Proportion	Contrast	Total time/sum of fixation (sec)	Contrast/ Total time	Preference
Image 1(A)	76	31.58	2.73	0.366	17.29	25.5	0.678	46.58
Image 1(B)	99	24.24	2.17	0.461	17.90	36.5	0.490	52.8
Image 2(A)	138	17.39	3.81	0.262	43.82	48.5	0.903	56.8
Image 2(B)	72	33.33	2.2	0.455	13.20	24.7	0.534	45.2
Image 3(A)	73	32.88	1.97	0.508	11.98	20.2	0.593	63.7
Image 3(B)	155	15.48	3.46	0.289	44.69	48	0.931	26.91
Image 4(A)	70	68.57	2.24	0.446	13.07	23.43	0.558	18.16
Image 4(B)	59	81.36	1.32	0.758	6.49	13.53	0.480	35.5
Image 4(C)	130	36.92	2.13	0.469	23.08	42.33	0.545	10.5
Image 4(D)	65	73.85	2.63	0.380	14.25	17.15	0.831	26.84
Image 5(A)	68	70.59	2.23	0.448	12.64	23.82	0.531	16.14
Image 5(B)	49	97.96	1.09	0.917	4.45	11.23	0.396	9.86
Image 5(C)	152	31.58	2.3	0.435	29.13	39.83	0.731	47.54
Image 5(D)	54	88.89	3.04	0.329	13.68	18.82	0.727	26.46
Image 6(A)	138	26.09	3.81	0.262	43.82	48.5	0.903	34.09
Image 6(B)	105	34.29	2.12	0.472	18.55	29.41	0.631	9.11
Image 6(C)	151	23.84	3.71	0.270	46.68	56.28	0.829	56.8
Image 7(A)	28	171.43	1.11	0.901	2.59	9.28	0.279	25.21
Image 7(B)	103	46.60	1.84	0.543	15.79	29.5	0.535	9.89
Image 7(C)	126	38.10	2.67	0.375	28.04	36.1	0.777	46.4
Image 7(D)	38	126.32	1.08	0.926	3.42	11.3	0.303	18.5
Image 8(A)	81	59.26	2.31	0.433	15.59	28.5	0.547	33.67
Image 8(B)	89	53.93	2.08	0.481	15.43	26.8	0.576	19.68
Image 8(C)	124	38.71	3.29	0.304	34.00	45.6	0.746	35.38
Image 8(D)	40	120.00	0.71	1.408	2.37	6.82	0.347	11.27

Note: As A, B, C, and D represents number of images in different stimuli which is used during experimental purpose.

These measures shed light on the participants' eye movements and visual focus levels while taking in each stimulus. The "Number of fixations (sum)/Fixation Count" field indicates the total number of fixations recorded for a certain stimulus. It shows how frequently participants adjusted their eyes or concentrated their attention on various aspects of the stimuli. The "Standard deviation (Std. devi.) Of fixations in sec/microseconds" measures how randomly or variably fixations last. A higher standard deviation shows that participants' fixations lasted for various lengths of time, showing variations in their visual exploration and attention patterns. The cumulative length of fixations on a stimulus is shown as "Total time (sum of fixations)

in sec/microseconds." It gives a sense of how long participants spend focusing on the stimulus overall, which reflects their level of interest and attentiveness. On the other side, the "Pureness," "Proportion," and "Contrast" columns represent participants' preferences and work as numerical indicators of a product's aesthetic beauty and preference. These measurements are used to assess the aesthetic value and appeal of the stimuli. The experiment tries to forecast how the design components and forms affect the product's perceived beauty and aesthetic preferences by studying the relationship between eye-tracking metrics and aesthetic preference metrics. The gathered information allows for the investigation of how various design characteristics affect the attractiveness and importance of the stimulus, revealing the function of design components in forming an aesthetic perception. A small explanation of table 6.2.3, is provided given below:
Throughout the eye-tracking experiment, "Element 1.A" received a total of 76 fixations. This element was the focus of participants' attention 76 times. 15.8% is the element's pureness percentage (or "Element 1.A"). It suggests that this design element is perceived as visually cleaner and less cluttered compared to elements with higher fixation counts because it received fewer fixations in comparison to other elements.

Fixation standard deviation (sec): The fixation standard deviation for "Element 1. A" is 2.73 seconds. It gauges the degree of variation in fixation times on this particular element. The idea that participants' gaze may have been less steady or more dispersed when looking at this element is supported by a higher value, which denotes more significant variability.

Relative to the standard deviation of fixations, the proportion value for "Element 1. A" is 0.37, which is calculated. A higher proportion value indicates that fixations on this element were more evenly distributed, which adds to the overall feeling of harmony and balance in the visual field.

Total time/sum of fixation (sec): During the eye-tracking experiment, participants focused their attention on "Element 1. A" for 25.5 seconds.

Contrast: The product of the standard deviation of fixations and the total number of fixations yields the contrast value for "Element 1. A" of 1.84. A higher contrast value means that this element was visually appealing and attention-grabbing, attracting a wide range of fixations.

Contrast/Total time: "Element 1. A" has a contrast/total time ratio 0.07. It shows how much time overall was spent on this element in relation to its contrast value. A higher ratio suggests that "Element 1. A" attracted a significant portion of participants' attention during the experiment.

Preference: "Element 1. A" has a 46.58 preference score. Based on their subjective assessments and emotional reactions, this suggests that participants expressed a moderate preference or liking for this design element.

The “number of fixation” on "Element 1. A" was moderate, indicating that it attracted a fair amount of interest. It was regarded as more visually appealing and had fixations distributed fairly evenly, adding to a sense of proportion and balance. The element's moderate contrast value indicated interesting and varied visual characteristics. A total of 25.5 seconds were spent by participants fixated on "Element 1. A," and gave it a 46.58 preference score, indicating a moderate level of liking. The heat maps of the logical images is shown given below in Figure 6.2.4.

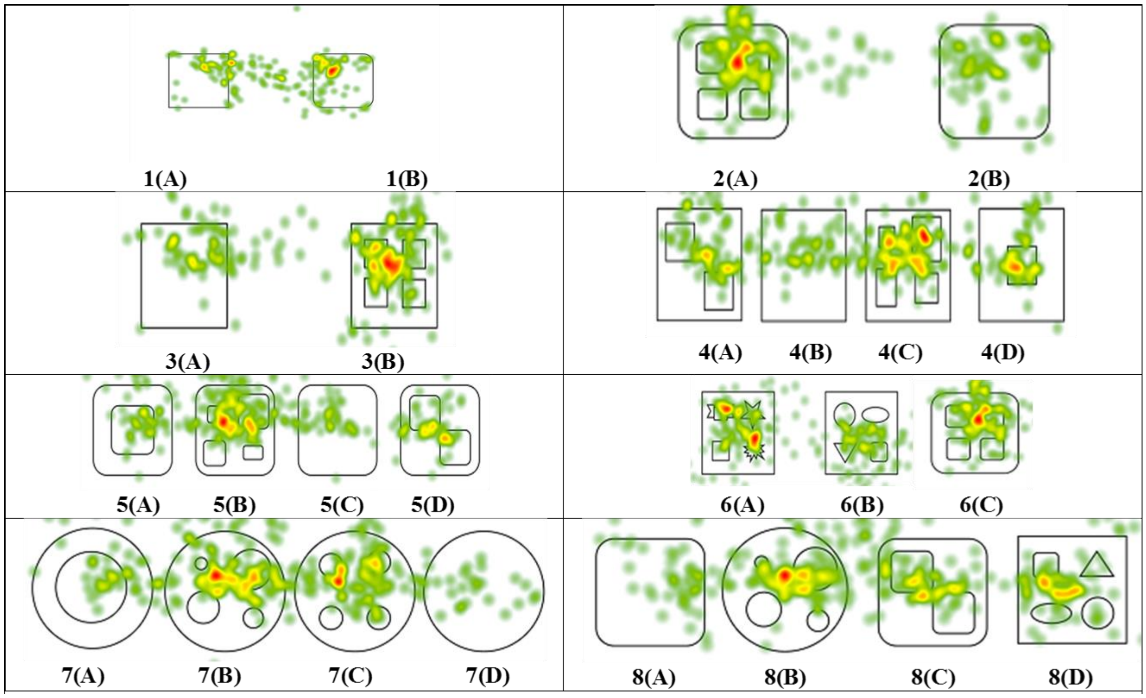


Figure 6.2.4, shows the hotspots of each logical image after eye tracking experiment

The standard deviation of fixations for Image 1(A) is 2.73 seconds (273 microseconds), while for Image 1(B) it is 2.17 seconds (217 microseconds). These statistics indicate the level of participants' attention drawn to the stimuli. A higher fixation count per fixation may suggest that the stimulus attracted more visual attention, requiring participants to focus on multiple details or characteristics to comprehend it fully. On the other hand, a lower fixation count implies that the stimulus was less visually engaging, requiring fewer fixations to understand. For Image 2(A) and 2(B), the fixation counts are 138 and 72, respectively. The standard deviation of fixations is 3.81 seconds (381 microseconds) for Image 2(A) and 220 microseconds (2.2 seconds) for Image 2(B). The heat map for these elements appears more intense compared to others. The "Standard deviation of fixations (sec)/(msec)" is a measure used in eye-tracking studies to indicate the variability in fixation durations among participants. It reflects how fixation periods are distributed around the mean value. Fixation duration refers to the time when the eyes remain stationary and focused on a specific object before shifting attention elsewhere. A higher standard deviation of fixations indicates greater variability in fixation durations among individuals. This variability may reflect differences in visual exploration or cognitive processing approaches employed by individuals. Regarding Image 8(A), 8(B), 8(C), and 8(D), the fixation counts are 81, 89, 124, and 40, respectively. The corresponding standard deviations of fixations (in seconds/microseconds) for these elements are 0.71 (710 microseconds), 2.31 (2310 microseconds), 2.08 (2080 microseconds), and 3.29 (3290 microseconds), respectively. Round items and circles often exhibit symmetry and follow Gestalt principles such as closure and continuity. These factors influence the perception of visual harmony and completeness. A higher fixation count for these elements indicates that individuals focused more on recognizing and appreciating their symmetrical or well-formed qualities. In conclusion, based on the fixation counts and aesthetic preferences, we can determine that elements 8(A) and 8(C) have a higher fixation count and receive more aesthetic preference compared to others.

6.2.13.2. Phase-II on real product

Phase II study, focused on the assessment of beauty and product aesthetics by using cameras as the product during phase II study. Before conducting any experiments, the visual characteristics of real cameras were established to serve as design examples. The study specifically considered the styling design and color aspects of the cameras. To guide the design of camera front views in this case study, design criteria were established based on the design elements found in present cameras available on the market. The design characteristics considered included 4 color design aspects (such as grip color, lens frame color, body color, and decorating line) and 8 tailoring design characteristics (such as camera buttons or switches, flash placement, location of light, lens frame shapes and placement, decorated line shapes, camera body shape, camera body dimensions in ratios, camera grip shapes, camera AF assist illuminated lamp, and logo location and dimensions). A comprehensive list of these parameters can be found in table 6.2.4, which provides detailed information about the design frameworks and considerations for the camera designs in the study.

Table 6.2.4, shows the list of the parameters of real time product (camera)

S. No.	Factors	Level 1	Level 2	Level 3	Level 4	Level 5
1	Camera button/switch and sharp/soft edges	Button/Switch with sharp edges	Button/Switch with soft round edges			
2	With flash/without flash and location of flash light	With flash and Left light	Without flash, the right light	With flash, the right light	Without flash, the left light	With flash and the centre light
3	Lens frame shapes and location	Right side of front section	Right (large)	Centre	Centre right	Centre right (large)
4	Lens frame colour	Black N0	White N10	5 GB 8/8	2.5 P 5/18	5 Y 9/12
5	Decorated line shapes	On Top of camera Lens	On Top and bottom of small area	On top and bottom large area	Top large area	Top and small area
6	Decorated lines colours	5Y 9/12	5GB 8/8	White N10	N 0	2.5 P 5/18
7	Body shape	Rectangle with sharp corner	Rectangle with soft edges	Rectangle with more round or soft edges	Rectangle with sharp edge hood	Rectangle with soft round edge hood
8	Body dimensions in ratios	1 : 1	1 : 1.414	1 : 1.618	1 : 1.732	1 : 2
9	Body colors	5R 5/16	7.5GY 8/12	7.5 PB 5/16	White N10	Black N0
10	Body elements (Grip shapes)	square shape	Golden rectangle shape	Thin line shape	D shape with golden rectangle	Square with one side filet

					proportion	
11	Grip colour	Black N0	White N10	5 GB 8/8	2.5 P 5/18	5 Y 9/12
12	Af assist illuminated lamp and logo location and their dimensions	Right Side Top lamp and logo dimensions in proportion 1:1	Left Side Top lamp and logo dimensions in proportion 1:1.414	Right Side Bottom lamp and logo dimensions in proportion 1:1618	Left side Bottom lamp and logo dimensions in proportion 1:1.732	Centre (Just near with camera Lens) lamp and logo dimensions in proportion 1:2

In Table 6.2.4, you can find the values for the color design characteristics, which include the RGB values representing the hues based on the Munsell color system (indicated in brackets). The selection of colors using the Munsell color circle aims to cover a wide range of colors to evaluate complementary directed harmony and analogous directed harmony. Considering all possible combinations of the stated design parameters, the total number of potential design samples would be up to 97,656,250 (2^15 × 11) using a "full factorial" approach. However, to efficiently identify design samples, Taguchi Orthogonal Arrays L50 (2^15 × 11) were employed to create partial factorial combinations of the design parameters. These partial factorial combinations can be seen in Appendix 6.2.C, Table 6.2.C, where the columns represent the design parameters and their corresponding levels. Once the 50 design samples were created based on Appendix 6.2.D (A), they were visually presented in Figures showcases the design samples for the camera front face, providing a visual representation of the different design variations. On the other hand, Appendix 6.2.D (A), illustrates several styling combinations and providing further visual examples of styling combinations for the cameras.

After creating the 50 design combinations using partial factorial groupings of design parameters, we proceeded to the phase II of the experiment. In this phase, we utilized eye-tracking equipment and an open-ended questionnaire to evaluate the aesthetic value of the product designs.

The open-ended questionnaire, including the types of questions asked, can be found in Appendix 6.2.D (A, B). Detailed images of each stimulus used in the experiment can be found in Appendix 6.2.D (A, B). For the design prototypes, an eye-tracking test was accompanied to quantify the aesthetic value of the products. Both the overall design sample and each of its individual parts were assessed to determine their beauty. The study employed qualitative and quantitative methodologies to evaluate the quantification of product beauty. The quantitative method utilized eye-tracking technology, which was discussed in detail in section 6.2.8 of the study.

The eye-tracker was used to collect quantitative measurements, examining participant preferences and visual attention towards the product's aesthetics. In addition to the quantitative approach, an open-ended questionnaire with subjective questions was employed to gather respondents' preferences regarding the product's aesthetics. This allowed participants to express their subjective evaluations and impressions of the beauty of the design samples. By integrating these quantitative and qualitative methodologies, this study aimed to comprehensively evaluate the quantification of product beauty, considering both the objective eye-tracking data and the subjective preferences expressed in the open-ended survey.

The results of the eye-tracking experiment and open-ended questionnaire are presented below, and they are further discussed with respect to gender differences and the entire study population. This analysis explores how design elements, visual characteristics, and various parameters of the design samples influence consumer perception of product beauty and aesthetics, taking into account human preferences.

During the trial, a total of 50 sets of photos were presented to the participants. However, the analysis included data from all 89 participants who were situated in the same section. The data from each participant's experiments were combined into a single dataset, resulting in a total of 69 subjects for analysis. To determine the attributes of beauty, the equations described in the study were applied to the gathered data.

Equation (6.2.1) was multiplied by 100 to calculate the percentage of pureness, as the minimum number of fixations is 1. The number of fixations was divided by the total number of individuals to measure pureness in fixations. To derive the proportion measure, Equation (6.2.2) was used. By dividing 1000 by the fixation period measured in milliseconds, the proportion was obtained as the inverse of a second. Equation (6.2.3) was employed to calculate the contrast attribute.

Table 6.2.6 provides an example of how the aesthetic attributes were determined for the figures in the first stimulus (Figure shown in Appendix 6.2.D (A)). Each stimulus's contrast, pureness, and proportional values are displayed in Table 6.2.6, along with the total duration and the Contrast/Total Time value, which is the contrast value divided by the total duration (Equation 6.2.4).

In Table 6.2.5, we provide the each value of variable which is obtained through eyetracking experiments and we represent how obtain the values of each variables by using each equation 6.2.1 to 6.2.4.

Table 6.2.5, represents the value each variables

Variables	Stimulus 1
Fixation Count	2044
Std. devi. of fixations (sec)	16.81
FD Sum (Total time)	697.86
Pureness (%)	1 / (2044/69)*100 = 3.3789
Proportion (Sec^{-1})	1/16.81 = 0.0576
Contrast	2044*16.81/69 = 497.97
Contrast/Total time	497.97/697.86 = 0.71

Additionally, Table 6.2.6 presents the percentage of respondents who chose the desired figure. Fixation times under 80 ms were excluded from the analysis as these very short fixations are often indicative of incorrect saccade preparation rather than processing of necessary information. The list of all the eyetracking data given appendix 6.2.F, in tables' format.

Table 6.2.6, shows the value of Contrast, Contrast /Total Time, and Preference values for 50 real stimuli

S. No.	Full body H * L (mm^2)	Full body color (R, G, B)	General Fixation Count	General Std. of fixations (sec)	General FD Sum	Pureness %	Proportion (sec^{-1})	Contrast	Contrast /Total Time	Overall aesthetic Preference
1	120, 120	232, 47, 68	2044	16.81	697.86	3.38	0.06	497.97	0.71	4.14
2	120, 169.68	146, 224, 63	1860	17.21	610.63	3.71	0.06	463.92	0.76	4.79

3	120, 194.16	83, 113, 232	1638	19.01	559.25	4.21	0.05	451.28	0.81	4.64
4	120, 207.84	255, 255, 255	1527	20.68	529.36	4.52	0.05	457.66	0.86	4.21
5	120, 240	0, 0, 0	1417	19.31	494.79	4.87	0.05	396.55	0.80	3.86
6	120, 120	146, 224, 63	1492	22.24	536.54	4.62	0.04	480.90	0.90	4.36
7	120, 169.68	83, 113, 232	1486	18.12	501.14	4.64	0.06	390.24	0.78	4.79
8	120, 194.16	255, 255, 255	1263	29.36	451.39	5.46	0.03	537.42	1.19	4.71
9	120, 207.84	0, 0, 0	1261	21.88	432.83	5.47	0.05	399.86	0.92	4.21
10	120, 240	232, 47, 68	1240	21.17	448.18	5.56	0.05	380.45	0.85	3.57
11	120, 120	232, 47, 68	1551	20.47	519.13	4.45	0.05	460.13	0.89	4.07
12	120, 169.68	146, 224, 63	1285	18.86	446.37	5.37	0.05	351.23	0.79	3.57
13	120, 194.16	83, 113, 232	1348	21.46	491.79	5.12	0.05	419.25	0.85	3.36
14	120, 207.84	255, 255, 255	1353	21.53	484.09	5.10	0.05	422.18	0.87	3.79
15	120, 240	0, 0, 0	1279	24.65	439.31	5.39	0.04	456.92	1.04	3.71
16	120, 120	83, 113, 232	1329	24.26	482.35	5.19	0.04	467.27	0.97	4.00
17	120, 169.68	255, 255, 255	1297	22.42	429.61	5.32	0.04	421.43	0.98	3.46
18	120, 194.16	0, 0, 0	1241	20.35	420.38	5.56	0.05	366.01	0.87	4.07
19	120, 207.84	232, 47, 68	1322	21.09	456.06	5.22	0.05	404.07	0.89	4.29
20	120, 240	146, 224, 63	1204	21.22	411.87	5.73	0.05	370.27	0.90	4.46
21	120, 120	83, 113, 232	1266	19.04	448.42	5.45	0.05	349.34	0.78	4.69
22	120, 169.68	255, 255, 255	1258	18.21	419.52	5.48	0.05	332.00	0.79	5.14
23	120, 194.16	0, 0, 0	1216	18.18	399.69	5.67	0.06	320.39	0.80	3.07
24	120, 207.84	232, 47, 68	1386	17	421.1	4.98	0.06	341.48	0.81	4.00
25	120, 240	146, 224, 63	1264	16.2	386.81	5.46	0.06	296.77	0.77	3.86
26	120, 120	146, 224, 63	1282	18.86	416.76	5.38	0.05	350.41	0.84	3.57
27	120, 169.68	146, 224, 63	1140	18.36	374.14	6.05	0.05	303.34	0.81	4.00
28	120, 194.16	83, 113, 232	1093	17.55	350.95	6.31	0.06	278.00	0.79	4.21
29	120, 207.84	255, 255, 255	1087	17.96	375.09	6.35	0.06	282.94	0.75	3.93
30	120, 240	0, 0, 0	1188	15.93	389.94	5.81	0.06	274.27	0.70	3.79
31	120, 120	232, 47, 68	1898	18.38	622.24	3.64	0.05	505.58	0.81	4.79
32	120, 169.68	255, 255, 255	1488	22.74	474.37	4.64	0.04	490.39	1.03	4.93
33	120, 194.16	0, 0, 0	1490	26.24	470.72	4.63	0.04	566.63	1.20	4.29
34	120, 207.84	232, 47, 68	1265	24.38	433.05	5.45	0.04	446.97	1.03	4.50
35	120, 240	146, 224, 63	1298	21.9	443.55	5.32	0.05	411.97	0.93	3.86
36	120, 120	83, 113, 232	1228	19.4	426.21	5.62	0.05	345.26	0.81	3.57

37	120, 169.68	0, 0, 0	1205	18.16	408.34	5.73	0.06	317.14	0.78	3.93
38	120, 194.16	232, 47, 68	1220	21.43	445.85	5.66	0.05	378.91	0.85	4.00
39	120, 207.84	146, 224, 63	1148	21.63	402.81	6.01	0.05	359.87	0.89	3.50
40	120, 240	83, 113, 232	1224	20.17	386.62	5.64	0.05	357.80	0.93	4.57
41	120, 120	255, 255, 255	1489	17.88	493.27	4.63	0.06	385.85	0.78	4.00
42	120, 169.68	0, 0, 0	1168	20.15	390.59	5.91	0.05	341.09	0.87	3.71
43	120, 194.16	232, 47, 68	1274	22.76	407.29	5.42	0.04	420.24	1.03	4.29
44	120, 207.84	146, 224, 63	1565	21.56	534.73	4.41	0.05	489.01	0.91	4.14
45	120, 240	83, 113, 232	1386	20.3	483.76	4.98	0.05	407.77	0.84	3.57
46	120, 120	255, 255, 255	1488	23.95	542.44	4.64	0.04	516.49	0.95	3.93
47	120, 169.68	0, 0, 0	1364	19.71	475.93	5.06	0.05	389.63	0.82	3.43
48	120, 194.16	232, 47, 68	1463	18.1	508.9	4.72	0.06	383.77	0.75	4.07
49	120, 207.84	146, 224, 63	1358	17.02	484.08	5.08	0.06	334.97	0.69	4.57
50	120, 240	83, 113, 232	1460	15.63	460.31	4.73	0.06	330.72	0.72	4.00

From Table 6.2.6, it is evident that when the Contrast/Total Time ratio is 0.5 or higher, the desired design is the one with a higher proportion value. On the other hand, when the Contrast/Total Time ratio is lower than 0.5, even if the proportion is higher, the design is not preferred. Furthermore, it can be observed that as the Contrast/Total Time ratio increases, the proportion decreases. In other words, subjects tend to prefer designs where the Contrast/Total Time ratio is closer to 0.5 rather than lower. As a result, maximum beauty is succeeded when the value of “Contrast” is half of the total fixation time. It should be noted that if the Contrast/Total Time ratio exceeds 1, it becomes difficult to predict the product's beauty or preference. Additionally, recording participants' subjective assessments of the general aesthetics of images is necessary to measure aesthetic preference. A scale ranging from 1 to 7 is utilized for this purpose, with each number representing a different degree of aesthetic appeal. The questionnaire containing the scale can be found in Appendix 6.2.D (A, B), and the outcome is given in appendix 6.2.E with in the table of 6.2.E. Participants express their aesthetic preferences by selecting a number on the scale from 1 to 7 that closely aligns with their perception of the image's aesthetics. Each number on the scale is associated with a specific descriptor indicating the level of aesthetic appeal it represents.

The selection process was utilized to investigate the assessment of beauty, leading to the discovery that the duration of contrast should fall within the range of 50% to 70% of the general fixation duration sum to achieve optimal beauty. To develop the beauty formula, it was important to determine the preference for each image with different levels of contrast in relation to the other images. A total of 50 images were selected for the study, each with a distinct contrast value ranging from 0.50 to 1.2 over the entire duration. Sixty-nine volunteers participated in the experiment and were asked to rate the images on a scale from 1 to 7 based on their overall aesthetic preference, Outline view, and Color combination. Each image received a rating ranging from 1 to 7, and the output of the rating scale is given in figure 6.2.5.

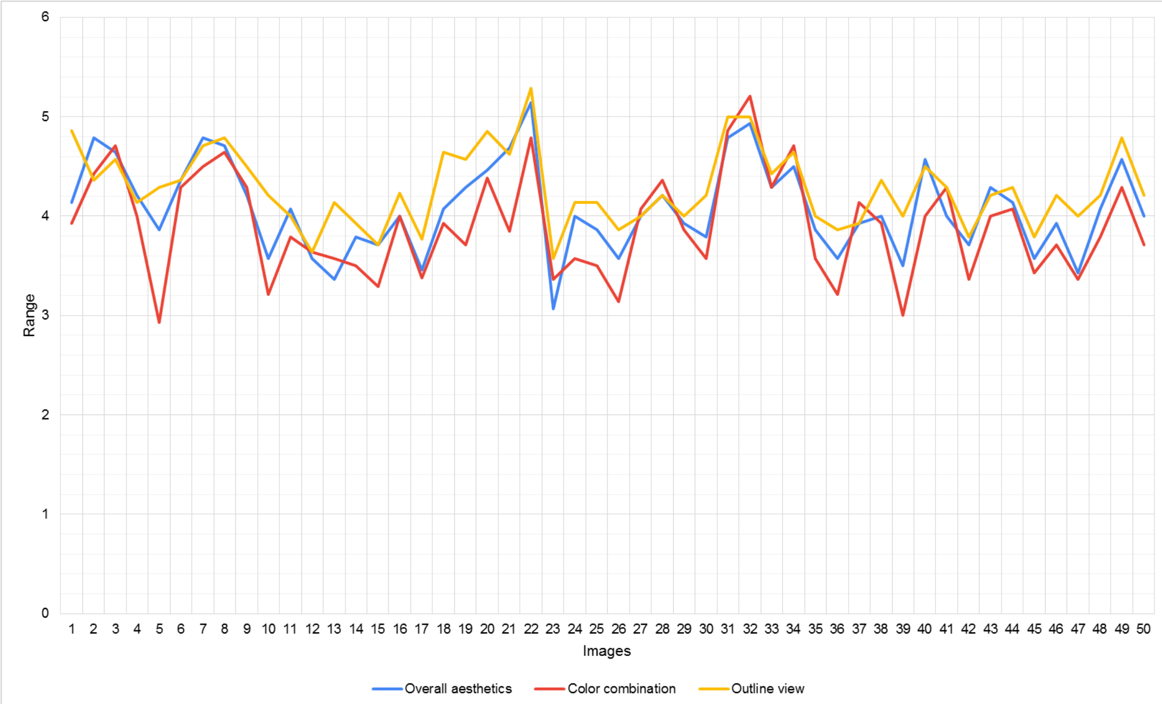


Figure 6.2.5, shows the results of scale for outline, color and aesthetic preference

The findings, as presented in Appendix 6.2.F and Table 6.2. F, indicate that as the contrast over time approaches 0.5, people tend to have a greater liking for the images. Moreover, the preference shows a more pronounced trend when the contrast-to-total time ratio is above 0.5 associated to when it is below 0.5. Based on these results, a beauty formula can be formulated to quantify the aesthetic appeal of the images.

Beauty measurement: Beauty = (Pureness * Proportion) / (Contrast / Total Time) (6.2.5)

Equation 6.2.5 states that the beauty value is calculated by multiplying the Pureness factor with the Proportion factor and after that dividing it by the Contrast/Total Time ratio value.

According to this equation, the perceived beauty is directly proportional to the product of Proportion and Pureness, it indicates that higher values of Proportion and Pureness contribute to a higher beauty rating. Although, the Contrast/Total Time ratio has an inversely proportional relationship with beauty, this means that a lower ratio suggests a higher beauty rating.

Further, this relationship suggests that designs with higher values of Proportion and Pureness are considered more beautiful, while a lower Contrast/Total Time ratio indicates a higher beauty rating. However, it's important to note that this equation 6.2.5 provides a simplified representation of beauty assessment and may not capture the full complexity of how individuals perceive beauty. Beauty is a subjective and multifaceted concept influenced by various factors, so this formula should be interpreted with caution and awareness of its limitations. The values beauty for each image is given in Table 6.2.7.

Table 6.2.7, shows the values of Contrast /Total Time, Aesthetics preference, and beauty

S. No.	Pureness %	Proportion (sec^{-1})	Contrast	Contrast /Total Time	Aesthetics preference	Beauty
1	3.38	0.06	497.97	0.71	4.14	0.29
2	3.71	0.06	463.92	0.76	4.79	0.29
3	4.21	0.05	451.28	0.81	4.64	0.26
4	4.52	0.05	457.66	0.86	4.21	0.26
5	4.87	0.05	396.55	0.80	3.86	0.30
6	4.62	0.04	480.90	0.90	4.36	0.21
7	4.64	0.06	390.24	0.78	4.79	0.36
8	5.46	0.03	537.42	1.19	4.71	0.14
9	5.47	0.05	399.86	0.92	4.21	0.30
10	5.56	0.05	380.45	0.85	3.57	0.33
11	4.45	0.05	460.13	0.89	4.07	0.25
12	5.37	0.05	351.23	0.79	3.57	0.34
13	5.12	0.05	419.25	0.85	3.36	0.30
14	5.10	0.05	422.18	0.87	3.79	0.29
15	5.39	0.04	456.92	1.04	3.71	0.21
16	5.19	0.04	467.27	0.97	4.00	0.21
17	5.32	0.04	421.43	0.98	3.46	0.22
18	5.56	0.05	366.01	0.87	4.07	0.32
19	5.22	0.05	404.07	0.89	4.29	0.29
20	5.73	0.05	370.27	0.90	4.46	0.32
21	5.45	0.05	349.34	0.78	4.69	0.35
22	5.48	0.05	332.00	0.79	5.14	0.35
23	5.67	0.06	320.39	0.80	3.07	0.43
24	4.98	0.06	341.48	0.81	4.00	0.37
25	5.46	0.06	296.77	0.77	3.86	0.43
26	5.38	0.05	350.41	0.84	3.57	0.32
27	6.05	0.05	303.34	0.81	4.00	0.37
28	6.31	0.06	278.00	0.79	4.21	0.48
29	6.35	0.06	282.94	0.75	3.93	0.51
30	5.81	0.06	274.27	0.70	3.79	0.50
31	3.64	0.05	505.58	0.81	4.79	0.22
32	4.64	0.04	490.39	1.03	4.93	0.18
33	4.63	0.04	566.63	1.20	4.29	0.15
34	5.45	0.04	446.97	1.03	4.50	0.21
35	5.32	0.05	411.97	0.93	3.86	0.29
36	5.62	0.05	345.26	0.81	3.57	0.35
37	5.73	0.06	317.14	0.78	3.93	0.44
38	5.66	0.05	378.91	0.85	4.00	0.33
39	6.01	0.05	359.87	0.89	3.50	0.34
40	5.64	0.05	357.80	0.93	4.57	0.30
41	4.63	0.06	385.85	0.78	4.00	0.36
42	5.91	0.05	341.09	0.87	3.71	0.34
43	5.42	0.04	420.24	1.03	4.29	0.21
44	4.41	0.05	489.01	0.91	4.14	0.24
45	4.98	0.05	407.77	0.84	3.57	0.30
46	4.64	0.04	516.49	0.95	3.93	0.20
47	5.06	0.05	389.63	0.82	3.43	0.31
48	4.72	0.06	383.77	0.75	4.07	0.38
49	5.08	0.06	334.97	0.69	4.57	0.44
50	4.73	0.06	330.72	0.72	4.00	0.39

The information presented is a dataset made up of various aesthetic preference-related characteristics. The percentage of purity/cleanliness in the stimulus/image is indicated by pureness. The degree to which the stimulus/image appears clear/devoid of contaminants is measured. The proportion or ratio of specific elements in the stimulus/image is shown by the value of proportion (sec^{-1}). The relationship between the various components of the image is quantified. The contrast variable shows how much the various components of the image differ or vary from one another. It gauges how pronounced the changes are. Additionally, contrast/Total Time computes the contrast divided by the overall duration. It might serve as a gauge for the rate of variation or change in the image over time. Next, the perceived beauty of the image is indicated by the beauty variable. It records the individual's evaluation of how appealing or appealing an image is. After finding the value of beauty, we conducted a regression analysis to analyze this relationship, and the results of this analysis are given in Table 6.2.8.

Table 6.2.8, shows the value Regression Model

Regression Statistics								
Multiple R	0.987381							
R Square	0.974921							
Adjusted R Square	0.972692							
Standard Error	0.014268							
Observations	50							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	4	0.356111	0.089028	437.3347	2.21E-35			
Residual	45	0.009161	0.000204					
Total	49	0.365272						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-0.20591	0.101985	-2.019	0.04947	-0.41131	-0.0005	-0.41131	-0.0005
Pureness %	0.071386	0.010266	6.95343	1.19E-08	0.05071	0.09206	0.05071	0.09206
Proportion(sec $^{-1}$)	6.95993	0.63474	10.965	2.68E-14	5.68149	8.23836	5.681491	8.23837
Contrast	6.2E-05	0.00012	0.500214	0.61936	-0.00019	0.00031	-0.00019	0.00031
Contras/Total Time	-0.2638	0.05298	-4.97954	9.85E-06	-0.3705	-0.1571	-0.3705	-0.1571

Regression analysis is a statistical method for determining how one or more independent and dependent variables are related. Regression analysis is used in the context of the given data to comprehend how the pureness, proportion, contrast, and contrast/total time (independent variables) affect the beauty of a design element (dependent variable). The objective of the regression model is to identify the line that best represents the relationship between these variables. The p-values linked to each coefficient show the independent variables' statistical importance in predicting beauty. A small p-value, such as 1.19E-08, indicates that the variable is highly significant and strongly influences how people perceive beauty. It is clear from this situation that Pureness% and Proportion (sec-1) are significant factors in determining beauty because of their extremely low p-values. The percentage of variation in the beauty that the independent variables can explain is shown by the R-squared value (0.974921). A high R-squared value suggests that the regression model fits the data well and that the independent variables selected explain a significant proportion of the variation in beauty.

The findings of the regression analysis in table 6.2.8, show a significant and strong association between the dependent variable (Beauty) and the independent variables (Proportion, Pureness, Contrast, and Contrast/Total Time). According to the high R-squared value (0.9749), the independent variables in the model can account for roughly 97.49% of the variability in Beauty. The coefficient estimations reveal the degree and direction of the correlations between the independent variables and Beauty. For instance, whereas the association between Contrast and Beauty is not statistically significant, an increase in Proportion and Pureness is connected with an increase in Beauty. The association between Contrast/Total Time and Beauty is negative, meaning that as Contrast/Total Time rises, Beauty tends to fall. The computed coefficients are all linked with very low p-values, which shows they are statistically significant. This indicates that the independent variables significantly affect how the diversity in Beauty is explained. The overall fit of the regression model is described in the ANOVA table. The F-statistic tests the null hypothesis, which states that all regression coefficients are zero (437.334).

The highly significant regression model indicates that at least one independent variable is significantly related to the dependent variable, according to the extremely low p-value (2.2128E-35). The strong F-statistic and low p-value show that the regression model fits the data well and that the independent variables significantly contribute to the explanation of Beauty's variability. The estimated coefficients for each independent variable in the model are shown in the coefficients table 9. The regression equation's estimated constant term, or y-intercept, is represented by the intercept coefficient (-0.20591). It shows what Beauty should be when all the independent factors are 0. These variables, which are the independent variables in the regression equation and have estimated coefficients attached to them, are Proportion, Pureness, Contrast, and Contrast/Total Time. The coefficients deliver perceptions of the degree and direction of the correlations between the independent variables and Beauty. For instance, if the other variables are held constant, the positive correlation for Pureness (0.07139) shows that an increase in Pureness causes an increase in Beauty. Similar to this, the Proportion (sec-1) positive coefficient (6.9599) indicates a relationship between Proportion (sec-1) and Beauty. The results of the regression analysis show a high and substantial correlation between the dependent variable (Beauty) and the independent variables (Pureness, Proportion (sec-1), Contrast, and Contrast/Total Time). The model effectively accounts for a large amount of the variation in Beauty, indicating that these independent variables significantly impact how much Beauty is valued. It's crucial to remember that regression analysis alone cannot prove causation; more investigation and evaluation of other variables are required before drawing firm conclusions. In this study, artificial neural networks (ANN) are employed in this study to improve the analysis and forecasting of aesthetic value in design components. Although ANN offers several benefits that complement and extend the analysis, regression analysis still provides valuable insights into the linear relationships between independent variables (such as pureness, proportion, contrast, and contrast/total time) and the dependent variable (beauty):

Contrary to linear regression, ANNs can capture intricate non-linear relationships between the input variables and the output (beauty). Complex interactions and combinations of design elements significantly impact design aesthetics, which unadorned to line better relationships may not capture well. These intricate and non-linear relationships can be modeled by ANNs, leading to more precise predictions.

Feature Extraction: ANNs can automatically extract pertinent features from the input data. Subtle patterns or feature combinations may influence the perception of beauty in design aesthetics. These relevant features can be learned and recognized by ANNs, which improves the model's ability to capture the essence of aesthetics.

Large Data Sets: ANN can handle large and varied data sets better. There are countless possible design components, iterations, and combinations. ANNs can effectively process and analyze such sizable data sets to generalize patterns and make reliable predictions.

Generalization and Adaptability: ANNs can generalize and adapt to new and unexplored data. This flexibility is crucial in design aesthetics because different cultural backgrounds, preferences, and contexts may have other ideas of what is beautiful. ANNs can extrapolate from the available data and offer insights useful for novel design scenarios.

Overall, ANNs provide a more reliable, adaptable, and sophisticated method of analyzing design aesthetics than regression analysis. They provide a potent tool for unraveling intricate connections and making precise predictions, empowering designers to produce more aesthetically pleasing goods based on a deeper comprehension of the variables that affect beauty.

6.2.14. Development of ANN model

As shown in figure 6.2.6, the artificial neural network model is sequentially developed by providing it with various aesthetics-related attributes. These qualities cover many components that enhance the product's aesthetic appeal. Conversely, the model's outputs include precise measurements of the product's size, design elements, and related eye-tracking data. An eye-tracking database was established with pertinent data for 50 examples matching the input attributes to aid the model's development. The artificial neural network model uses this sequential method to create a link between the input attributes and the related outputs. The program can then make predictions or generate insights about the product's dimensions (like length and breadth, measured in millimeters) and body color (represented in terms of R, G, and B values). This model may make predictions or offer helpful information about the product's dimensions and body color based on the specified aesthetic attributes by utilizing the power of artificial neural networks to learn from the input-output interactions in the eye-tracking database.

Development of an artificial neural network model: In figure 6.2.6, a sequential approach of creating an artificial neural network model is presented.

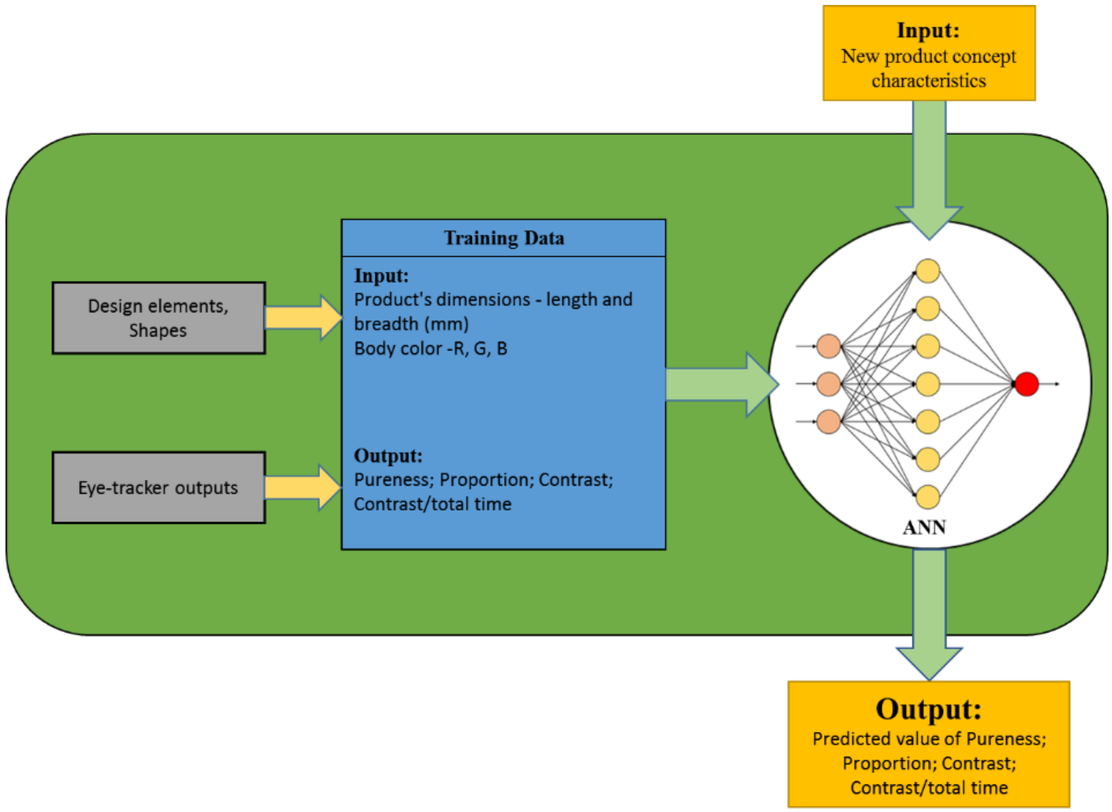


Figure 6.2.6, Development of the ANN model.

The initial inputs for the artificial neural network (ANN) model are related to the product's aesthetics, specifically pureness, proportion, contrast, and contrast/total time. These inputs serve as the starting point for calculating the corresponding outputs. To facilitate this process, a product aesthetics inventory database was created, containing information for the 50 scenarios in the input dataset. This database allows for the determination of output values based on the provided input data. In order to simplify the calculation of the outcomes values, the input parameters, for example the product's dimensions (length and breadth in millimeters) and body color (R, G, B values), are chosen at appropriate levels. This selection allows for a more straightforward mapping of the inputs to the corresponding output outcomes. The structural design of the "artificial neural network model" is then determined based on the selected input and outcomes parameters, also known as variables. The chosen architecture serves as the framework for training the model. When the model is trained and evaluated using the available data, it becomes capable of predicting the output outcomes (pureness, proportion, contrast, and contrast/total time) corresponding to the given inputs (product's dimensions and body color). Figure 6 provides an overview of this process, illustrating how the trained ANN model can generate output values based on the provided input data. In the subsequent sections, further details regarding the architecture of the ANN model and the algorithm employed for its training and testing will be discussed.

6.2.15. Architecture of ANN model

In Figure 7, we depicts the schematic diagram of the "artificial neural network" (ANN) model, which was constructed using MATLAB 2020b.

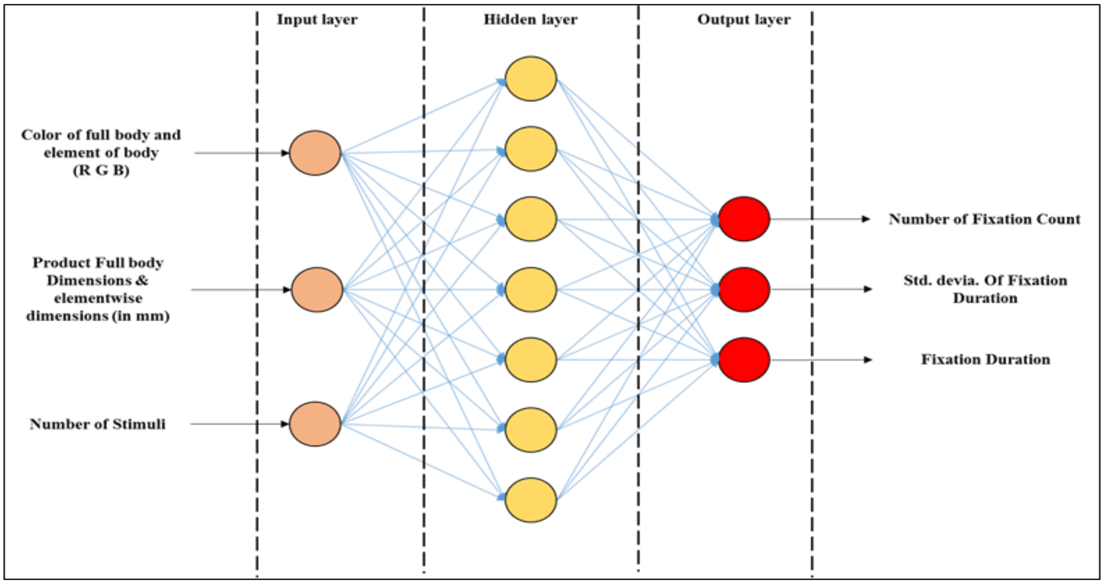


Figure 6.2.7, Architecture of Artificial Neural Network (ANN) model

The ANN architecture comprises several key elements, including the "input variables", "input layer", "hidden layer", "output layer", and "output" variables. The interconnected neurons within the ANN model are organized across multiple levels. The amount of neurons in the input and output layers can vary depending on the specific data being utilized. Generally, the input layer consists of neurons equivalent to the number of input variables being considered. However, in the hidden layer, the number of neurons is typically determined by the user and is often equal to or marginally higher than the total amount of the input and outcome variables (Tang et al., 2013; Tan et al., 2016). For this study, ten neurons were utilized in the hidden layer. Each neuron in the input layer gathers data from the input variables and transmits it to the neurons in the hidden layer. The hidden layer processes this input data by assigning appropriate weights to the input. When the accumulated information of a specific neuron surpasses a predefined threshold, it is transmitted to the output layer. Ultimately, the output layer retrieves this data as the predicted value for the corresponding output variable. Figure 4 illustrates the structural design of the ANN model, highlighting the "input layer", "hidden layer", and "output layer".

6.2.16. Training and testing of ANN model

The artificial neural network (ANN) is trained with the help of a set of known input-output pairs once its architecture has been defined. Figure 8 illustrates the algorithm employed to develop and evaluate the ANN model. The variable 'N' in the diagram represents the number of neurons in the hidden layer of the ANN. Typically, the sum of the input and output parameters is used as an initial estimate for the number of neurons in the hidden layer, which can be adjusted as needed during the training process. The training and testing algorithm involves several steps. Initially, the weights and biases of the ANN model are initialized randomly. The ANN is then presented with a set of input-output pairs, and using the current weights and biases, it makes predictions for the outputs. These predicted outcomes are compared to the known target outputs obtained from the training data. After determining the architecture of the artificial neural network (ANN), the next step is to train the model using a set of known inputs and outcomes. Figure 8 illustrates the algorithm used for training and testing the ANN model. In the figure, 'N' represents the number of neurons in the hidden layer of the ANN structural design. Typically, 'N' is initially set to the sum of the input and outcomes parameters and can be adjusted as needed during the training process. As mentioned in Section 3.1, for this study, a total of 50 data sets were created. These data sets serve as the training data for the ANN model.

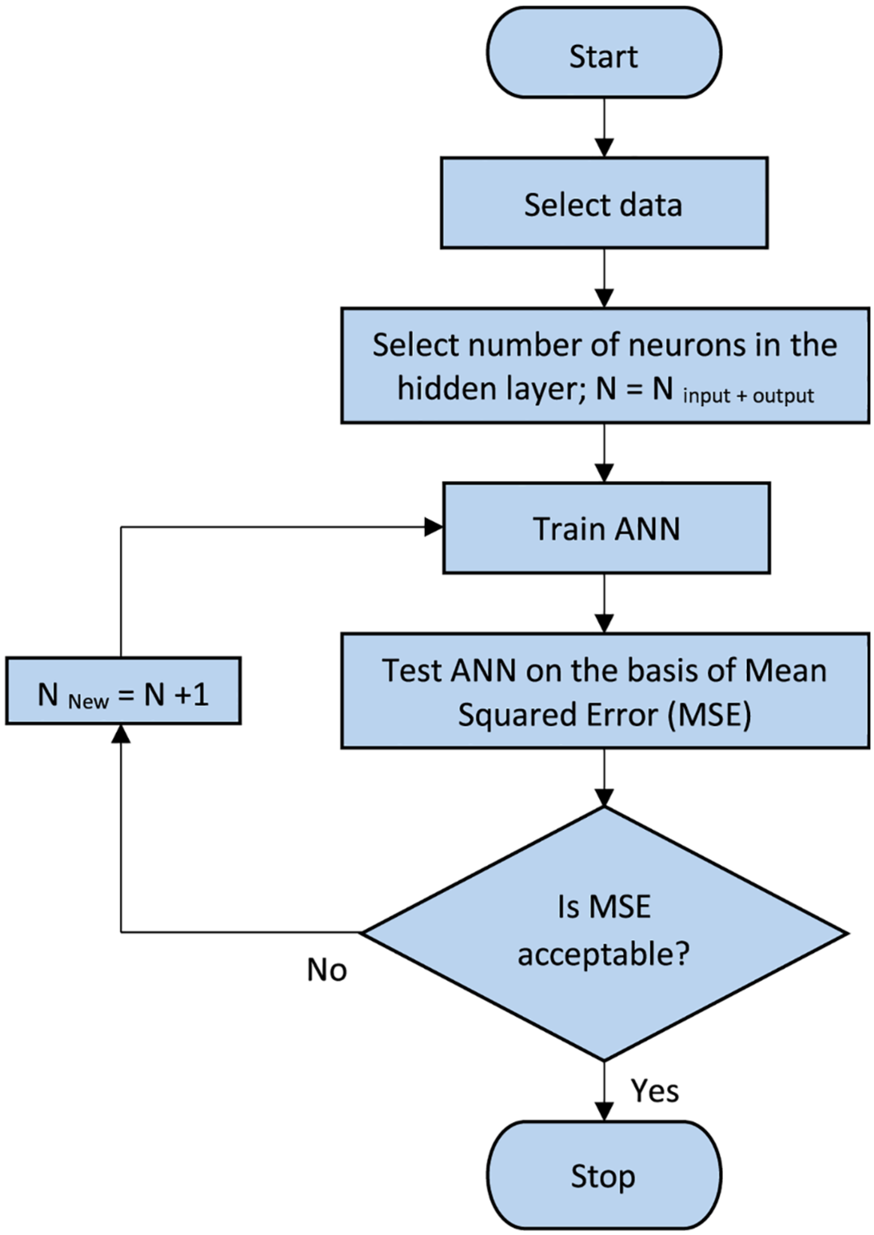


Figure. 6.2.8, Algorithm for training and testing of the ANN model.

Out of the 50 data sets, 86% (total of 44) were used for training the ANN model, 7% (total of 3) were used for “testing”, and 7% (total of 3) were used for justification. The limited data availability was due to restrictions on respondent participation. During the training process, the ANN model learns the relationship between input and output values by adjusting the weights of the neurons. Based on these weights, the model calculates predicted outputs and compares them with the real outcomes to determine the error. The "Levenberg-Marquardt" training algorithm/optimizer is employed iteratively to minimize the error (Lera & Pinzolas, 2002). This iterative weight modification procedure, known as backpropagation, continues until a “global minimum error” is attained. The Mean Squared Error (MSE) is used to assess the model's performance by measuring how closely the regression line fits the data points. MSE is chosen because squaring the errors gives more weight to outlier predictions with larger errors. Squaring the errors also ensures positive values, removing uncertainty related to sign. The ANN model is trained by inputting the calculated input and outcome values. The model then learns how the input and output data are related and assigns unique weights to each neuron. Using these weights, the model predicts its expected outputs. The difference between the expected and actual outputs is compared, and the error is calculated. This process is repeated to minimize the difference between the expected and actual outputs, and the weights are adjusted accordingly. The "Levenberg-Marquardt" training algorithm/optimizer is used to optimize the network's neuron outcomes and reduce the error.

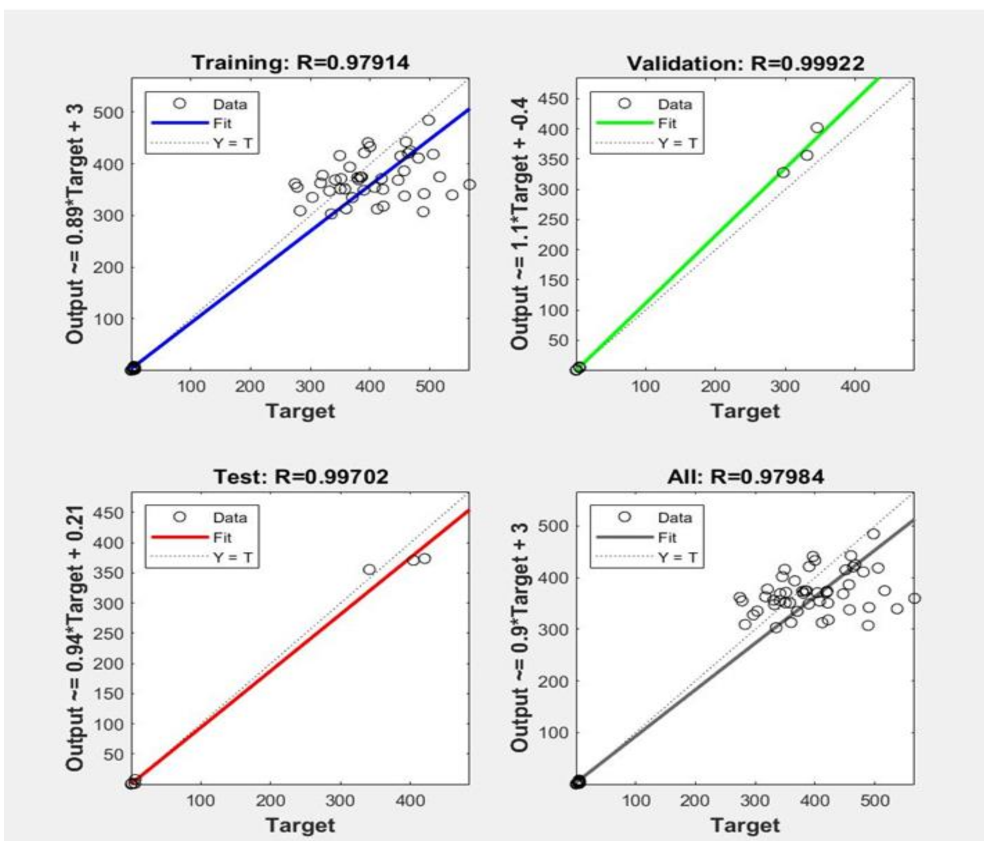


Figure. 6.2.9, Regression plot of ANN model (Source: MATLAB2020b)

'Backpropagation' refers to the continuous process of modifying and fine-tuning the weights in the ANN model. It continues until the model achieves a minimum global error (Nguyen et al., 2021). The model's performance is assessed using the Mean Squared Error (MSE) value, which measures how closely the regression line fits the data points. MSE was selected because it emphasizes outlier predictions with larger errors due to the squaring operation in the function. This helps ensure that the trained model does not have significant errors from outlier predictions. Furthermore, squaring the errors guarantees positive values and eliminates sign-related ambiguity. During this research work, the "MSE" value was determined to be 405, which is significantly lower than the threshold of 500.

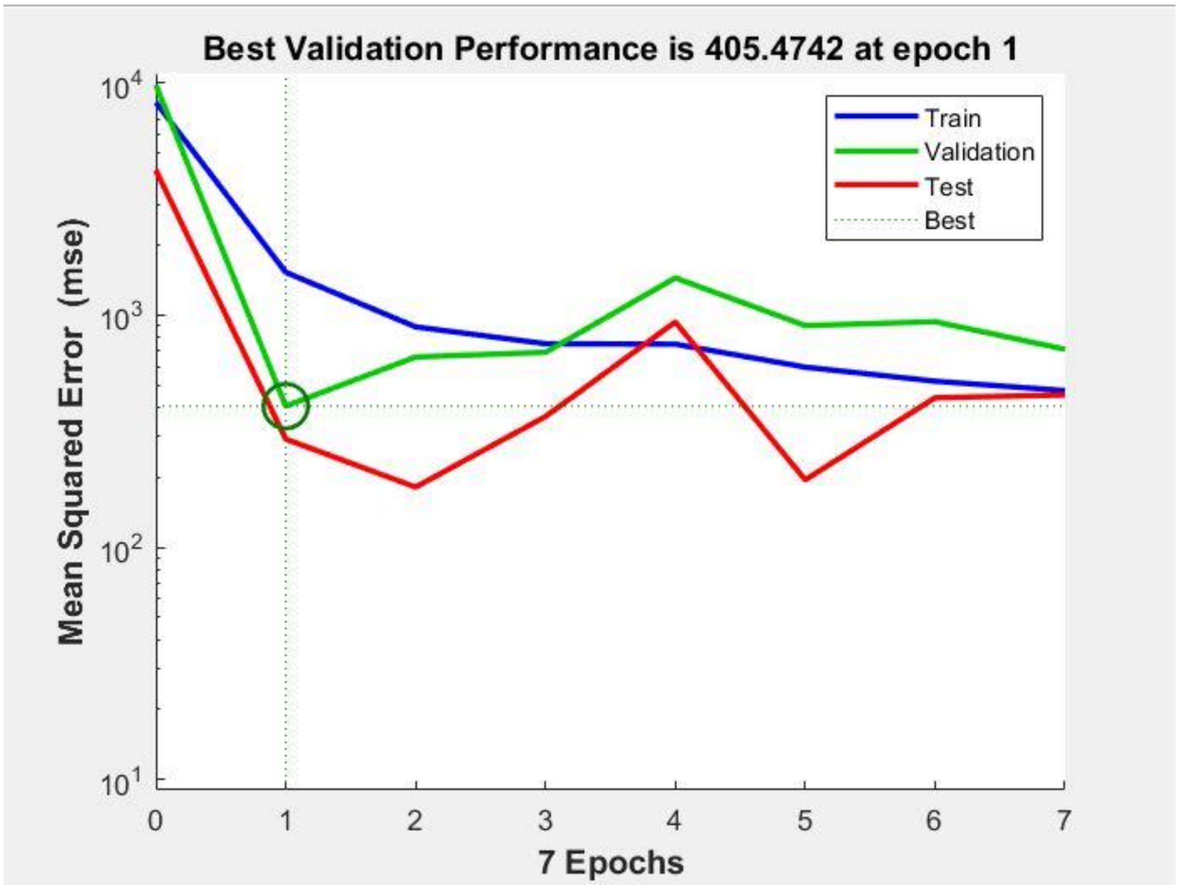


Figure 6.2.10, shows the Mean square error

The Mean Squared Error (MSE) over the training iterations (epochs) is displayed in the performance plot of the ANN model (Figure 6.2.8). Each epoch represents a complete iteration of the neural network's training data. The MSE value decreases throughout training as the neurons' weights are changed to reduce the error between the predicted outputs and the actual results. In particular, Figure 6.2.10 shows the MSE values at various points during training.

The ANN model reaches convergence at Epoch 7, according to Figure 6.2.10. The model has thus successfully learned the underlying relationships between the input variables (pureness, proportion, contrast, and contrast/total time) and the output variable (beauty) after seven training iterations. The model's weights have been adjusted to a point where the error is reduced, proving that it has effectively captured the complexities of design aesthetics.

The training of the ANN model is finished at the point of convergence (Epoch 7). This indicates that the model has received sufficient training and is prepared to be applied to predicting beauty scores based on input variables.

The researchers conducted a linear regression analysis to assess the trained ANN model's accuracy (Figure 6.2.9). In this analysis, the actual target values initially entered during model training (also referred to as "goals") are contrasted with the projected outputs of the model. The relationship between the target (real) values and the projected outcomes is shown by the regression plot in Figure 6.2.9 (vertical axis, horizontal axis). The target values and the projected outputs of the model are very closely correlated, as shown by the overall regression coefficient (R), which is 0.997. In other words, the model's predictions closely match the actual beauty ratings, demonstrating the precision and efficiency of the trained ANN model in evaluating product aesthetics based on pureness, proportion, and contrast factors.

6.2.17. GUI developed through AI tool

The ANN model was integrated with MATLAB's GUIDE function, which stands for "Graphical User Interface Development Environment," to develop the GUI tool. The GUI components are organized within a structure called handles, which is a fundamental part of GUIDE. Each callback function created by MATLAB receives the handles array. These callback functions typically involve user interactions with the GUI, such as selecting items from menus or clicking on push buttons. Figure 6.2.11, provides a schematic diagram illustrating the process of creating the GUI tool. With the GUI tool, designers now have an AI-powered tool at their disposal to calculate predicted values of the product's dimensions (length and breadth in mm) and body color (R, G, B) for all 50 samples in the input dataset. Please note that the reference to figure 6.2.11, seems to be a repetition, as figure 6.2.10, was previously mentioned in relation to the performance plot of the ANN model. The developed ANN model can be effectively utilized by entering the values of the product's dimensions (length and breadth in mm) and body color (R, G, B) into the tool's GUI. This GUI serves as a user-friendly interface for utilizing the ANN model and forecasting the significance of pureness, proportion, contrast, and contrast/total time in a product concept.

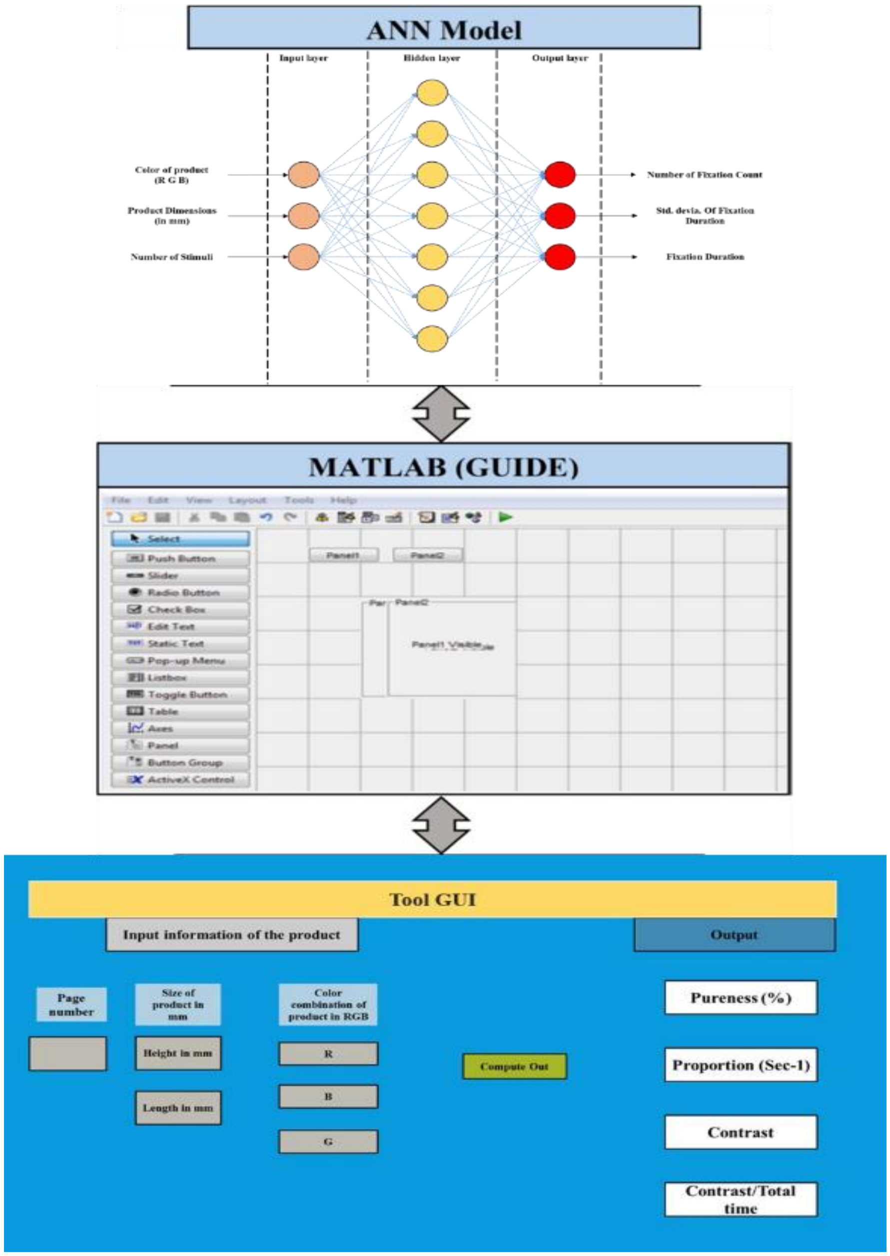


Figure 6.2.11, Tool GUI for ANN model.

Figure 6.2.11, illustrates a flow diagram that outlines the stepwise procedure for using the tool GUI. According to the commands presented in figure 6.2.11, designers should follow a step-wise-step method to input the significant details of the product's dimensions and body color into the respective boxes within the tool's GUI. By inputting these values, the tool will provide the corresponding outputs and predictions based on the ANN model. The suggested goal of evaluating the aesthetics of cameras or other products has been accomplished by using numerous mathematical formulas, some of which were previously mentioned but are now obsolete. The methodology used in this research depends on a theoretical perspective derived from both consumers and designers, in contrast to earlier studies in this sector. This innovative method acknowledges the value of considering end users' and designers' opinions and preferences when assessing the visual attractiveness of cameras or other items. The suggested plan seeks to offer a thorough and impartial evaluation of beauty by including the theoretical viewpoints of these critical stakeholders. This change in strategy sets the current study apart from past research projects and emphasizes its distinctive contribution to the study of product aesthetics evaluation.

It is clear from studying the core of product beauty that it is influenced by contrasting elements, with the best results coming from finding a careful balance between contrast, purity, and proportion. There are a few things to take into account, though. First, a maximum of 69 respondents could participate in an eye-tracking study. While this is appropriate for this kind of study, more respondents would probably produce more precise and reliable conclusions. This study also focuses on comprehending and creating a mathematical method to evaluate the beauty of two-dimensional camera photographs (the study's stimuli). Additionally, a tool powered by artificial intelligence was designed to assist designers in refining and bettering the aesthetics of cameras. Designers are given objective measurements and guidance to improve the visual appeal of their camera designs by fusing mathematical methodologies with AI tools. To assure the precision and efficacy of these techniques for determining and enhancing product beauty, it's crucial to acknowledge the potential for additional research and improvement.

Creating a beauty measurement formula designed explicitly for 2-D cameras was the primary goal of this work. This algorithm could be used to evaluate and quantify the aesthetic attributes of cameras. Nevertheless, it is important to remember that the methodology and guiding concepts used in this study have effects that go beyond the world of cameras. The fundamental ideas can provide a strong foundation for expanding beauty measuring formulas to other product categories. These formulations must be modified and adjusted to fit various items, which calls for more research and improvement. Future research should focus on the applicability of the developed formula to various product categories. By performing additional research, it will be feasible to identify and include particular aesthetic characteristics pertinent to multiple product types. Beyond the capabilities of 2-D cameras, this ongoing work has the potential to make it easier to create specialized beauty assessment methods for a variety of products.

A useful strategy in product design and evaluation is to evaluate the product (camera) using a Graphical User Interface (GUI) with both designers and regular participants. Individuals can interact with the product and give feedback using GUIs, which are interactive and user-friendly. The GUI is tailored to the unique features and capabilities of the camera in this situation, making it a useful tool for gathering user feedback and improving the design. There are some inputs given by designers and normal participants and some of images is given below.

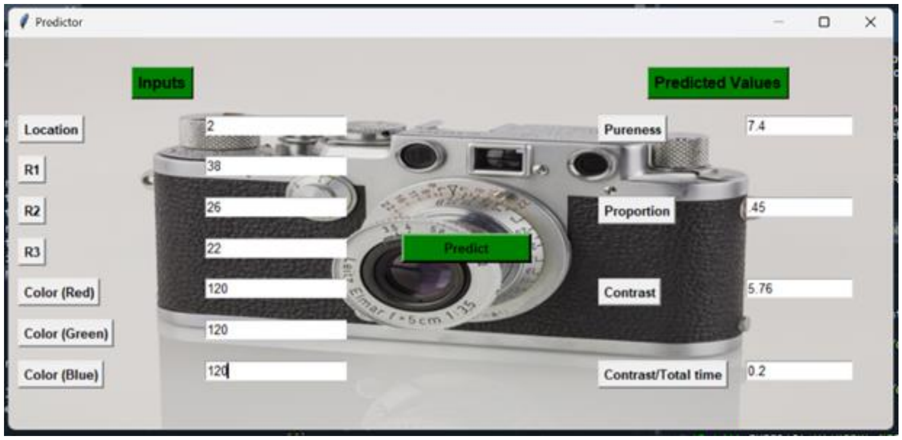


Figure 13 (a), Input of first participant of GUI ANN model.

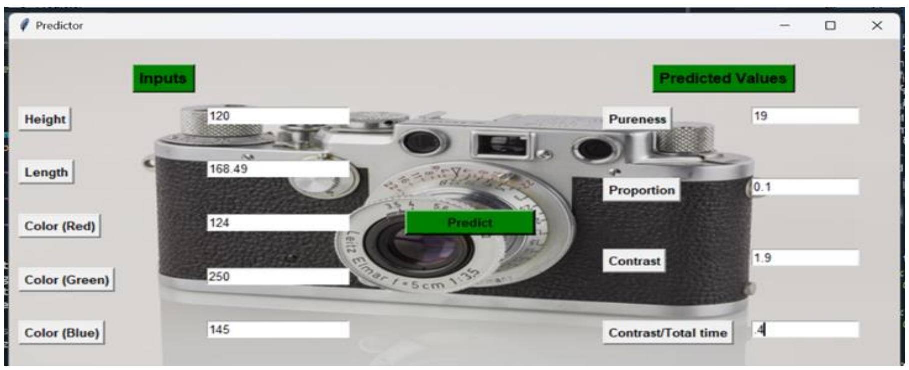


Figure 13 (b), Input of second participant of GUI ANN model.

6.2.18. Summary

In this study, proportion, pureness, contrast, and beauty are key aesthetic influences that affect visual preferences in the fields of art, engineering, and psychology. Additionally, it has developed a system that is objective, trustworthy, and repeatable allowing anybody, at any time, to evaluate these aesthetic traits by observing eye behaviour. The use of Artificial Neural Networks (ANN) and a mathematical formula to measure the aesthetic appeal and utility of items has produced encouraging results. The procedure shows its ability to accurately approximate the ultimate preference for product aesthetics by measuring human eye fixation counts, fixation durations, and standard fixation durations using eye-tracking experiments. By combining this aesthetic measurement system with AI technology, designers may evaluate ideas objectively before they are manufactured. With the help of this methodology and technology, designers may improve and evaluate the aesthetic value of their creations. It is a helpful tool for experienced designers, design focus groups, and beginning designers alike, each with particular goals. This methodology can benefit design students in educational settings since it helps them comprehend visual design concepts more deeply and allows them to judge aesthetics more dispassionately. Using this strategy, designers can decide how best to improve their works' physical relevance and aesthetic appeal.

This study offers a valuable pathway for design students and researchers to enhance the quality of product aesthetics in their designs. It enables them to assess and support the improvement of aesthetic design, focusing on the beauty of the product. By relying on consumer perspectives rather than solely relying on personal taste or intuition, industrial designers and researchers can benefit from this study's findings. Moreover, this study provides insights into identifying aesthetically pleasing designs, even when the changes made are subtle and challenging to evaluate. The mathematical approach utilized to assess beauty can be applied across various domains to determine the level of visual appeal in different arrangements. In this study, a novel AI tool was developed to help designers choose the best design elements to maximize a product's aesthetic appeal. The tool was created using an Artificial Neural Network (ANN) technique to do this. The tool's effectiveness and timeliness were evaluated compared to the traditional methods of running eye-tracking tests, gathering data, and performing data analysis. During the investigation, the suggested method showed an incredible accuracy of over 97% in predicting outputs related to pureness, proportion, contrast, and contrast/total time values. This outstanding accuracy strongly supports the tool's efficacy. Importantly, this instrument is a ground-breaking breakthrough because it is the first for evaluating objects' visual appeal. The tool's capabilities also made it possible to instantly recognize the effects of any changes to the design parameters, allowing designers to see trade-offs and design changes in the product as they happened. Designers may make wise judgments and enhance the visual elements of their creations thanks to insightful real-time feedback.

The next critical stage is defining the pertinent criteria to create a thorough model for improving beauty. Each meter represents the point where a certain aesthetic quality and a design aspect meet. One measure is the capacity to regulate the proportion in form or the purity of shape. The specific beauty value associated with each metric can be ascertained using the proposed method. A more extensive database of pertinent data is required to improve the model further. Eye-tracking technology can be combined with this data to produce quicker and more accurate results. The evaluation of three-dimensional rigid bodies using this methodology has enormous potential, and using the findings from the rigid body analysis, any product's beauty can be estimated. This model has the potential to give designers a robust and unbiased framework for assessing and increasing the aesthetic aspects of various items by extending the dataset and utilizing eye-tracking technologies. The suggested approach is flexible and adaptable to a range of product kinds and locations where objective quantification of visual appeal is required. This study has provided a fresh perspective that can be the basis for further research, laying the foundations for a workable solution to a previously unresolved problem. There is potential to eliminate the need for eye-tracking technology as more data is gathered and incorporated into the AI tool. This connection will help designers optimize their works' visual appeal while enabling businesses to reduce rejection rates based on product beauty by integrating all aspects of product data. This methodology can transform how we assess and improve the visual appeal of things with further development and data gathering, offering designers and businesses invaluable assistance in producing aesthetically appealing and marketable items.

CHAPTER 7

A comprehensive understanding is required: Can we develop a method to develop aesthetically improved products? (To support designers to improve product aesthetics: suitable support for industrial designers)

7.1.Introduction

Product aesthetics have become a crucial element that can make or break a product's success in today's competitive market. Customers are heavily influenced by a product's aesthetic appeal and design, functionality, and price. As a result, companies increasingly realize how important aesthetics are to drawing in customers and maintaining a competitive edge. Industrial designers are essential to the entire process of developing a product, from conception to completion. Modern consumer goods like laptops, smartphones, and other electronic devices are successful partly because of their designers' skill in producing aesthetically pleasing and user-friendly designs. But creating products with improved aesthetics is a difficult task that necessitates a thorough knowledge of the factors affecting aesthetics. Our primary goal in this section is to use the conclusions and findings from the earlier phases of our research, during which we pinpointed the crucial elements affecting product aesthetics. By comprehending these elements, we can help industrial designers in their efforts to develop more aesthetically pleasing products that connect with customers on a deeper level. Our thorough research has uncovered key elements that significantly impact a product's visual and non-visual appeal, beauty, and attractiveness. These elements include form, color, texture, proportion, symmetry, and overall design composition. We have created a set of guidelines and invited designers to incorporate these elements into their design processes when developing new products in light of this critical knowledge.

Our strategy ensures that designers are concerned with meeting functional requirements and gratifying consumers' emotional and aesthetic desires by bridging the gap between consumer preferences and design considerations. Numerous variables, such as cultural backgrounds, lifestyle preferences, and emotional reactions to design elements, impact consumer preferences. Our approach helps designers comprehend these preferences better and incorporate them into their creations, resulting in goods that genuinely appeal to their target market. Giving designers access to this knowledge enables them to produce items that transcend simple functionality and become desirable objects. Customers are drawn to products that make them feel good, and aesthetically pleasing designs have the potential to evoke robust emotional responses. Products are more likely to distinguish themselves from the competition and build a solid brand presence. Giving designers access to this knowledge enables them to produce items that transcend simple functionality and become desirable objects. Customers are drawn to products that make them feel good, and aesthetically pleasing designs have the potential to evoke robust emotional responses. Products are more likely to distinguish themselves from the competition and build a solid brand presence.

To do this, we will engage various designers from various fields in several studies and experiments. We will learn more about designers' cognitive thinking processes and approaches to product aesthetics by working with them and soliciting their expertise. We will investigate the effects of various elements on the aesthetic form and allure of products through sketching sessions and design experiments. The ultimate objective of this study is to provide industrial designers with a valuable and efficient support system that improves their capacity to produce visually appealing and aesthetically enhanced products. To create innovative and successful product designs that have a lasting impact on consumers in today's competitive market, it is essential to understand aesthetics at a deeper level and consider the factors identified during the design process.

7.2.Aim and Methodology

As stated in the previous section of our research, the main objective of this study is to evaluate and quantify the factors or attributes we discovered after a thorough literature search. In particular, we seek to comprehend how these elements affect the general aesthetics of products. We aim to learn important things about the essential components that contribute to the visual appeal, beauty, and attractiveness of products by analyzing the effects of these identified factors. We will gain a deeper understanding of the connection between these elements and perceived aesthetics as a result of this investigation, which will be helpful for industrial designers in making products that consumers find aesthetically pleasing. With the methodology chosen for this study, we hope to gain a thorough understanding of product aesthetics and create a strong strategy for influencing the product design process. As part of this methodology, the following steps are taken:

Finding Influential Factors: The first step is to locate and meticulously list the elements that significantly impact a product's aesthetics. These factors cover visual and non-visual components, such as form, color, texture, proportion, symmetry, and overall design composition. We learn essential information about what consumers find appealing about a product by looking at these elements.

Evaluation: Based on the factors found, we rate the aesthetics of engineering.

The next step is developing a method to influence the product design process. This is done by understanding the influential factors and assessment metrics. This method will direct designers to incorporate the identified elements into their design choices. It will act as a framework to motivate designers to give aesthetics equal weight with functional factors.

Integration and Implementation: We will incorporate the developed method into the current design processes to guarantee its applicability and efficacy. Designers can produce goods that satisfy functional requirements and resonate with consumers' wants and desires by seamlessly incorporating aesthetic considerations.

Assessing Efficacy with the Aid of Designers: We will work with designers and ask for their input on the experiment design in order to evaluate the efficacy of the developed method. During the design process, designers will be asked to use the method and incorporate the identified factors into their product concepts. We can assess how the method affects the final designs and the extent to which it improves the product aesthetics by using this hands-on approach.

By employing this methodology, we aim to close the gap between consumer preferences and design considerations. The objective is to equip industrial designers with the information, resources, and techniques needed to produce aesthetically enhanced products that meet consumers' needs, capture their attention, and satisfy their wants. Ultimately, our research aims to elevate product aesthetics as a crucial component of successful product development in today's cutthroat market.

7.3.Prime constituents of engineering aesthetics

Creating images to evaluate engineering aesthetics entails several crucial steps to assess the primary aesthetic components of appropriateness, pureness, proportion, and contrast. Here is a description of the actions taken:

Attractiveness: Attractiveness is an indicator of aesthetic assessment, and it is an expressive response to any object or product with aesthetic importance that is supposed to be carefully associated with an eyewitness's hedonic feelings (Marin et al., 2016; Martindale et al., 2018; Rahal & Fiedler, 2019). "Metaphors are frequently used in greeting cards, posters, and ads (McQuarrie & Mick, 1996; van Mulken et al., 2010; Gao et al., 2017). Because of their intrinsic perceptual incongruence, metaphors can arouse emotional and aesthetic responses (Tendahl & Gibbs, 2008)" Metaphors connect many thoughts or ideas by moving beyond literal language. Metaphors add depth and complexity to communication by clicking one picture with another, frequently using figurative language. This depth of significance captures the audience's imagination and elicits strong feelings. The impacts of metaphors were especially explored within a female-to-male complementary paradigm in study (Gao et al., 2017). The research's conclusions showed that metaphors were superior to the usage of precise and literal words in terms of their stunning appeal and attractiveness. Metaphors have a unique power to draw people in and make an impression that sticks. They provide a novel and inventive viewpoint that enables a more complex and moving expression of ideas. In addition, it underlined that women illustrated a stronger tendency towards unique metaphors as compare to the traditional ones (Baskerville et al., 2018). This description reveals the significant function of metaphors, fostering attraction, and capturing attention particularly among female who are moved from unconventional to innovative expressions. The perception, judgment of art and beauty, and appreciation is the region of aesthetics. The realm of aesthetics is the perception, appreciation, and judgment of beauty and art. Aesthetic object has potentials "in accordance with principles of taste or artistic beauty; intended or giving to provide pleasure through beauty; of pleasing appearance" (Baskerville et al., 2018).

Perception of function (appropriateness): Aesthetics is concerned with the functionality and concinnity of the product. Further beauty is linked to the concinnity and the attractiveness is related with functionality (Yadav, Jain, Shukla, et al., 2013a). On the other hand, attractiveness or unattractiveness is the perception that is developed through the product's aesthetic impression. In the early 21th century, Coates (2003) described their own theory related to the perception of product attractiveness. He positively describes aesthetics with concinnity and information factors. Concinnity is associated with logic and order (for example, in a proper way), which possibly supports the customer in understanding the product (Crilly et al., 2004, 2009). In addition, Coates (2003) also defines aesthetics as a combination of objective and subjective qualities. Objective qualities may be perceived as the quantity of "contrast" that a formation/design provides in opposition to within itself and its background. This depends on how specific design components are put together. For instance, objects that use a diversity of lines, shapes, and textures and are a starkly different color from the context in which they are observed will demonstrate great contrast. The innovation deemed in the design may be regarded as subjective information. This is mainly based on how far the product deviates from forms that the consumer is currently accustomed to. For instance, products that use shapes and lines drastically different from those typically seen attract curiosity because of their uniqueness. The two factors may consider the objective quality of product aesthetics; the first one is the amount of "Contrast" present by design (product) in contradiction to its background or surrounding itself, and the second is the "Order" perceived in the design. Subjective quality is concerned with the consumer's familiarity with the product and to what extent the design of the product makes sense to the consumers. This is determined by the customer's personal, cultural and visual experiences that assist them in understanding the product. The consumer's personal interaction, cultural, and visual, plays an essential part in reaching a decision. Through their comprehensive knowledge of the product, customers engage themselves in a development of their personal creation. If the information is greater than concinnity, in that case, the product could be confusing, ugly, and meaningless. On the other hand, if the information is less than concinnity, the product will be boring and dull. That balance is required among shapes, forms, and functionality to create the attractive product. Beauty is produced from logical or rational physical appearance relations (Kostellow, 2002; Khalighy et al., 2012) in that a proper sense of balance among these relationships produces a most favorable pleasantness. The standard of beauty is primarily generated from the key element which makes human beings capable of distinguishing visual elements. To describe powerful and measurable essential features of aesthetics it is necessary to initiate with the very basic level. By imagining/visualizing a completely spotless or fresh or new painting board, the very first feature or thing that attracts any human being is a visual element of design elements and it is known as "contrast".

Contrast: Kostellow (2002) defines the relationship between beauty and the different design elements. They also described how a product could be visually delightful using these elements. The visually delightful is one of the critical characteristics that come to designers' perception when designing any new product. Since visual aesthetic is a physical/visual appearance, it is directly associated with "what is seen" by a human being. The reason that the eye can recognise an object is because of the difference between the properties of the object and the properties of the background (Kostellow, 2002). For example, in current situations, what things or object makes you capable of understanding or recognizing the script on this manuscript or chapter is due to the difference in the colour or proportion of the words/text. According to Coates (2003), this is named as 'contrast'. Contrast is associated with the visual properties of the product, and it is not only restricted to the product's context, but it can also include other domains such as surgery, painting, and many more. In other words, contrast is produced by variation among the visual/physical properties of the design element and the background of the product. For instance, the variation among the length and the height of a product produces a contrast (Elam, 2001). Furthermore, the sum of these variations intensifies the contrast (Coates, 2003; Crilly et al., 2004a). Consequently, contrast is made by the quantity and the quality of the variations produced by the "elements" and the "composition of the gestalt". Higher the variation in elements and composition, higher the contrast, or lower the variation means lower the contrast (Khalighy et al., 2014).

Pureness: Kostellow (2002) describes in their work that pureness is a measurable quantity of contrast. Coates (2003) also defines in their study that the design elements fascinate the human being, for example; lower the pureness means higher the (curiosity) power of the fixing the mind (grabber) and vice versa (Khalighy et al., 2012). Similarly, the quantity of visual/physical elements rises, another factor which is known as "pureness". This factor is expressible in quantity, an essential characteristic of the term "beauty".

Proportion: There is another factor called "proportion," which is defined based on both similarity and dissimilarity when the visual elements interact with everyone. The term "proportion" is a qualitative portion of "contrast" (Kostellow, 2002). Since, it depends more on the consumers/user's observation and real-time case studies. Proportion is described on the basis of the visual similarity among the properties of the design elements, for example, size, nature, place, and colour (Papanek, 2022). In other words, proportion determines the stability generated by the visual weights of the gestalt composition (Coates, 2003). Thus, lower the likeness means lower proportion, and higher the likeness means higher the proportion. “A design not only has to be structural, it has to appear to be structural. You have to recognize structure like you recognize a hot stove.” “Always imagine these things one hundred times as large, and you’ll see that the proportions make a huge difference.” And these three (proportion, pureness, contrast) factors are the main constituent that combinely represents “beauty” (Kostellow, 2002; Coates, 2003; D. Norman, 2004).

7.4.Experimental details

Participant Information: Industrial designers from two different groups, one with three to four years of work experience and the other with five to seven years or more of industrial expertise, participated in the study.

There were two stages to the evaluation process:

Phase 1: Making a sketch:

The first stage involved the initial trio of designers, who had to create concept sketches for two distinct products: a camera and a car.

Purity, proportion, contrast, and appropriateness were among the many factors that the designers took into account while creating the sketches and other design elements.

Phase 2: Assessment by senior designers:

The study moved on to the second phase after finishing the first phase.

Senior designers were enlisted to review the sketches produced by the initial group of designers during this phase.

The senior designers were given access to the graphics containing the product sketches, and they were then asked to rate them using the 11-point rating scale listed in Table 7.1. The study's main objective was to gain a thorough understanding of how the identified factors—pureness, proportion, contrast, and appropriateness—affect product aesthetics. The study aimed to assess these factors' efficacy in enhancing the products' visual appeal by including both junior and senior designers in the evaluation process. The senior designers' assessments of the junior designers' sketches gave them insightful information about how design elements affect the aesthetics of the final product. This multi-phase methodology ensured the relationship between design elements and the aesthetic appeal was thoroughly and insightfully analyzed. It also made it possible for the study to provide insightful suggestions for creating aesthetically pleasing and improved products. The study aimed to offer a well-rounded understanding of product aesthetics and contribute to the development of more appealing and attractive designs by combining the knowledge and viewpoints of both junior and senior designers.

Table 7.1, shows the detail of designer

Serial number	Industrial designer	Average Experience	Domain
1	1	3	Automobile
2	1	4	Furniture
3	2	7	Kitchen product

Participants' Information (Step 1):

The first and second groups of industrial designers participated in the study. Three designers with an average of three to four years of experience made up the first group. Designers with at least five to seven years' worth of industrial expertise were included in the second group. A unique serial number was given to each participant as a means of identification.

Phase 1 - Sketch Creation, Step 2:

The first group of designers was tasked with producing product sketches for two particular items: a camera and a car, during the first stage of the evaluation process. While creating these sketches, the designers kept in mind a number of design principles, such as simplicity, proportion, contrast, and appropriateness. The objective was to make sure that during the sketch creation process, the product aesthetics were carefully taken into account.

Step 3: Senior Designers' Evaluation of Phase 2

The study proceeded to the second phase after finishing the first. Senior designers were involved in this phase to evaluate the sketches made by the initial group of designers. These senior designers have years of experience and are highly knowledgeable in their respective fields, which include kitchen goods, furniture, and automobiles. The senior designers were given the graphics containing the product sketches for review.

4th step: A rating system

The senior designers used a precise 11-point rating scale to evaluate various product images. With the help of this rating system, the designers could provide accurate and thorough evaluations of the product's aesthetics based on the following characteristics: appropriateness, appropriateness, pureness, proportion, and contrast. The scale's 11-point rating system provided a wide range of evaluation options, allowing for a more complex assessment of the design components.

Step 5: Obtaining Reliable and Complete Evaluations

Purity, proportion, contrast, and appropriateness were the factors that were chosen as the basis for the study's main goal: accurate and thorough evaluations of the product aesthetics. The researchers made use of the senior industrial designers' knowledge and the 11-point rating scale to achieve this. The findings of the study would be based on in-depth knowledge of the subject matter thanks to the senior designers' wealth of experience and profound understanding of design aesthetics.

Step 6: The importance of senior designers' knowledge

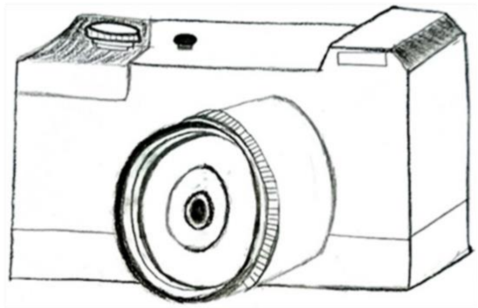
Given their extensive experience in the relevant fields, senior designers' participation in the evaluation process contributed useful insights and perspectives. Their evaluations helped to strengthen our understanding of how design factors affect product aesthetics and provided helpful advice for producing more aesthetically pleasing products.

The study sought to achieve a thorough and insightful analysis of the relationship between design elements and aesthetic appeal by using this multi-phase approach and involving both junior and senior designers. The study's credibility and potential to produce useful suggestions for enhancing product aesthetics were boosted by the combination of the 11-point rating scale and the senior designers' experience.

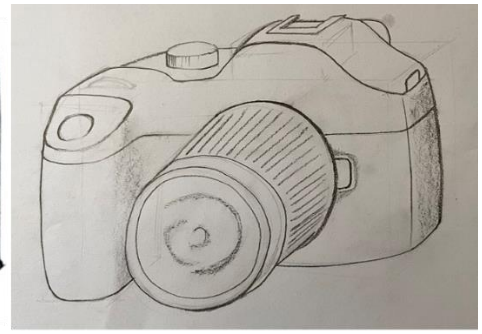
Table 7.2, shows the 11 point rating scale

	Aesthetically Poor					**Aesthetically Average (Neutral)**					**Aesthetically Excellent**
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

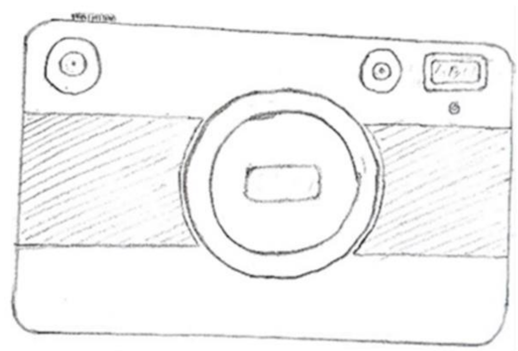
Image number											



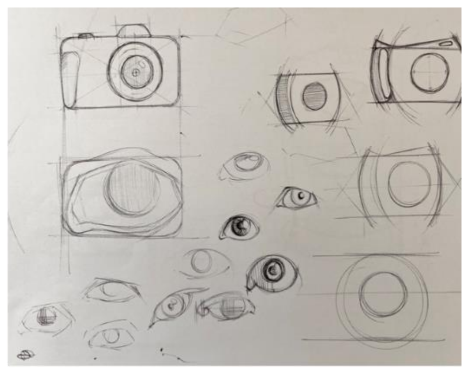
7.1 (a)



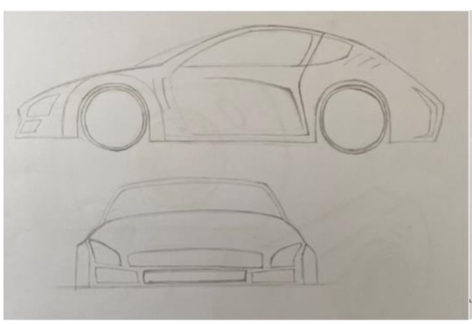
7.1 (b)



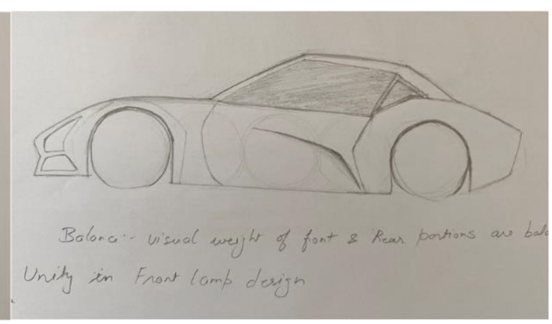
7.2 (a)



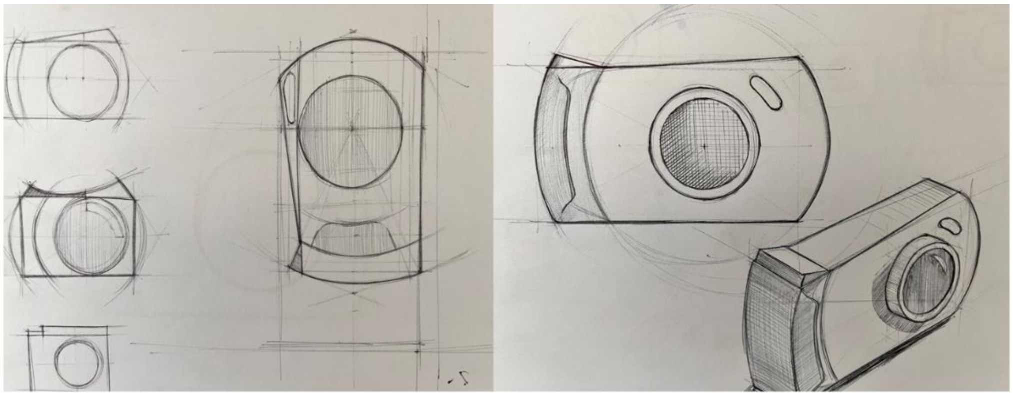
7.2 (b)



7.3 (a)



7.3 (b)



7.4 (a) 7.4 (b)

Figure 7.1-4 (a, b), shows the sketches drawn by designers with and without considering the various factors

Figure 7.1 thoroughly summarizes the factors considered and ignored during the product design process. These elements are crucial components that support the product's overall aesthetic appeal. To achieve the desired design outcome, the design team carefully evaluated the significance and relevance of each variable. Purity (the design's clarity and simplicity), proportion (the relative sizes and spatial relationships of design elements), contrast (the difference in visual properties that create interest and emphasis), and appropriateness (how well the design fits its intended purpose and context), among others, maybe some of the factors taken into account. To improve the product's aesthetics, consideration was given to these factors.

Table 7.3, shows the outcome of 11 point scale

Image number	Aesthetically Poor	Very Low Aesthetic Appeal	Low Aesthetic Appeal	Moderate Aesthetic Appeal	Moderately High Aesthetic Appeal	Aesthetically Average (Neutral)	Moderately High Aesthetic Appeal	High Aesthetic Appeal	Very High Aesthetic Appeal	Extremely High Aesthetic Appeal	Aesthetically Excellent
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1 (a) without indication of features				3 (D1)	4(D2)						
1(b) with indication of features					4(D1)		6(D2)				
2 (a) without indication of features					4(D1)	5(D2)					
2 (b) with indication of features								7(D1), 7(D2)			

3(a) without indication of features							6(D1)	7(D2)			
3 (b) with indication of features								7(D1),	8(D2)		
4 (a) without indication of features					4(D1)	5(D2)					
4 (b) with indication of features							6(D1)		8(D2)		

Step 1: Senior industrial designers' evaluations

The results of the 11-point rating scale, which two senior industrial designers used to evaluate the product images, are shown in Table 7.3. According to the scale, the images were given aesthetic appeal ratings ranging from "Aesthetically Poor" (rating of 0) to "Aesthetically Excellent" (rating of 10). The designers' perceptions of elements like purity, proportion, contrast, and appropriateness—all essential for judging the designs' overall aesthetic quality—were used to determine the ratings.

Image evaluation in step 2:

The senior designers carefully examined and rated each image using an 11-point scale. For instance, Designer 1 (D1) gave Image 1(a) a moderately high aesthetic appeal rating (rating of 4) and Designer 2 (D2) gave it a moderately high to high rating (rating of 6). D1 gave Image 1(b) a higher rating of 6, and D2 gave it a very high rating of 8. Similar to Image 2(a), Image 2(b) received a high rating of 7 from both D1 and D2, while Image 2(a) received ratings of 4 from D1 and 5 from D2.

Step 3: Evaluation of Various Features

The presence or absence of particular features and how those features affected the aesthetics as a whole were taken into consideration by the designers when evaluating the images. For instance, the aesthetic appeal of Images 3(a) and 3(b) was evaluated based on the presence or absence of specific characteristics or indicators. D1 and D2 gave Image 3(a) ratings of 6 and 7, respectively, while D1 and D2 gave Image 3(b) ratings of 7 and 8.

Step 4: Aesthetic Assessment of Different Design Alternatives

Additionally, each image's various design options were assessed by the designers. For instance, Image 4(a) received ratings of 4 (D1) and 5 (D2) due to the absence of specific features. Contrarily, Image 4(b) with feature indication received higher ratings of 6 (D1) and 8 (D2). These analyses assisted in identifying which design features significantly influenced the product's overall aesthetic appeal.

The study sought to learn more about the effects of design factors on product aesthetics by conducting this evaluation process with senior industrial designers. The designers were able to offer insightful criticism and suggestions for producing products with appealing visuals thanks to the detailed evaluations using the 11-point rating scale.

7.5.Results and data analysis

The results of the rating scale, which represents the average of the two senior industrial designers' ratings for each product image, are shown in Table 7.4. The ratings, which are based on pureness, proportion, contrast, and appropriateness, indicate the overall aesthetic appeal of the images. The scale goes from "Aesthetically Poor" (zero) to "Aesthetically Excellent" (10).

Table 7.4, Average value of 11 rating scales

Image number	Average value of Rating scale results
1 (a) without indication of features	3.5
1(b) without indication of features	5
2 (a) without indication of features	4.5
2 (b) with indication of features	7
3(a) without indication of features	6.5
3 (b) with indication of features	7.5
4 (a) without indication of features	4.5
4 (b) with indication of features	7

Analysis: The analysis of the participants' ratings provides valuable insights into the perceived aesthetic appeal of the images under consideration. Let's further elaborate on the findings and their implications:

1st Step: Scale of Rating Results: The average score for each product image on the 11-point rating scale is shown in Table 7.4. The ratings were calculated by averaging the two senior industrial designers' scores on the criteria of appropriateness, pureness, proportion, and contrast. The ratings on the scale run from "Aesthetically Poor" (0 points) to "Aesthetically Excellent" (10 points). The perceived overall aesthetic appeal of the product images is reflected in these ratings.

Image 1 analysis in step 2: The average rating for Image 1(a) with no indication of features was 3.5. This rating puts it in the lower half of the rating scale, indicating that the evaluators did not find it to be particularly visually appealing. The bathe lack of distinguishing characteristics or visual cues may influence this perception. The average rating for Image 1(b) with feature indication was 5, indicating an improvement in aesthetic appeal. This implies that adding design elements improved the image's visual appeal.

Image 2 Analysis in Step 3: The average rating for Image 2(a) without any indication of features was 4.5, which puts it closer to the "Aesthetically Average" range. This shows that while the image has some aesthetic appeal, it still needs to be polished. A higher rating of 7 was given to Image 2(b) with the indication of features, indicating a noticeably better aesthetic appeal. The image's visual appeal was significantly impacted by the addition of extra features.

Image 3 analysis in Step 4: Without any indication of features, Image 3(a) received an average rating of 6.5, placing it in the "Aesthetically Average" category. This shows that although the image is aesthetically pleasing, there is still room for improvement. The average rating for Image 3(b) with feature indication was 7.5, indicating an improvement in aesthetic appeal. The presence of features significantly increased the image's visual appeal.

Image 4 Analysis in Step 5: The average rating for Image 4(a) without any indication of features was 4.5, placing it in the same "Aesthetically Average" category. This implies that while there is potential for improvement, the image has some aesthetic value. A higher rating of 7 was given to Image 4(b) with the indication of features, indicating a noticeably improved aesthetic appeal. The image's overall visual appeal was noticeably improved by the addition of features.

Step 6: General Consequences: According to the analysis, pictures that effectively incorporate design elements like proportion, purity, contrast, and appropriateness are seen as more beautiful than pictures that don't. By highlighting the importance of taking into account elements like form, proportion, contrast, and appropriateness during the product design process, the rating scale offers designers useful feedback. Designers can produce goods that not only fulfil their intended functions but also appeal to customers' aesthetic preferences and desires by incorporating these features into their product designs.

Step 7: Subjectivity and Upcoming Studies: It is important to understand that everyone has different aesthetic preferences. The analysis is based on participant feedback from a particular group. The factors influencing perceived aesthetic appeal could be better understood by conducting additional research and soliciting feedback from a larger and more diverse audience.

Iterative design process, step 8: Iterative research and user feedback are helpful to ensure a thorough understanding of the factors influencing aesthetic appeal and to fine-tune the design process accordingly. Designers can produce goods that successfully strike a balance between functionality and aesthetics, satisfying both consumer needs and desires, by iterating continuously and incorporating user feedback.

7.6.Summary

The rating scale's results, determined by the assessments of two senior industrial designers, provide insightful information about the aesthetic quality of product images. The images' average aesthetic scores, ranging from "Aesthetically Poor" to "Aesthetically Excellent," clearly indicate the designers' opinions. The analysis reveals exciting trends. With no indication of features, Image 1 received a lower score of 3.5, indicating a lack of aesthetic appeal. However, the rating went up to 5, showing an improvement in aesthetic appeal when features were added to Image 1(b). This emphasizes how crucial it is to include design elements to improve product visual appeal. Similar to Image 1, Image 2 without features received a rating of 4.5, denoting a moderate level of aesthetic appeal. In contrast, Image 2(b) with features received a higher rating of 7, demonstrating the significant influence of additional features on aesthetic appeal. Images 3 (a) and (b) displayed a similar pattern, with the image with features receiving a higher score and the one without receiving a moderate rating. Images 4 with and without features received ratings of 4.5 and 7, respectively, indicating a significant improvement in aesthetic appeal when features were added. The study aimed to assess the aesthetic appeal of product images in relation to industrial design. The evaluation process involved two groups of industrial designers, one with three to four years of work experience and the other with five to seven years or more of experience in the industry. Two phases make up the evaluation process. In the first stage, junior designers produced product sketches for a camera and a car, considering design elements like appropriateness, pureness, proportion, and contrast. Senior designers evaluated and rated the images using an 11-point rating scale in the second phase to determine their aesthetic appeal. According to the findings, people found images with well-integrated design elements—such as proportion, purity, contrast, and appropriateness—to be more aesthetically pleasing. The addition of features greatly enhanced the product images' visual appeal. This emphasised the significance of considering design aesthetics in addition to functionality to produce aesthetically pleasing and enhanced products.

Physical Significance:

Consumer Appeal and Aesthetics: This research emphasises the importance of aesthetics in product design and how it affects consumer appeal. Products that are aesthetically pleasing and visually appealing are more likely to appeal to consumers, increasing their desirability and the possibility of higher sales.

Purity, proportion, contrast, and appropriateness are just a few examples of the design elements that the study shows have a significant impact on how people perceive a product's aesthetic appeal. Effectively incorporating these components can improve users' overall visual experiences.

Balance of Form and Function: The research highlights how crucial it is for product designers to balance form and function. Aesthetics play a role in user satisfaction's emotional and psychological components, even though the functionality is vital for satisfying user needs.

Iterative Design Process: According to the study, designers should iterate on their designs and seek feedback toto continuously enhance their creations' aesthetic appeal. By using an iterative process, products are improved to match customer preferences.

The subjectivity of Aesthetic Preferences: The study recognizes that individual tastes can vary and that aesthetic preferences can be subjective. However, by considering the outlined design criteria, designers can produce goods that are more appealing to a broader market and satisfy a variety of customer demands.

Expertise of Senior Designers: Senior industrial designers' insights and opinions are extremely valuable when included in the evaluation process. Their wealth of knowledge aids in ensuring that the study's conclusions are founded on a profound knowledge of design aesthetics.

The study highlights the significance of aesthetics in industrial design and how it affects consumer perception and product desirability in its conclusion. Designers can produce visually appealing products that connect with customers and raise general user satisfaction by effectively incorporating design elements and soliciting feedback throughout the design process. The research highlights the importance of proportions, purity, contrast, and appropriateness in producing aesthetically pleasing designs. The feedback from the scale offers helpful advice to designers, encouraging the inclusion of these components to improve functionality and aesthetics in product design. Understanding that aesthetic preferences are arbitrary and everyone has different tastes is crucial. The analysis is based on a particular set of participants, and increasing the sample size might provide more information. Future research should consider a more representative audience to validate the results and make wise design choices. This study's conclusion highlights the importance of integrating functional and aesthetic considerations in product design. Designers can produce goods that fulfill their intended purpose and captivate customers through an aesthetic appeal by carefully weighing factors like proportion, purity, contrast, and appropriateness. The best products strike the perfect balance between functionality and aesthetics through iterative design processes and user feedback, ultimately satisfying the needs and preferences of the target market.

CHAPTER 8

CONCLUSIONS AND FUTURE WORK

This chapter presents the conclusions of the research work conducted in this study. It also provides the key contributions of this study, along with the limitations and the directions for carrying forward this research in the future. In this study, a comprehensive review of the literature was carried out by using the search strings as: (("product design" or "aesthetic-design" or "engineering aesthetics design" or "product development" or "factors of product design" or "design elements" or “consumer behaviour”) and ("method" or "tool" or "technique" or "framework" or "guideline" or "procedure")). A total of 372 relevant articles were identified and reviewed critically.

It was observed the understanding of the “product design” or “engineering aesthetics design” or “product development” or “factors of product design” or “design elements”) through the critical review of the literature within industrial designers is not up to the level that can help them for understanding and improvement of aesthetic of any product. During literature search, we identify that there is no exact definitions for engineering aesthetics and limited studies has been done to identify the basic or essential attributes or characteristics or variables of product aesthetic design. It was identified that there are various factors that can influence and effects engineering product aesthetics design, but an identification and comprehensive understanding of these factors are missing in the literature. During literature search, we identify there were limited amount of studies on the quantification of product aesthetics. At the same time, in literature we were unable to find the AI based tool of the assessment of product beauty. This tool can supports or assists designers to for the enchantment of products beauty at the very beginning stage of product development. To achieve this aim, three different research objectives were formulated.

First objective focused on identifying the different definitions of aesthetics in term of psychology as well as engineering. During this study, we done analyzation of part of speech, cluster development, and made of generic definitions. The study looks at several definitions of aesthetics from a philosophical and engineering standpoint. Twelve professional purposes were picked after 24 meanings were reviewed, and their commonalities were examined to produce a single report. It is crucial to remember that the researchers sought to create a shared purpose of aesthetics based on the perceptions of acknowledged specialists in philosophy and engineering. A general definition was developed, even though it might not fit all academic fields precisely. While engineering aesthetics was defined by combining parts from philosophy aesthetics and identifying components pertinent to engineering, the philosophical aesthetics definition integrates the ideas of beauty and attractiveness. With the help of this general concept, the proper tests, characteristics, and measurement techniques for engineering aesthetics were found. The study suggests additional methods for examining product aesthetics, including "product characteristics tests" and "assessment of previous product aesthetics based tests." Contrast, appropriateness, proportion, rhythm, harmony, unity, and sense of function are engineering features that have been proven crucial for assessing aesthetics. The generic engineering aesthetics definitions adopt a logical and mathematical perspective while considering the influence of philosophy and art, in contrast to philosophical explanations, which frequently concentrate on fields like theatre, literature, music, and poetry. The results of this study have consequences for design professionals and educators, providing chances to improve product aesthetics through suitable methodologies and testing. The study is anticipated to help designers enhance the visual features of their products, which will help businesses in various ways.

In second objective we focused on visual and non-visual factors and their sub factors of product. First we study, visual aspects of automobiles and other items have been the subject of extensive investigation because they significantly impact consumer and designer perceptions. Our literature analysis, however, showed needs to be more consistency between how consumers and designers see the visual elements of automotive design. Industrial designers, marketing decision-makers, and brand value enhancement experts must bridge this divide. This gap can be attributed, in part, to the fact that designers frequently work alone, without directly contacting potential customers to learn about their preferences. Designers usually receive feedback from marketing experts or statistical data in technical language, missing out on the emotional and human values that need to be properly articulated. Face-to-face interactions with real consumers are necessary for designers to solve this issue and incorporate their viewpoints into the design process. By including consumers in the design phase, we may observe a difference in automotive designs that are more closely in line with consumer expectations. Industrial specialists must consider these elements early on in the product development process because they are critical to the success of cars in today's market. Future research should also consider additional characteristics, such as corporate strategy, organizational communication, R&D vision, and cross-disciplinary collaboration, since these aspects indirectly impact how people operate inside organizations. For instance, it has been discovered that corporate communication affects a group's creativity and innovation. Elements including organizational support, supervisory encouragement, freedom, resources, and challenging job positively impact creative thinking. Further, in the next research studied the non-visual elements that affect consumers' and designers' cognitive approaches to automobile products. Our empirical study proves the numerous elements that contribute to a product's success. We were able to analyze the cognitive behaviour of customers and bridge the gap between their perspectives through questionnaires given to both consumers and designers. The open-ended survey discovered new non-visual elements previously absent from the literature. We analyzed and weighted these factors using rank/average value and the Pareto principle to determine the most important aspects influencing car design and buying decisions. Mileage/fuel efficiency, safety features, dependability, ergonomics, and quality/warranty were the most important factors found. We go into great detail about each factor's contribution to a product's success and provide examples. It is significant to remember that it is impractical to satisfy every consumer's need in a single design due to their variety of requirements. Nevertheless, this study offers helpful insights for designers to comprehend client needs better. Future perspectives can be gained by expanding this effort to include a bigger sample size of customers and designers. To verify the applicability of our suggested research, the outcomes and conclusions from our study can be applied to various industry setups. Indirect influences on employee performance can also be attributed to additional factors not covered in this study, including business strategy, R&D vision, organisational communication, and cross-disciplinary collaboration. Organisational communication, for instance, has been noted as an influencing factor for collective creativity and innovation. Creativity is also favourably correlated with elements like organisational support, workgroup collaboration, supervisory encouragement, freedom, resources, and demanding jobs. To obtain a competitive edge, businesses should prioritize corporate initiatives, including superior after-sales services. Similarly, marketing experts, companies, and R&D divisions should concentrate on identifying the concealed needs of today's consumers. Instead of relying exclusively on data gathered from social networking sites or customers' everyday lives, it is crucial to interact directly with consumers to understand these wants or desires that affect consumer perceptions when acquiring a new product.

The psychology of customers during the car-buying process is the subject of upcoming studies, which recognise that consumers' behaviour in this area has changed due to the importance of cars in people's lives. The objective is to assist auto manufacturers in understanding consumer psychology and informing decisions. A literature study and survey investigated non-visual aspects that affect consumers' cognitive behaviour when buying cars. To determine how the discovered factors affected consumer cognition, further analysis was done using the DEMATEL method. The results show that "Car cost" emerges as the critical variable influencing car buyers' psychology. Customers believe that more expensive cars are more likely to draw attention and interpret the price as a measure of their purchasing power. Consumers' cognitive appeal is highly impacted by an automobile's "brand value" since knowledge about a car sticks in their memories and influences their purchasing behaviour. Additionally, to attract customers, automakers should highlight the "reliability" component because, in the long run, a car considered reliable is a preferred option. A car's "Engine performance" and "Eco-mode feature" are important features since they have an impact on other non-visual aspects of the vehicle. A reliable engine not only reinforces dependability but also helps to justify the car's price. Designers should prioritize these elements when conceptualizing cars to capture consumers' interest and increase sales and market share. To acquire a deeper understanding of the non-visual aspects impacting consumer cognition when purchasing an automobile, additional study can be done by involving a more significant sample of customers. Additionally, cognition-based studies like eye tracking might reveal more about the thinking processes of consumers.

In third research study, the aims to better understand consumer expectations for these aspects by examining the effects of aesthetic features that are appropriate for product design. This study focuses on the cognitive perception of customers, which offers valuable insights for decision-making. Previous research has mainly concentrated on the emotional and intuitive components from the standpoint of industrial product designers. A combination of traditional and cutting-edge approaches, tools, and equipment is used to gather consumers' cognitive approach to suitability aspects. To better understand human visual and cognitive thinking, the research is conducted in two phases using a variety of product categories with a range of functionalities. The study clarifies how suitability features affect consumer choice before product purchase. Data collection from eye-tracking investigations is labour- and time-intensive due to the intricacy and individuality of human mental processes. The primary goal is to better comprehend consumer expectations for appropriate aesthetic elements in product design. In contrast to earlier studies, which mainly concentrated on emotional and intuitive judgments of industrial product designers, the current study analyses consumers' cognitive assessments of product aesthetics. The research uses a variety of strategies and tools to record consumers' cognitive interpretations of appropriateness aspects. The results underline the significance of appropriateness in customers' decision-making and highlight the complex nature of eye-tracking studies, which are influenced by outside factors and take a lot of time and effort. The hypotheses look at how the Frequency Match Ratio (FMR) score, eye-tracking findings, product silhouette, customer decision-making, and perception of function relate to one another. Overall, the study advances knowledge of the interactions between product aesthetics, cognitive processing, consumer behaviour, and how appropriateness affects consumer decision-making.

Further, we studied, the primary aesthetic factors that affect art, engineering, and psychology are proportion, purity, contrast, and beauty. It presents an impartial and trustworthy method that enables the assessment of these aesthetic qualities through observing eye behaviour using Artificial Neural Networks (ANN) and a mathematical formula. The system measures eye fixation counts, durations, and standard durations through eye-tracking trials to approximate the ultimate preference for product aesthetics. Designers can unbiasedly assess concepts and raise the aesthetic worth of their works by integrating this aesthetic measuring method with AI technology. By enhancing their comprehension of visual design principles and encouraging objective aesthetic judgments, this practice assists both seasoned and inexperienced designers and design students. It aids designers in improving the functional and aesthetically pleasing aspects of their creations. The study offers a valuable technique for researchers and design students to improve the standard of product aesthetics in their designs. They can evaluate and enhance the aesthetic design while concentrating on the attractiveness of the final result. Industrial designers and researchers might profit from the study's conclusions by adding customer viewpoints, which provide insights into discovering visually acceptable products even when tiny alterations are difficult to evaluate. The mathematical method for evaluating beauty can be used to assess the degree of visual appeal in various configurations in various contexts. The study unveils a cutting-edge AI tool that helps designers pick the ideal design components to maximise a product's aesthetic appeal. When the tool's effectiveness was tested, it showed a remarkable accuracy of over 97% for predicting aesthetic outcomes relating to purity, proportion, contrast, and contrast/total time values. This ground-breaking tool lets designers immediately recognize the consequences of design parameter changes by enabling trade-offs and in-the-moment adjustments to visual elements.

The following step entails determining the pertinent standards to develop a thorough model for enhancing beauty, including standards for proportion and shape purity. A more extensive library of relevant data is required to improve the model further, which can then be paired with eye-tracking technology to generate quicker and more precise results. The approach has enormous potential for determining the beauty of any product based on the results of rigid body analysis and evaluating the beauty of three-dimensional rigid bodies. Extending the dataset and combining eye-tracking technology offers designers a solid and objective framework for evaluating and refining the aesthetic qualities of various goods. The suggested method is scalable to various product types and settings where the objective measurement of visual attractiveness is needed. Eye-tracking technology may become unnecessary as more data is obtained and merged into the AI tool, allowing designers to maximise aesthetic appeal and lower rejection rates based on product beauty through thorough product data integration. By helping designers and companies create visually pleasing and commercial products, this methodology can revolutionize how we evaluate and enhance the visual appeal of numerous objects.

8.1.Key contributions

The key contributions of this research are summarized below.

1. A generic concept of aesthetics that considers beauty and attractiveness was developed due to the study's discovery of similarities between philosophical and engineering definitions of aesthetics. It highlighted technical elements essential for evaluating aesthetics and suggested approaches for studying product aesthetics. The study provides ramifications for design experts and educators, providing chances to enhance product aesthetics through

appropriate testing and procedures, ultimately helping businesses. While it might be familiar territory for seasoned product designers, it's crucial to note that the unique perspective of a mechanical engineer adds a valuable dimension to the exploration of aesthetics. This study strives to bridge the gap between philosophical aesthetics and engineering, contributing a fresh viewpoint that could potentially enrich the understanding of aesthetics for both mechanical engineers and product designers. The interdisciplinary approach aims to foster collaboration and create a more holistic comprehension of aesthetics in the broader context of design and engineering.

2. Bridging the gap between consumer and designer perceptions of visual elements in automotive design is crucial for industrial designers, marketing decision-makers, and brand value enhancement experts. Including real consumers in the design phase and considering additional factors like corporate strategy and organizational communication can lead to automotive designs that better align with consumer expectations and enhance creativity and innovation. The key contribution lies in the detailed exploration and analysis presented, offering specific insights, methodologies, and tools that can facilitate and enhance the process of bridging this gap. By delving into the intricate dynamics of user preferences, cognitive processes, and design decision-making, the research aims to provide actionable recommendations and practical strategies that go beyond general awareness, fostering a more nuanced and effective approach to aligning automotive design practices with user expectations.
3. The study on non-visual elements in automobile products highlights factors such as mileage/fuel efficiency, safety features, dependability, ergonomics, and quality/warranty as crucial influences on consumer buying decisions and product success. Understanding the non-visual elements that influence consumers' cognitive behavior when buying cars, such as car cost, brand value, reliability, engine performance, and eco-mode features, is crucial for auto manufacturers to comprehend consumer psychology and make informed decisions. Prioritizing these non-visual aspects in car design can capture consumer interest, increase sales, and enhance market share, emphasizing the importance of considering factors beyond visual aesthetics. The research not only identifies these non-visual elements but also delves deeper into their prioritization and weightage by both consumers and designers. The unique aspect is the development of a decision-making tool for designers based on these insights, providing a structured and data-driven approach to address the intricate interplay of non-visual elements in the design process. This tool offers a practical contribution to the field by bridging the gap between theoretical understanding and actionable design decisions, thereby enhancing the overall value of the research for practitioners and researchers alike.
4. This research focuses on understanding how aesthetic features that are appropriate for product design impact consumer choice and decision-making, specifically examining the cognitive perception of customers. It sheds light on the significance of appropriateness in customers' decision-making and enhances our understanding of the complex relationship between product aesthetics, cognitive processing, and consumer behavior. By employing a combination of traditional and cutting-edge approaches, tools, and equipment, this study gathers consumers' cognitive approach to suitability aspects and explores how appropriateness factors influence consumer expectations and choice before making a purchase. The findings contribute to advancing knowledge about the role of aesthetics in consumer decision-making and highlight the intricate nature of eye-tracking studies in capturing consumers' cognitive interpretations.

5. This research introduces an impartial and reliable method for assessing aesthetic qualities, such as proportion, purity, contrast, and beauty, by leveraging eye-tracking technology and Artificial Neural Networks (ANN), enabling designers to enhance the aesthetic value of their creations and make objective aesthetic judgments. The study unveils a cutting-edge AI tool that accurately predicts aesthetic outcomes and allows designers to make real-time adjustments to visual elements, revolutionizing the evaluation and enhancement of product aesthetics and providing a scalable framework applicable to various product types and settings. The gap identified in the literature lies in the need for a systematic approach to incorporate non-visual elements into the design process. Our research addresses this gap by not only identifying these crucial variables but also by providing a structured tool that enables designers to make informed decisions based on empirical insights. This contribution aims to enhance the efficiency and effectiveness of the design process, aligning it with user preferences and expectations. We believe that this practical tool, grounded in empirical research, adds value to the existing body of knowledge and provides a tangible resource for designers seeking to navigate the complex landscape of non-visual elements in product design.
6. Evaluations key lines: The rating scale's findings demonstrate the significance of including elements like proportion, pureness, contrast, and appropriateness in the design process by showing how adding design elements significantly improves the aesthetic appeal of product images. Indeed, user psychology and perception studies constitute a significant body of knowledge in the design research domain. However, our thesis goes beyond merely reiterating existing cognitive processing concepts. We contribute to the field by emphasizing the practical application of these cognitive insights. The key gap we address is the translation of cognitive variables into a tangible decision-making tool for designers. By connecting theoretical understanding with a hands-on tool, we aim to bridge the existing divide between cognitive research and its direct implementation in the design process. This effort reflects our commitment to making cognitive insights accessible and actionable for designers, thereby enhancing the overall quality and user-centricity of product design practices.
7. The analysis highlights the need for designers to strike a balance between functionality and aesthetics, as goods that succeed in both areas are more likely to connect with customers and fulfill their preferences for appealing and aesthetically pleasing designs. The extensive statistical analysis conducted aimed to provide a comprehensive understanding of user attention and gaze patterns in relation to aesthetic elements. We acknowledge that eye-tracking alone may not directly measure or detect aesthetics, but our intention was to uncover correlations between visual attention and perceived aesthetics. The statistical rigor was employed to ensure the validity and reliability of the findings.

7.2.Limitations and scope for future work

Even though the different aspects of this work have been completed and evaluated, there are certain limitations associated with this study are mentioned as: Assessing aesthetic attributes inevitably includes making subjective judgments, which can differ from person to person. Although the study used objective measurements, it should be noted that judging aesthetic preferences may still be subject to inherent subjectivity. External influences and elements: Cultural background, social environment, and personal experiences are just a few external factors that can impact an individual's aesthetic choices. These variables might affect the generalizability of the results because they were not explicitly taken into account in the study. The current limitation of the proposed tool is its ability to analyze the beauty of only one product at a time. However, by incorporating additional features to handle multiple product details, the tool can be expanded into a more versatile and generalized format. This enhancement would enable designers and researchers to assess the aesthetic qualities of multiple products simultaneously, providing a broader perspective and enhancing the tool's overall utility for product evaluation and design.

Sample size and participant diversity: The study's sample size or lack of participant diversity may limit how far the results may be applied. The validity and application of the findings might be improved by using a more extensive and varied sample. The study may have concentrated on particular product categories or situations, which may have limited the generalizability of the results to other fields. A more thorough grasp of aesthetic elements can result from considering various items or contexts. Reliance on eye-tracking technology: Although it offers valuable information about visual attention and fixation patterns, it has several drawbacks. Elements like participant weariness, calibration issues, or individual variations in eye movements may impact the accuracy and reliability of the eye-tracking data.

The following aspects can be considered for carrying forward the research conducted in this study.

- Industrial designers would benefit greatly from research into the crucial elements, traits, and variables of product aesthetic design specific to engineering.
- Increasing Consistency between Designers and Customers: The study strongly emphasized the necessity of more consistency between how customers and designers view visual aspects in automobile design. Future studies might look into practical ways to close this gap, like including in-person consumer contacts in the design process. Procedures that satisfy customer expectations may result from early consideration of their preferences and input.
- Extending Non-Visual Factors Analysis: The study uncovered significant non-visual influences on car design and purchasing choices. Future research should consider additional factors that indirectly influence people's behavior, such as business strategy, organizational communication, R&D vision, and cross-disciplinary collaboration. Exploring these aspects would give a comprehensive grasp of the factors impacting consumer cognition.
- The study mainly concentrated on aesthetic elements: proportion, purity, contrast, and attractiveness. Other crucial aesthetic aspects or dimensions may have been missed. Future studies might consider a broader range of aesthetic variables to provide a more thorough understanding of product aesthetics.
- The study brought attention to the role of cognitive perception in consumers' choice of appropriate aesthetic components in product design. Future studies could investigate how consumers cognitively judge various product categories and features. A more profound knowledge of consumer expectations would result from looking into how appropriateness characteristics affect consumer decisions before product purchase.
- We aimed to leverage EYE tracking as a tool to gain insights into user gaze patterns during aesthetic evaluations. However, we understand that the effectiveness and relevance of this tool in evaluating aesthetics may not have been clearly communicated in the chapter and we have revisit the presentation of these results to better align them with the objectives of our thesis. Regarding the statistical analysis, we recognized that there may be instances where a more concise approach could be beneficial. We have carefully reassess the statistical methods employed,

ensuring that every analysis performed is directly contributing to the understanding of our research questions and objectives.

- Future research in the domain of engineering aesthetics could explore various dimensions to enrich our understanding and application of aesthetic principles. Firstly, delving into cross-cultural aesthetics would provide valuable insights into how cultural backgrounds shape preferences, influencing design decisions. At the same time, advanced measurement techniques, such as combining eye-tracking with neuroscientific tools, can be further developed to offer more nuanced and accurate assessments of aesthetic experiences. Further, examining the application of engineering aesthetics in emerging technologies, like artificial intelligence or augmented reality, would address the evolving landscape of user interactions. Longitudinal studies tracking user satisfaction over time could provide a more comprehensive understanding of the lasting impact of engineering aesthetics. Additionally, fostering effective collaboration between engineering and product/industrial designers, validating aesthetic models, and integrating sustainability into design aesthetics are areas that warrant dedicated exploration. The incorporation of artificial intelligence in the design process and educational initiatives to emphasize aesthetics in engineering curricula also present exciting avenues for future research. Overall, these directions aim to build upon the current thesis, contributing to the evolving discourse on engineering aesthetics. Artificial Neural Networks (ANN) and eye behaviour observations are used in the research to present a new AI-based tool for evaluating aesthetic attributes. Future research should focus on growing the dataset and further developing the model to increase the precision and effectiveness of aesthetic evaluations. In addition, looking into alternatives to eye-tracking technologies might produce quicker and more accurate results while lowering dependency on specific data collection techniques.

REFERENCES

A, B., Dhawan, R., Gupta, S., & Mangaleswaran, R. (2020). *Shaping the new normal*.

Agost, M.-J., & Vergara, M. (2014a). Relationship between meanings, emotions, product preferences and personal values. Application to ceramic tile floorings. *Applied Ergonomics*, *45*(4), 1076–1086. https://doi.org/10.1016/j.apergo.2014.01.008

Agost, M.-J., & Vergara, M. (2014b). Relationship between meanings, emotions, product preferences and personal values. Application to ceramic tile floorings. *Applied Ergonomics*, *45*(4), 1076–1086. https://doi.org/10.1016/j.apergo.2014.01.008

Aktar Demirtas, E., Anagun, A. S., & Koksal, G. (2009). Determination of optimal product styles by ordinal logistic regression versus conjoint analysis for kitchen faucets. *International Journal of Industrial Ergonomics*, *39*(5), 866–875. https://doi.org/10.1016/j.ergon.2009.06.007

Alba, J. W., & Williams, E. F. (2013). Pleasure principles: A review of research on hedonic consumption. *Journal of Consumer Psychology*, *23*(1), 2–18. https://doi.org/10.1016/j.jcps.2012.07.003

Alecu, F. (2010). *The Pareto Principle in the Modern Economy*. *2*(3), 4.

Alibage, A., & Jetter, A. (2017). *Drivers of Consumers' Emotional Engagement with Everyday Products: An Intensive Review of the Literature and an Attempt to Conceptualize the Consumer-Product Interactions Within the Emotional Design Process*. 34.

Angelova, B., & Zekiri, J. (2011). Measuring Customer Satisfaction with Service Quality Using American Customer Satisfaction Model. *International Journal of Academic Research in Business and Social Sciences*, *1*(3), 27. https://doi.org/10.6007/ijarbss.v1i2.35

Archer, N. P., & Wesolowsky, G. O. (1996). Consumer response to service and product quality: A study of motor vehicle owners. *Journal of Operations Management*, *14*(2), 103–118. https://doi.org/10.1016/0272-6963(95)00045-3

Arnheim, R. (1969). *Visual thinking*. University of California Press.

Arnheim, R. (1974). *Art and Visual Perception_ A Psychology of the Creative Eye*. University of California Press.

Attneave, F. (1954). Some informational aspects of visual perception. *Psychological Review*, *61*(3), 183–193. https://doi.org/10.1037/h0054663

Audi, R. (Ed.). (1995). *The Cambridge dictionary of philosophy*. Cambridge University Press.

Audi, R. (Ed.). (2015). *The Cambridge dictionary of philosophy* (Third edition). Cambridge University Press.

Barnes, C., & Lillford, S. P. (2009). Decision support for the design of affective products. *Journal of Engineering Design*, *20*(5), 477–492. https://doi.org/10.1080/09544820902875041

Baskerville, R. L., Kaul, M., & Storey, V. C. (2018). Aesthetics in design science research. *European Journal of Information Systems*, *27*(2), 140–153. https://doi.org/10.1080/0960085X.2017.1395545

Baxter, M. (1995). *Product Design* (1st ed.). CRC Press. https://doi.org/10.1201/9781315275246

Beardsley, M. C. (1981). *Aesthetics_ Problems in the Philosophy of Criticism-Harcourt, Brace & World, Inc. (1958).pdf*.

Belén del Río, A., Vázquez, R., & Iglesias, V. (2001). The effects of brand associations on consumer response. *Journal of Consumer Marketing*, *18*(5), 410–425. https://doi.org/10.1108/07363760110398808

Berger, J., Norman, R. Z., Balkwell, J. W., & Smith, R. F. (1992). Status Inconsistency in Task Situations: A Test of Four Status Processing Principles. *American Sociological Review*, *57*(6), 843. https://doi.org/10.2307/2096127

Berger, J., Rosenholtz, S. J., & Zelditch, M. (1980). Status Organizing Processes. *Annual Review of Sociology*, *6*(1), 479–508. https://doi.org/10.1146/annurev.so.06.080180.002403

Bertoni, A., Hallstedt, S. I., Dasari, S. K., & Andersson, P. (2020). Integration of value and sustainability assessment in design space exploration by machine learning: An aerospace application. *Design Science*, *6*, e2. https://doi.org/10.1017/dsj.2019.29

Bhandari, U., Chang, K., & Neben, T. (2019). Understanding the impact of perceived visual aesthetics on user evaluations: An emotional perspective. *Information & Management*, *56*(1), 85–93. https://doi.org/10.1016/j.im.2018.07.003

Birkhoff, G. D. (1933). *Aesthetic Measure* (1st ed.). MIT.

Birmingham, R. (Ed.). (1997). *Understanding engineering design: Context, theory, and practice*. Prentice Hall.

Blessing, L. T. M., & Chakrabarti, A. (2009a). *DRM, a Design Research Methodology*. Springer London. https://doi.org/10.1007/978-1-84882-587-1

Blessing, L. T. M., & Chakrabarti, A. (2009b). *DRM, a Design Research Methodology*. Springer London. https://doi.org/10.1007/978-1-84882-587-1

Blijlevens, J., Thurgood, C., Hekkert, P., Chen, L.-L., Leder, H., & Whitfield, T. W. A. (2017). The Aesthetic Pleasure in Design Scale: The development of a scale to measure aesthetic pleasure for designed artifacts. *Psychology of Aesthetics, Creativity, and the Arts*, *11*(1), 86–98. https://doi.org/10.1037/aca0000098

Bloch, P. H. (1995a). Seeking the Ideal Form: Product Design and Consumer Response. *Journal of Marketing*, *59*(3), 16. https://doi.org/10.2307/1252116

Bloch, P. H. (1995b). *Seeking the ideal form: Product design and consumer response*.

Bloch, P. H. (2011). Product Design and Marketing: Reflections After Fifteen Years: Product Design and Marketing: Reflections After Fifteen Years. *Journal of Product Innovation Management*, *28*(3), 378–380. https://doi.org/10.1111/j.1540-5885.2011.00805.x

Bloch, P. H., Brunel, F. F., & Arnold, T. J. (2003). Individual Differences in the Centrality of Visual Product Aesthetics: Concept and Measurement. *Journal of Consumer Research*, *29*(4), 551–565. https://doi.org/10.1086/346250

Bordens, K. S., & Abbott, B. B. (2011). *Research design and methods: A process approach* (8th ed). McGraw-Hill.

Bottani, E., & Rizzi, A. (2008). An adapted multi-criteria approach to suppliers and products selection—An application oriented to lead-time reduction. *International Journal of Production Economics*, *111*(2), 763–781. https://doi.org/10.1016/j.ijpe.2007.03.012

Brunel, F. F., & Kumar, R. (2007). *Design and the Big Five: Linking Visual Product Aesthetics to Product Personality*. 3.

Bruner, G. C. (2015). *Marketing scales handbook ; 7,*. GCBII Productions.

Burtan, D., Joyce, K., Burn, J. F., Handy, T. C., Ho, S., & Leonards, U. (2021). The nature effect in motion: Visual exposure to environmental scenes impacts cognitive load and human gait kinematics. *Royal Society Open Science*, *8*(1), 201100. https://doi.org/10.1098/rsos.201100

Camargo, F. R., & Henson, B. (2015). Beyond usability: Designing for consumers' product experience using the Rasch model. *Journal of Engineering Design*, *26*(4–6), 121–139. https://doi.org/10.1080/09544828.2015.1034254

Candi, M., Jae, H., Makarem, S., & Mohan, M. (2017). Consumer responses to functional, aesthetic and symbolic product design in online reviews. *Journal of Business Research*, *81*, 31–39. https://doi.org/10.1016/j.jbusres.2017.08.006

Cash, P., Isaksson, O., Maier, A., & Summers, J. (2022). Sampling in design research: Eight key considerations. *Design Studies*, *78*, 101077. https://doi.org/10.1016/j.destud.2021.101077

Cawthon, N. (2007). Qualities of perceived aesthetic in data visualization. *Proceedings of the 2007 Conference on Designing for User EXperiences - DUX '07*, 1. https://doi.org/10.1145/1389908.1389920

Chakrabarti, A., & Gupta, A. (2007). *DESIGN FOR EMOTIONS*. 12.

Chang, D.-Y. (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal of Operational Research*, *95*(3), 649–655. https://doi.org/10.1016/0377-2217(95)00300-2

Chang, H.-C., Lai, H.-H., & Chang, Y.-M. (2007a). A measurement scale for evaluating the attractiveness of a passenger car form aimed at young consumers. *International Journal of Industrial Ergonomics*, *37*(1), 21–30. https://doi.org/10.1016/j.ergon.2006.09.014

Chang, H.-C., Lai, H.-H., & Chang, Y.-M. (2007b). A measurement scale for evaluating the attractiveness of a passenger car form aimed at young consumers. *International Journal of Industrial Ergonomics*, *37*(1), 21–30. https://doi.org/10.1016/j.ergon.2006.09.014

Chang, W., & Wu, T.-Y. (2007). *Exploring Types and Characteristics of Product Forms*. 11.

Charters, S. (2006). Aesthetic Products and Aesthetic Consumption: A Review. *Consumption Markets & Culture*, *9*(3), 235–255. https://doi.org/10.1080/10253860600772255

Chen, C.-C., & Chuang, M.-C. (2008). Integrating the Kano model into a robust design approach to enhance customer satisfaction with product design. *International Journal of Production Economics*, *114*(2), 667–681. https://doi.org/10.1016/j.ijpe.2008.02.015

Cheng, J. T., Tracy, J. L., & Henrich, J. (2010). Pride, personality, and the evolutionary foundations of human social status. *Evolution and Human Behavior*, *31*(5), 334–347. https://doi.org/10.1016/j.evolhumbehav.2010.02.004

Chiu, Y., Lin, C., & Tang, L. (2005). Gender differs: Assessing a model of online purchase intentions in e-tail service. *International Journal of Service Industry Management*, *16*(5), 416–435. https://doi.org/10.1108/09564230510625741

Chou, C.-C., & Yu, K.-W. (2013). Application of a New Hybrid Fuzzy AHP Model to the Location Choice. *Mathematical Problems in Engineering*, *2013*, 1–12. https://doi.org/10.1155/2013/592138

Choudhary, D., & Shankar, R. (2012). An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: A case study from India. *Energy*, *42*(1), 510–521. https://doi.org/10.1016/j.energy.2012.03.010

Chris Jones, J. (1987). *Design Methods: Seeds of human futures*. Wiley.

Christiaans, H. H. C. M. (2002). Creativity as a Design Criterion. *Creativity Research Journal*, *14*(1), 41–54. https://doi.org/10.1207/S15326934CRJ1401_4

Chuang, M. C., Chang, C. C., & Hsu, S. H. (2001a). Perceptual factors underlying user preferences toward product form of mobile phones. *International Journal of Industrial Ergonomics*, *27*(4), 247–258. https://doi.org/10.1016/S0169-8141(00)00054-8

Chuang, M. C., Chang, C. C., & Hsu, S. H. (2001b). Perceptual factors underlying user preferences toward product form of mobile phones. *International Journal of Industrial Ergonomics*, *27*(4), 247–258. https://doi.org/10.1016/S0169-8141(00)00054-8

Clark, M. (Ed.). (2000). *Revenge of the aesthetic: The place of literature in theory today*. University of California Press.

Coates, D. (2003). *Watches tell more than time: Product design, information, and the quest for elegance*. McGraw-Hill.

Costell, E., Tárrega, A., & Bayarri, S. (2010). Food Acceptance: The Role of Consumer Perception and Attitudes. *Chemosensory Perception*, *3*(1), 42–50. https://doi.org/10.1007/s12078-009-9057-1

Cox, D., & Cox, A. D. (2002a). Beyond First Impressions: The Effects of Repeated Exposure on Consumer Liking of Visually Complex and Simple Product Designs. *Journal of the Academy of Marketing Science*, *30*(2), 119–130. https://doi.org/10.1177/03079459994371

Cox, D., & Cox, A. D. (2002b). Beyond First Impressions: The Effects of Repeated Exposure on Consumer Liking of Visually Complex and Simple Product Designs. *Journal of the Academy of Marketing Science*, *30*(2), 119–130. https://doi.org/10.1177/03079459994371

Cretu, A. E., & Brodie, R. J. (2007a). The influence of brand image and company reputation where manufacturers market to small firms: A customer value perspective. *Industrial Marketing Management*, *36*(2), 230–240. https://doi.org/10.1016/j.indmarman.2005.08.013

Cretu, A. E., & Brodie, R. J. (2007b). The influence of brand image and company reputation where manufacturers market to small firms: A customer value perspective. *Industrial Marketing Management*, *36*(2), 230–240. https://doi.org/10.1016/j.indmarman.2005.08.013

Creusen, M. E. H. (2015). Consumer Response to Product Form. In M. G. Luchs, K. S. Swan, & A. Griffin (Eds.), *Design Thinking* (pp. 301–318). John Wiley & Sons, Inc. https://doi.org/10.1002/9781119154273.ch20

Creusen, M. E. H., & Schoormans, J. P. L. (2005a). The Different Roles of Product Appearance in Consumer Choice*. *Journal of Product Innovation Management*, *22*(1), 63–81. https://doi.org/10.1111/j.0737-6782.2005.00103.x

Creusen, M. E. H., & Schoormans, J. P. L. (2005b). The Different Roles of Product Appearance in Consumer Choice*. *Journal of Product Innovation Management*, *22*(1), 63–81. https://doi.org/10.1111/j.0737-6782.2005.00103.x

Crilly, N., Moultrie, J., & Clarkson, P. J. (2004a). Seeing things: Consumer response to the visual domain in product design. *Design Studies*, *25*(6), 547–577. https://doi.org/10.1016/j.destud.2004.03.001

Crilly, N., Moultrie, J., & Clarkson, P. J. (2004b). Seeing things: Consumer response to the visual domain in product design. *Design Studies*, *25*(6), 547–577. https://doi.org/10.1016/j.destud.2004.03.001

Crilly, N., Moultrie, J., & Clarkson, P. J. (2009a). Shaping things: Intended consumer response and the other determinants of product form. *Design Studies*, *30*(3), 224–254. https://doi.org/10.1016/j.destud.2008.08.001

Crilly, N., Moultrie, J., & Clarkson, P. J. (2009b). Shaping things: Intended consumer response and the other determinants of product form. *Design Studies*, *30*(3), 224–254. https://doi.org/10.1016/j.destud.2008.08.001

Crozier, W. R. (1994). *Manufactured pleasures: Psychological responses to design*. Manchester University Press ; Distributed exclusively in the USA and Canada by St. Martin's Press.

Culbertson, T. D., & Simpson, T. W. (2014). Using Shape Grammars to Identify Salient Features in Support of Product Family Design. *Volume 7: 2nd Biennial International Conference on Dynamics for Design; 26th International Conference on Design Theory and Methodology*, V007T07A036. https://doi.org/10.1115/DETC2014-34125

Cupchik, G. C. (1993). Component and relational processing in aesthetics. *Poetics*, *22*(1–2), 171–183. https://doi.org/10.1016/0304-422X(93)90027-E

de Pontual, L., Mathieu, Y., Golzio, C., Rio, M., Malan, V., Boddaert, N., Soufflet, C., Picard, C., Durandy, A., Dobbie, A., Heron, D., Isidor, B., Motte, J., Newburry-Ecob, R., Pasquier, L., Tardieu, M., Viot, G., Jaubert, F., Munnich, A., … Amiel, J. (2009). Mutational, functional, and expression studies of the *TCF4* gene in Pitt-Hopkins syndrome. *Human Mutation*, *30*(4), 669–676. https://doi.org/10.1002/humu.20935

Desmet, P. (2003). Measuring Emotion: Development and Application of an Instrument to Measure Emotional Responses to Products. In M. A. Blythe, K. Overbeeke, A. F. Monk, & P. C. Wright (Eds.), *Funology* (Vol. 3, pp. 111–123). Springer Netherlands. https://doi.org/10.1007/1-4020-2967-5_12

Desmet, P., & Hekkert, P. (2007). *Framework of Product Experience*. 11.

Desmet, P. M. A., Ortíz Nicolás, J. C., & Schoormans, J. P. (2008). Product personality in physical interaction. *Design Studies*, *29*(5), 458–477. https://doi.org/10.1016/j.destud.2008.06.003

Diefenbach, S., & Hassenzahl, M. (2011). The dilemma of the hedonic – Appreciated, but hard to justify. *Interacting with Computers*, *23*(5), 461–472. https://doi.org/10.1016/j.intcom.2011.07.002

East, R., Hammond, K., & Lomax, W. (2008). Measuring the impact of positive and negative word of mouth on brand purchase probability. *International Journal of Research in Marketing*, *25*(3), 215–224. https://doi.org/10.1016/j.ijresmar.2008.04.001

Eastman, J. K., & Iyer, R. (2012). *The Relationship Between Cognitive Age And Status Consumption: An Exploratory Look*. 17.

Eckstein, M. K., Guerra-Carrillo, B., Miller Singley, A. T., & Bunge, S. A. (2017). Beyond eye gaze: What else can eyetracking reveal about cognition and cognitive development? *Developmental Cognitive Neuroscience*, *25*, 69–91. https://doi.org/10.1016/j.dcn.2016.11.001

Eisenmann, M., Grauberger, P., & Matthiesen, S. (2021). SUPPORTING EARLY STAGES OF DESIGN METHOD VALIDATION - AN APPROACH TO ASSESS APPLICABILITY. *Proceedings of the Design Society*, *1*, 2821–2830. https://doi.org/10.1017/pds.2021.543

Elam, K. (2001). *Geometry of design: Studies in proportion and composition*. Princeton Architectural Press.

Elliott, G. R., & Cameron, R. C. (1994). Consumer Perception of Product Quality and the Country-of-Origin Effect [1]. *Journal of International Marketing*, *2*(2), 49–62. https://doi.org/10.1177/1069031X9400200204

Etcoff, N. L. (2000). *Survival of the prettiest: The science of beauty* (1. Anchor books ed). Anchor Books.

Falck, A.-C., Örtengren, R., & Högberg, D. (2010). The impact of poor assembly ergonomics on product quality: A cost-benefit analysis in car manufacturing: Poor Assembly Ergonomics and Product Quality. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *20*(1), 24–41. https://doi.org/10.1002/hfm.20172

FALL, M. (1984, October 15). *What Does "ProductQuality" Really Mean?*

Fenko, A., & van Rompay, T. J. L. (2018). Consumer-Driven Product Design. In *Methods in Consumer Research, Volume 2* (pp. 427–462). Elsevier. https://doi.org/10.1016/B978-0-08-101743-2.00018-2

Foroudi, P., Melewar, T. C., & Gupta, S. (2017). Corporate Logo: History, Definition, and Components. *International Studies of Management & Organization*, *47*(2), 176–196. https://doi.org/10.1080/00208825.2017.1256166

Fynes, B., & De Búrca, S. (2005). The effects of design quality on quality performance. *International Journal of Production Economics*, *96*(1), 1–14. https://doi.org/10.1016/j.ijpe.2004.02.008

Galanter, P. (2010). *Complexity, Neuroaesthetics, and Computational Aesthetic Evaluation*. 13th Generative Art Conference GA2010.

Gao, Z., Yang, Q., Ma, X., Becker, B., Li, K., Zhou, F., & Kendrick, K. M. (2017). Men Who Compliment a Woman's Appearance Using Metaphorical Language: Associations with Creativity, Masculinity, Intelligence and Attractiveness. *Frontiers in Psychology*, *8*, 2185. https://doi.org/10.3389/fpsyg.2017.02185

Gardas, B. B., Mangla, S. K., Raut, R. D., Narkhede, B., & Luthra, S. (2019). Green talent management to unlock sustainability in the oil and gas sector. *Journal of Cleaner Production*, *229*, 850–862. https://doi.org/10.1016/j.jclepro.2019.05.018

Garner, W. R. (2014). *The processing of information and structure*. Psychology Press. http://site.ebrary.com/id/10828753

Ghodeswar Bhimrao M. (2008). Building brand identity in competitive markets: A conceptual model. *Journal of Product & Brand Management*, *17*(1), 4–12. https://doi.org/10.1108/10610420810856468

Gilal, N. G., Zhang, J., & Gilal, F. G. (2018). Linking product design to consumer behavior: The moderating role of consumption experience. *Psychology Research and Behavior Management*, *Volume 11*, 169–185. https://doi.org/10.2147/PRBM.S161384

G_Monö, R. (1997). *Design_for_product_understanding*.

Godau, D. (2017). *Beyond the Car*.

Goldman, A. H. (2001). *The Journal of Aesthetics and Art Criticism*.

Gombrich, E. H. (1979). *The Sense of Order: A Study in the Psychology of Decorative Art*. 7.

Gombrich, E. H. (1995). *The Story of Art*. Phaidon Publishers Inc.

Goonetilleke, R. S., & Feizhou, S. (2001). A methodology to determine the optimum seat depth. *International Journal of Industrial Ergonomics*, *27*(4), 207–217. https://doi.org/10.1016/S0169-8141(00)00051-2

Gössling, S., & Metzler, D. (2017). Germany's climate policy: Facing an automobile dilemma. *Energy Policy*, *105*, 418–428. https://doi.org/10.1016/j.enpol.2017.03.019

Greene, D. L. (2018). *Consumers' Willingness to Pay for Fuel Economy and Implications for Sales of New Vehicles and Scrappage of Used Vehicles:* 40.

Grosfeld-Nir, A., Ronen, B., & Kozlovsky, N. (2007a). The Pareto managerial principle: When does it apply? *International Journal of Production Research*, *45*(10), 2317–2325. https://doi.org/10.1080/00207540600818203

Grosfeld-Nir, A., Ronen, B., & Kozlovsky, N. (2007b). The Pareto managerial principle: When does it apply? *International Journal of Production Research*, *45*(10), 2317–2325. https://doi.org/10.1080/00207540600818203

Guyer, P. (2008). The psychology of Kant's aesthetics. *Studies in History and Philosophy of Science Part A*, *39*(4), 483–494. https://doi.org/10.1016/j.shpsa.2008.09.010

Hanna, K. (2010). *Effects of the Centrality of Visual Product Aesthetics and Aesthetic Experiences on Impulse Buying Behavior for Fashion Products.pdf*. *Volume 34 Issue 12 / Pages.1947-1956 / 2010 / 1225-1151(pISSN) / 2234-0793(eISSN)*.

Hardy, T., Schmitt, B., & Simonson, A. (1999). Marketing Aesthetics: The Strategic Management of Brands, Identity, and Image. *Design Issues*, *15*(1), 81. https://doi.org/10.2307/1511791

Hassenzahl, M. (2004a). Beautiful Objects as an Extension of the Self: A Reply. *Human-Computer Interaction*, *19*(4), 377–386. https://doi.org/10.1207/s15327051hci1904_7

Hassenzahl, M. (2004b). The Interplay of Beauty, Goodness, and Usability in Interactive Products. *Human-Computer Interaction*, *19*(4), 319–349. https://doi.org/10.1207/s15327051hci1904_2

Hassenzahl, M. (2008). AESTHETICS IN INTERACTIVE PRODUCTS: CORRELATES AND CONSEQUENCES OF BEAUTY. In *Product Experience* (pp. 287–302). Elsevier. https://doi.org/10.1016/B978-008045089-6.50014-9

Heaney, J.-G., Goldsmith, R. E., & Jusoh, W. J. W. (2005). Status Consumption Among Malaysian Consumers: Exploring Its Relationships with Materialism and Attention-to-Social-Comparison-Information. *Journal of International Consumer Marketing*, *17*(4), 83–98. https://doi.org/10.1300/J046v17n04_05

Heitmann, M., Landwehr, J. R., Schreiner, T. F., & van Heerde, H. J. (2020). Leveraging Brand Equity for Effective Visual Product Design. *Journal of Marketing Research*, *57*(2), 257–277. https://doi.org/10.1177/0022243720904004

Hekkert, P. (2006). Design aesthetics: Principles of pleasure in design. *Psychology Science*, *48*(2), 157.

Hekkert, P., & Leder, H. (2008). PRODUCT AESTHETICS. In *Product Experience* (pp. 259–285). Elsevier. https://doi.org/10.1016/B978-008045089-6.50013-7

Hekkert, P., Snelders, D., & Wieringen, P. C. W. (2003). 'Most advanced, yet acceptable': Typicality and novelty as joint predictors of aesthetic preference in industrial design. *British Journal of Psychology*, *94*(1), 111–124. https://doi.org/10.1348/000712603762842147

Hekkert, P., & Wieringen, P. C. W. V. (1996). Beauty in the Eye of Expert and Nonexpert Beholders: A Study in the Appraisal of Art. *The American Journal of Psychology*, *109*(3), 389. https://doi.org/10.2307/1423013

Helander, M. G., Khalid, H. M., Lim, T. Y., Peng, H., & Yang, X. (2013). Emotional needs of car buyers and emotional intent of car designers. *Theoretical Issues in Ergonomics Science*, *14*(5), 455–474. https://doi.org/10.1080/1463922X.2012.656152

Heller Baird, C., & Parasnis, G. (2011). From social media to Social CRM: Reinventing the customer relationship. *Strategy & Leadership*, *39*(6), 27–34. https://doi.org/10.1108/10878571111176600

Hennighausen, C., Hudders, L., Lange, B. P., & Fink, H. (2016). What If the Rival Drives a Porsche?: Luxury Car Spending as a Costly Signal in Male Intrasexual Competition. *Evolutionary Psychology*, *14*(4), 147470491667821. https://doi.org/10.1177/1474704916678217

Hertenstein, J. H., Platt, M. B., & Veryzer, R. W. (2005). The Impact of Industrial Design Effectiveness on Corporate Financial Performance*. *Journal of Product Innovation Management*, *22*(1), 3–21. https://doi.org/10.1111/j.0737-6782.2005.00100.x

Hiebert, R. E. (2001). Emotional Branding: How Successful Brands Gain the Irrational Edge. *Public Relations Review*, *27*(2), 244–245. https://doi.org/10.1016/S0363-8111(01)00084-4

Hirschman, E. C., & Holbrook, M. B. (1982). Hedonic Consumption: Emerging Concepts, Methods and Propositions. *Journal of Marketing*, *46*(3), 92. https://doi.org/10.2307/1251707

Ho, A. G., & Siu, K. W. M. G. (2012). Emotion Design, Emotional Design, Emotionalize Design: A Review on Their Relationships from a New Perspective. *The Design Journal*, *15*(1), 9–32. https://doi.org/10.2752/175630612X13192035508462

Hochberg, J., & McAlister, E. (1953). A quantitative approach, to figural "goodness". *Journal of Experimental Psychology*, *46*(5), 361–364. https://doi.org/10.1037/h0055809

Hoegg, J., Alba, J. W., & Dahl, D. W. (2010). The good, the bad, and the ugly: Influence of aesthetics on product feature judgments. *Journal of Consumer Psychology*, *20*(4), 419–430. https://doi.org/10.1016/j.jcps.2010.07.002

Hogan, H. W. (1978). A Theoretical Reconciliation of Competing Views of Time Perception. *The American Journal of Psychology*, *91*(3), 417. https://doi.org/10.2307/1421689

Holbrook, M. B., & Hirschman, E. C. (1982). The Experiential Aspects of Consumption: Consumer Fantasies, Feelings, and Fun. *Journal of Consumer Research*, *9*(2), 132. https://doi.org/10.1086/208906

Homburg, C., Schwemmle, M., & Kuehnl, C. (2015). New Product Design: Concept, Measurement, and Consequences. *Journal of Marketing*, *79*(3), 41–56. https://doi.org/10.1509/jm.14.0199

Honderich, T. (Ed.). (1995). *The Oxford companion to philosophy*. Oxford University Press.

Hsiao, S.-W., & Chen, C.-H. (1997). A semantic and shape grammar based approach for product design. *Design Studies*, *18*(3), 275–296. https://doi.org/10.1016/S0142-694X(97)00037-9

Hsiao, S.-W., Chiu, F.-Y., & Chen, C. S. (2008). Applying aesthetics measurement to product design. *International Journal of Industrial Ergonomics*, *38*(11–12), 910–920. https://doi.org/10.1016/j.ergon.2008.02.009

Hsiao, S.-W., Chiu, F.-Y., & Lu, S.-H. (2010). Product-form design model based on genetic algorithms. *International Journal of Industrial Ergonomics*, *40*(3), 237–246. https://doi.org/10.1016/j.ergon.2010.01.009

Hsiao, S.-W., & Liu, M. C. (2002). A morphing method for shape generation and image prediction in product design. *Design Studies*, *23*(6), 533–556. https://doi.org/10.1016/S0142-694X(01)00028-X

Hsu, S. H., Chuang, M. C., & Chang, C. C. (2000a). A semantic differential study of designers' and users' product form perception. *International Journal of Industrial Ergonomics*, *25*(4), 375–391. https://doi.org/10.1016/S0169-8141(99)00026-8

Hsu, S. H., Chuang, M. C., & Chang, C. C. (2000b). A semantic differential study of designers' and users' product form perception. *International Journal of Industrial Ergonomics*, *25*(4), 375–391. https://doi.org/10.1016/S0169-8141(99)00026-8

Huang, C.-Y., Shyu, J. Z., & Tzeng, G.-H. (2007). Reconfiguring the innovation policy portfolios for Taiwan's SIP Mall industry. *Technovation*, *27*(12), 744–765. https://doi.org/10.1016/j.technovation.2007.04.002

Huang, M.-S., Tsai, H.-C., & Huang, T.-H. (2011). Applying Kansei engineering to industrial machinery trade show booth design. *International Journal of Industrial Ergonomics*, *41*(1), 72–78. https://doi.org/10.1016/j.ergon.2010.10.002

Huang, T., & Henry, K. (2009). *How does "green" meanthe emerging semantics of product design*. MX Design Conference 2009.

Huang, Y., Chen, C.-H., & Khoo, L. P. (2012). Products classification in emotional design using a basic-emotion based semantic differential method. *International Journal of Industrial Ergonomics*, *42*(6), 569–580. https://doi.org/10.1016/j.ergon.2012.09.002

Hughes, H. S. (2022). *Marcel, Maritain and the Secular World*. 15.

Humphrey, D. (1997). Preferences in Symmetries and Symmetries in Drawings: Asymmetries between Ages and Sexes. *Empirical Studies of the Arts*, *15*(1), 41–60. https://doi.org/10.2190/DF5N-HGFB-MVPK-U34D

Hung, W.-K., & Chen, L.-L. (2012). *Effects of Novelty and Its Dimensions on Aesthetic Preference in Product Design*. 10.

Ivančić, mag.oec, V. (2014). *IMPROVING THE DECISION MAKING PROCESS TROUGH THE PARETO PRINCIPLE APPLICATION*.

Ivančić, V. (2014). *Improving the Decision Making Porcess trough the Pareto Principle Application*.

Jacobsen, T., Schubotz, R. I., Höfel, L., & Cramon, D. Y. v. (2006). Brain correlates of aesthetic judgment of beauty. *NeuroImage*, *29*(1), 276–285. https://doi.org/10.1016/j.neuroimage.2005.07.010

Jagtap, S. (2017). Attributes and Emotions in Product Form Design: A Survey of Professional Industrial Designers. In A. Chakrabarti & D. Chakrabarti (Eds.), *Research into Design for Communities, Volume 2* (Vol. 66, pp. 705–714). Springer Singapore. https://doi.org/10.1007/978-981-10-3521-0_60

Jindo, T., & Hirasago, K. (1997). Application studies to car interior of Kansei engineering. *International Journal of Industrial Ergonomics*, *19*(2), 105–114. https://doi.org/10.1016/S0169-8141(96)00007-8

Jitender, J., & Sarkar, P. (2018). *Understanding the Relationship between Aesthetics and Product Design*. *5*(3), 6.

Johnston, R. (1995). *The determinants of service quality: Satisfiers and dissatisfiers*.

Jordan, P. W. (1998a). Human factors for pleasure in product use. *Applied Ergonomics*, *29*(1), 25–33. https://doi.org/10.1016/S0003-6870(97)00022-7

Jordan, P. W. (1998b). Human factors for pleasure in product use. *Applied Ergonomics*, *29*(1), 25–33. https://doi.org/10.1016/S0003-6870(97)00022-7

Jordan, P. W. (2003). *How to Make Brilliant Stuff That People Love ... And Make Big Money Out of It!!: And Make Big Money Out of It.* http://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=143928

Jordan, P. W. (2005). *Designing pleasurable products: An introduction to the new human factors*. http://gateway.library.qut.edu.au/login?url=http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=94298

Joy, A., Sherry, J. F., Venkatesh, A., Wang, J., & Chan, R. (2012). Fast Fashion, Sustainability, and the Ethical Appeal of Luxury Brands. *Fashion Theory*, *16*(3), 273–295. https://doi.org/10.2752/175174112X13340749707123

Kaelin, E. F., Ingarden, R., & McCormick, P. J. (1986). Selected Papers in Aesthetics. *The Journal of Aesthetics and Art Criticism*, *45*(1), 89. https://doi.org/10.2307/430470

Kamp, I. (2012). The influence of car-seat design on its character experience. *Applied Ergonomics*, *43*(2), 329–335. https://doi.org/10.1016/j.apergo.2011.06.008

Kano N., Seraku N., Takahashi F., & Tsuji S. (1984). *Attractive quality and natural quality* (No. 2). Japan Society for Quality Control. https://doi.org/10.20684/quality.14.2_147

Karlsson, B. S., Aronsson, N., & Svensson, K. A. (2003). Using semantic environment description as a tool to evaluate car interiors. *Ergonomics*, *46*(13–14), 1408–1422. https://doi.org/10.1080/00140130310001624905

Kaur, P. (2014). Selection of Vendor Based on Intuitionistic Fuzzy Analytical Hierarchy Process. *Advances in Operations Research*, *2014*, 1–10. https://doi.org/10.1155/2014/987690

Kaya, T., & Kahraman, C. (2010). Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: The case of Istanbul. *Energy*, *35*(6), 2517–2527. https://doi.org/10.1016/j.energy.2010.02.051

Kelly, J., & Papalambros, P. Y. (2007). *USE OF SHAPE PREFERENCE INFORMATION IN PRODUCT DESIGN*. 11.

Khalid, H. M., & Helander, M. G. (2006a). Customer Emotional Needs in Product Design. *Concurrent Engineering*, *14*(3), 197–206. https://doi.org/10.1177/1063293X06068387

Khalid, H. M., & Helander, M. G. (2006b). Customer Emotional Needs in Product Design. *Concurrent Engineering*, *14*(3), 197–206. https://doi.org/10.1177/1063293X06068387

Khalid, H. M., & Helander, M. G. (2006c). Customer Emotional Needs in Product Design. *Concurrent Engineering*, *14*(3), 197–206. https://doi.org/10.1177/1063293X06068387

Khalighy, S., Green, G., Scheepers, C., & Whittet, C. (2014). *MEASURING AESTHETIC IN DESIGN*. 12.

Khalighy, S., Green, G., & Whittet, C. (2012). *PRODUCT AESTHETICS AND CREATIVITY*. 9.

Kieran, M. (1997). Aesthetic Value: Beauty, Ugliness and Incoherence. *Philosophy*, *72*(281), 383–399. https://doi.org/10.1017/S0031819100057077

Kilincci, O., & Onal, S. A. (2011). Fuzzy AHP approach for supplier selection in a washing machine company. *Expert Systems with Applications*, *38*(8), 9656–9664. https://doi.org/10.1016/j.eswa.2011.01.159

Koch, J., Gritsch, A., & Reinhart, G. (2016). Process design for the management of changes in manufacturing: Toward a Manufacturing Change Management process. *CIRP Journal of Manufacturing Science and Technology*, *14*, 10–19. https://doi.org/10.1016/j.cirpj.2016.04.010

Koffka, K. (1935). *Principles of Gestalt Psychology*. 14.

Kostellow, R. R. (2002). *Elements of design*. Princeton Architectural Press.

Kotler, P. (Ed.). (1999). *Principles of marketing* (2. European ed). Prentice Hall Europe.

Kotler, P., & Alexander Rath, G. (1984). DESIGN: A POWERFUL BUT NEGLECTED STRATEGIC TOOL. *Journal of Business Strategy*, *5*(2), 16–21. https://doi.org/10.1108/eb039054

Kraus, M. W., Park, J. W., & Tan, J. J. X. (2017). Signs of Social Class: The Experience of Economic Inequality in Everyday Life. *Perspectives on Psychological Science*, *12*(3), 422–435. https://doi.org/10.1177/1745691616673192

Krish, S. (2011). A practical generative design method. *Computer-Aided Design*, *43*(1), 88–100. https://doi.org/10.1016/j.cad.2010.09.009

Krishna, A., & Morrin, M. (2008). Does Touch Affect Taste? The Perceptual Transfer of Product Container Haptic Cues. *Journal of Consumer Research*, *34*(6), 807–818. https://doi.org/10.1086/523286

Kubovy, M. (2000). *Inniut and Kooliut: Trends in Israeli Narrative Literature, 1995-1999*. 23.

Kumar, A., & Dash, M. K. (2017). Causal Modelling and Analysis Evaluation of Online Reputation Management Using Fuzzy Delphi and DEMATEL: *International Journal of Strategic Decision Sciences*, *8*(1), 27–45. https://doi.org/10.4018/IJSDS.2017010103

Kumar, J. S. (2017). The Psychology of Colour Influences Consumers’ Buying Behaviour – A Diagnostic Study. *Ushus - Journal of Business Management*, *16*(4), 1–13. https://doi.org/10.12725/ujbm.41.1

Kumar, M., & Garg, N. (2010a). Aesthetic principles and cognitive emotion appraisals: How much of the beauty lies in the eye of the beholder? *Journal of Consumer Psychology*, *20*(4), 485–494. https://doi.org/10.1016/j.jcps.2010.06.015

Kumar, M., & Garg, N. (2010b). Aesthetic principles and cognitive emotion appraisals: How much of the beauty lies in the eye of the beholder? *Journal of Consumer Psychology*, *20*(4), 485–494. https://doi.org/10.1016/j.jcps.2010.06.015

Kuo, Y., & Chen, P. (2006). Selection of mobile value-added services for system operators using fuzzy synthetic evaluation. *Expert Systems with Applications*, *30*(4), 612–620. https://doi.org/10.1016/j.eswa.2005.07.007

Lai, H.-H., Chang, Y.-M., & Chang, H.-C. (2005a). A robust design approach for enhancing the feeling quality of a product: A car profile case study. *International Journal of Industrial Ergonomics*, *35*(5), 445–460. https://doi.org/10.1016/j.ergon.2004.10.008

Lai, H.-H., Chang, Y.-M., & Chang, H.-C. (2005b). A robust design approach for enhancing the feeling quality of a product: A car profile case study. *International Journal of Industrial Ergonomics*, *35*(5), 445–460. https://doi.org/10.1016/j.ergon.2004.10.008

Lai, H.-H., Lin, Y.-C., Yeh, C.-H., & Wei, C.-H. (2006). User-oriented design for the optimal combination on product design. *International Journal of Production Economics*, *100*(2), 253–267. https://doi.org/10.1016/j.ijpe.2004.11.005

Landwehr, J. R., McGill, A. L., & Herrmann, A. (2011). It’s Got the Look: The Effect of Friendly and Aggressive “Facial” Expressions on Product Liking and Sales. *Journal of Marketing*, *75*(3), 132–146. https://doi.org/10.1509/jmkg.75.3.132

Langlois, J. H., & Roggman, L. A. (1990). Attractive Faces Are Only Average. *Psychological Science*, *1*(2), 115–121. https://doi.org/10.1111/j.1467-9280.1990.tb00079.x

Lavie, T., & Tractinsky, N. (2004). Assessing dimensions of perceived visual aesthetics of web sites. *International Journal of Human-Computer Studies*, *60*(3), 269–298. https://doi.org/10.1016/j.ijhcs.2003.09.002

Lawson, B. (2010). *How designers think: The design process demystified* (Reprint). Elsevier Architectural Press.

Lee, J., Jung, B., & Chu, W. (2015). *Signaling Environmental Altruism through Design: 9*(2), 13.

Lee, S., & Koubek, R. J. (2010). The effects of usability and web design attributes on user preference for e-commerce web sites. *Computers in Industry*, *61*(4), 329–341. https://doi.org/10.1016/j.compind.2009.12.004

Lee, T. (2018). Sense, substance, fruit: Examining poetic descriptions of how people experience fruits as input for design considerations. *International Journal of Food Design*, *3*(1), 3–19. https://doi.org/10.1386/ijfd.3.1.3_1

Li, Y., & Zhu, L. (2019). Optimization of user experience in mobile application design by using a fuzzy analytic-network-process-based Taguchi method. *Applied Soft Computing*, *79*, 268–282. https://doi.org/10.1016/j.asoc.2019.03.048

Lin, X., Featherman, M., Brooks, S. L., & Hajli, N. (2019). Exploring Gender Differences in Online Consumer Purchase Decision Making: An Online Product Presentation Perspective. *Information Systems Frontiers*, *21*(5), 1187–1201. https://doi.org/10.1007/s10796-018-9831-1

Lin, Y.-C., Yeh, C.-H., & Wei, C.-C. (2013). How will the use of graphics affect visual aesthetics? A user-centered approach for web page design. *International Journal of Human-Computer Studies*, *71*(3), 217–227. https://doi.org/10.1016/j.ijhcs.2012.10.013

Lindgaard, G., & Dudek, C. (2003). What is this evasive beast we call user satisfaction? *Interacting with Computers*, *15*(3), 429–452. https://doi.org/10.1016/S0953-5438(02)00063-2

Liu, K.-C., & Racherla, U. S. (Eds.). (2019). *Innovation, Economic Development, and Intellectual Property in India and China: Comparing Six Economic Sectors*. Springer Singapore. https://doi.org/10.1007/978-981-13-8102-7

Liu, Y. (2003). Engineering aesthetics and aesthetic ergonomics: Theoretical foundations and a dual-process research methodology. *Ergonomics*, *46*(13–14), 1273–1292. https://doi.org/10.1080/00140130310001610829

Liu, Y., Li, K. J., Chen, H. (Allan), & Balachander, S. (2017). The Effects of Products' Aesthetic Design on Demand and Marketing-Mix Effectiveness: The Role of Segment Prototypicality and Brand Consistency. *Journal of Marketing*, *81*(1), 83–102. https://doi.org/10.1509/jm.15.0315

Luo, S.-J., Fu, Y.-T., & Zhou, Y.-X. (2012). Perceptual matching of shape design style between wheel hub and car type. *International Journal of Industrial Ergonomics*, *42*(1), 90–102. https://doi.org/10.1016/j.ergon.2011.10.001

Luthans, F., Avolio, B. J., Avey, J. B., & Norman, S. M. (2007). POSITIVE PSYCHOLOGICAL CAPITAL: MEASUREMENT AND RELATIONSHIP WITH PERFORMANCE AND SATISFACTION. *Personnel Psychology*, *60*(3), 541–572. https://doi.org/10.1111/j.1744-6570.2007.00083.x

MacDonald, A. S. (2001). Aesthetic intelligence: Optimizing user-centred design. *Journal of Engineering Design*, *12*(1), 37–45. https://doi.org/10.1080/09544820010031562

Mangla, S. K., Luthra, S., Jakhar, S. K., Tyagi, M., & Narkhede, B. E. (2018). Benchmarking the logistics management implementation using Delphi and fuzzy DEMATEL. *Benchmarking: An International Journal*, *25*(6), 1795–1828. https://doi.org/10.1108/BIJ-01-2017-0006

Mangla, S., Kumar, P., & Barua, M. K. (2014). *AN EVALUATION OF ATTRIBUTE FOR IMPROVING THE GREEN SUPPLY CHAIN PERFORMANCE VIA DEMATEL METHOD*. 6.

Manu, M. (2011). *Quality and Customer Satisfaction Perspective in Organisations by Gap and Total Quality Improvement Methods*. https://doi.org/10.13140/RG.2.2.34692.35202

Marin, M. M., Lampatz, A., Wandl, M., & Leder, H. (2016). Berlyne Revisited: Evidence for the Multifaceted Nature of Hedonic Tone in the Appreciation of Paintings and Music. *Frontiers in Human Neuroscience*, *10*. https://doi.org/10.3389/fnhum.2016.00536

Martindale, C., Locher, P., & Petrov, V. M. (2018). *Evolutionary and neurocognitive approaches to aesthetics, creativity, and the arts*. Routledge. https://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=2102110

Martindale, C., & Moore, K. (1988). Priming, prototypicality, and preference. *Journal of Experimental Psychology: Human Perception and Performance*, *14*(4), 661–670. https://doi.org/10.1037/0096-1523.14.4.661

Matsubara, Y., & Nagamachi, M. (1997). Hybrid Kansei engineering system and design support. *International Journal of Industrial Ergonomics*, *19*(2), 81–92. https://doi.org/10.1016/S0169-8141(96)00005-4

McFerran, B., Aquino, K., & Tracy, J. L. (2014). Evidence for two facets of pride in consumption: Findings from luxury brands. *Journal of Consumer Psychology*, *24*(4), 455–471. https://doi.org/10.1016/j.jcps.2014.03.004

Mciver, D. L., & Gaut, B. (2002). *The Routledge Companion To Aesthetics*. Taylor & Francis Ltd.

McKeown, C. (2014). Neuroergonomics: A cognitive neuroscience approach to human factors and ergonomics. *Ergonomics*, *57*(1), 137–138. https://doi.org/10.1080/00140139.2013.847545

McQuarrie, E. F., & Mick, D. G. (1996). Figures of Rhetoric in Advertising Language. *Journal of Consumer Research*, *22*(4), 424. https://doi.org/10.1086/209459

Merleau-Ponty, M. (1964). *The primacy of perception*. NORTHWESTER N UNIVERSIT Y PRES S.

Mono, R. (1997). *Design for product understanding _ the aesthetics of design from a semiotic approach*.

Monö, R. (2004). *Design for product understanding: The aesthetics of design from a semiotic approach* (First ed., 2). Liber.

Morris, R. (2009). *The fundamentals of product design*. AVA Publ.

Moshagen, M., & Thielsch, M. T. (2010). Facets of visual aesthetics. *International Journal of Human-Computer Studies*, *68*(10), 689–709. https://doi.org/10.1016/j.ijhcs.2010.05.006

Moulson, T., & Sproles, G. (2000a). Styling strategy. *Business Horizons*, *43*(5), 45–52. https://doi.org/10.1016/S0007-6813(00)80008-7

Moulson, T., & Sproles, G. (2000b). Styling strategy. *Business Horizons*, *43*(5), 45–52. https://doi.org/10.1016/S0007-6813(00)80008-7

Mugge, R. (2011). *Product Appearance as a Cue for Performance Quality: The Influence of Product Personality*. 3.

Mugge, R., Dahl, D. W., & Schoormans, J. P. L. (2018). “What You See, Is What You Get?” Guidelines for Influencing Consumers’ Perceptions of Consumer Durables through Product Appearance. *Journal of Product Innovation Management*, *35*(3), 309–329. https://doi.org/10.1111/jpim.12403

Mugge, R., Govers, P. C. M., & Schoormans, J. P. L. (2009). The development and testing of a product personality scale. *Design Studies*, *30*(3), 287–302. https://doi.org/10.1016/j.destud.2008.10.002

Müller, B., Kocher, B., & Crettaz, A. (2013). The effects of visual rejuvenation through brand logos. *Journal of Business Research*, *66*(1), 82–88. https://doi.org/10.1016/j.jbusres.2011.07.026

Muller, M. J. (2001). Layered participatory analysis: New developments in the CARD technique. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems - CHI ’01*, 90–97. https://doi.org/10.1145/365024.365054

Mumcu, Y., & Kimzan, H. S. (2015a). The Effect of Visual Product Aesthetics on Consumers’ Price Sensitivity. *Procedia Economics and Finance*, *26*, 528–534. https://doi.org/10.1016/S2212-5671(15)00883-7

Mumcu, Y., & Kimzan, H. S. (2015b). The Effect of Visual Product Aesthetics on Consumers’ Price Sensitivity. *Procedia Economics and Finance*, *26*, 528–534. https://doi.org/10.1016/S2212-5671(15)00883-7

Musch, J., & Klauer, K. C. (Eds.). (2003). *The Psychology of Evaluation: Affective Processes in Cognition and Emotion* (0 ed.). Psychology Press. https://doi.org/10.4324/9781410606853

Nagamachi, M. (1995a). Kansei Engineering: A new ergonomic consumer-oriented technology for product development. *International Journal of Industrial Ergonomics*, *15*(1), 3–11. https://doi.org/10.1016/0169-8141(94)00052-5

Nagamachi, M. (1995b). Kansei Engineering: A new ergonomic consumer-oriented technology for product development. *International Journal of Industrial Ergonomics*, *15*(1), 3–11. https://doi.org/10.1016/0169-8141(94)00052-5

Nagamachi, M. (2002). Kansei engineering as a powerful consumer-oriented technology for product development. *Applied Ergonomics*, *33*(3), 289–294. https://doi.org/10.1016/S0003-6870(02)00019-4

Nagamachi, M., Okazaki, Y., & Ishikawa, M. (2006). Kansei engineering and application of the rough sets model. *Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering*, *220*(8), 763–768. https://doi.org/10.1243/09596518JSCE161

Naghadehi, M. Z., Mikaeil, R., & Ataei, M. (2009). The application of fuzzy analytic hierarchy process (FAHP) approach to selection of optimum underground mining method for Jajarm Bauxite Mine, Iran. *Expert Systems with Applications*, *36*(4), 8218–8226. https://doi.org/10.1016/j.eswa.2008.10.006

Nassereddine, M., & Eskandari, H. (2017a). An integrated MCDM approach to evaluate public transportation systems in Tehran. *Transportation Research Part A: Policy and Practice*, *106*, 427–439. https://doi.org/10.1016/j.tra.2017.10.013

Nassereddine, M., & Eskandari, H. (2017b). An integrated MCDM approach to evaluate public transportation systems in Tehran. *Transportation Research Part A: Policy and Practice*, *106*, 427–439. https://doi.org/10.1016/j.tra.2017.10.013

Ngo, D. C. L., & Byrne, J. G. (2001). *ANOTHER LOOK AT A MODEL FOR EVALUATING INTERFACE AESTHETICS*. *11*, 21.

Noble, C. H., & Kumar, M. (2008). Using product design strategically to create deeper consumer connections. *Business Horizons*, *51*(5), 441–450. https://doi.org/10.1016/j.bushor.2008.03.006

Noble, C. H., & Kumar, M. (2010). Exploring the Appeal of Product Design: A Grounded, Value-Based Model of Key Design Elements and Relationships*: Exploring the Appeal of Product Design. *Journal of Product Innovation Management*, *27*(5), 640–657. https://doi.org/10.1111/j.1540-5885.2010.00742.x

Norman, D. (2002). Emotion & design: Attractive things work better. *Interactions*, *9*(4), 36–42. https://doi.org/10.1145/543434.543435

Norman, D. (2004). Introduction to This Special Section on Beauty, Goodness, and Usability. *Human-Computer Interaction*, *19*(4), 311–318. https://doi.org/10.1207/s15327051hci1904_1

Norman, D. A. (2003). *Emotional-Design-Why-We-Love-or-Hate-Everyday-Things-Donald-Norman.pdf*.

Norman, D. A. (2004). *Emotional Design: Why We Love (or Hate) Everyday Things*. Perseus Books Group.

Norman, G. (2010a). Likert scales, levels of measurement and the “laws” of statistics. *Advances in Health Sciences Education*, *15*(5), 625–632. https://doi.org/10.1007/s10459-010-9222-y

Norman, G. (2010b). Likert scales, levels of measurement and the “laws” of statistics. *Advances in Health Sciences Education*, *15*(5), 625–632. https://doi.org/10.1007/s10459-010-9222-y

Okonkwo, U. (2007). *Luxury fashion branding: Trends, tactics, techniques*. Palgrave Macmillan. http://www.myilibrary.com?id=191495

Önüt, S., Efendigil, T., & Soner Kara, S. (2010). A combined fuzzy MCDM approach for selecting shopping center site: An example from Istanbul, Turkey. *Expert Systems with Applications*, *37*(3), 1973–1980. https://doi.org/10.1016/j.eswa.2009.06.080

Ooi, J., Promentilla, M. A. B., Tan, R. R., Ng, D. K. S., & Chemmangattuvalappil, N. G. (2018). Integration of Fuzzy Analytic Hierarchy Process into multi-objective Computer Aided Molecular Design. *Computers & Chemical Engineering*, *109*, 191–202. https://doi.org/10.1016/j.compchemeng.2017.11.015

Orth, U. R., & Malkewitz, K. (2008). *Holistic Package Design and Consumer Brand Impressions*. 18.

Osborne, H., & Langer, S. K. (1984). Susanne K. Langer’s “Mind: An Essay on Human Feeling.” *Journal of Aesthetic Education*, *18*(1), 83. https://doi.org/10.2307/3332574

Page, C., & Herr, P. M. (2002). An Investigation of the Processes by Which Product Design and Brand Strength Interact to Determine Initial Affect and Quality Judgments. *Journal of Consumer Psychology*, *12*(2), 133–147. https://doi.org/10.1207/S15327663JCP1202_06

Palmer, S. E. (1991). Goodness, Gestalt, groups, and Garner: Local symmetry subgroups as a theory of figural goodness. In G. R. Lockhead & J. R. Pomerantz (Eds.), *The perception of structure: Essays in honor of Wendell R. Garner.* (pp. 23–39). American Psychological Association. https://doi.org/10.1037/10101-001

Papanek, M. L. (2022). *Psychological Aspects of Minority Group Membership: The Concepts of Kurt Lewin*. 9.

Peighambari, K., Sattari, S., Kordestani, A., & Oghazi, P. (2016a). Consumer Behavior Research: A Synthesis of the Recent Literature. *SAGE Open*, *6*(2), 215824401664563. https://doi.org/10.1177/2158244016645638

Peighambari, K., Sattari, S., Kordestani, A., & Oghazi, P. (2016b). Consumer Behavior Research: A Synthesis of the Recent Literature. *SAGE Open*, *6*(2), 215824401664563. https://doi.org/10.1177/2158244016645638

Perks, H., Cooper, R., & Jones, C. (2005). Characterizing the Role of Design in New Product Development: An Empirically Derived Taxonomy*. *Journal of Product Innovation Management*, *22*(2), 111–127. https://doi.org/10.1111/j.0737-6782.2005.00109.x

Perona, M., & Saccani, N. (2004). Integration techniques in customer–supplier relationships: An empirical research in the Italian industry of household appliances. *International Journal of Production Economics*, *89*(2), 189–205. https://doi.org/10.1016/S0925-5273(03)00012-4

Petiot, J.-F., & Yannou, B. (2004a). Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics. *International Journal of Industrial Ergonomics*, *33*(6), 507–525. https://doi.org/10.1016/j.ergon.2003.12.004

Petiot, J.-F., & Yannou, B. (2004b). Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics. *International Journal of Industrial Ergonomics*, *33*(6), 507–525. https://doi.org/10.1016/j.ergon.2003.12.004

Pham, B. (1999). *Design for aesthetics: Interactions of design variables and aesthetic properties* (B. E. Rogowitz & T. N. Pappas, Eds.; pp. 364–371). https://doi.org/10.1117/12.348457

Pirinen, M. (2020). *Game of the Name – Titles and Titling of Visual Artworks in Theoretical Discussions from 1960 to 2015*.

Pittard, N., Ewing, M., & Jevons, C. (2007). Aesthetic theory and logo design: Examining consumer response to proportion across cultures. *International Marketing Review*, *24*(4), 457–473. https://doi.org/10.1108/02651330710761026

Porteous, J. D. (2013). *Environmental Aesthetics: Ideas, Politics and Planning* (0 ed.). Routledge. https://doi.org/10.4324/9780203437322

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2013). *The influence of unity-in-variety on aesthetic appreciation of car interiors*. 6.

Promjun, S., & Sahachaisaeree, N. (2012). Factors Determining Athletic Footwear Design: A Case of Product Appearance and Functionality. *Procedia - Social and Behavioral Sciences*, *36*, 520–528. https://doi.org/10.1016/j.sbspro.2012.03.057

Rader, M. (1966). *A Modern Book Of Esthetics* (3rd ed.).

Rafaeli, A., & Vilnai-Yavetz, I. (2003). Discerning Organizational Boundaries Through Physical Artifacts. In N. Paulsen & T. Hernes (Eds.), *Managing Boundaries in Organizations* (pp. 188–210). Palgrave Macmillan UK. https://doi.org/10.1057/9780230512559_11

Rahal, R.-M., & Fiedler, S. (2019). Understanding cognitive and affective mechanisms in social psychology through eye-tracking. *Journal of Experimental Social Psychology*, *85*, 103842. https://doi.org/10.1016/j.jesp.2019.103842

Rajput, S., & Singh, S. P. (2019). Identifying Industry 4.0 IoT enablers by integrated PCA-ISM-DEMATEL approach. *Management Decision*, *57*(8), 1784–1817. https://doi.org/10.1108/MD-04-2018-0378

Ramachandran, V. S., & Blakeslee, S. (1999). *Phantoms in the brain: Probing the mysteries of the human mind* (1st Quill edition published 1999). William Morrow, An Imprint of Harper Collins Publishers.

Ramos-Mejía, M., Jauregui-Becker, J. M., Koers-Stuiver, M., & Franco-Garcia, M.-L. (2019). Cycles of action and reflection as the basis of transformative innovation. *Management Research Review*, *42*(1), 141–154. https://doi.org/10.1108/MRR-02-2018-0063

Ranscombe, C., Hicks, B., Mullineux, G., & Singh, B. (2012a). Visually decomposing vehicle images: Exploring the influence of different aesthetic features on consumer perception of brand. *Design Studies*, *33*(4), 319–341. https://doi.org/10.1016/j.destud.2011.06.006

Ranscombe, C., Hicks, B., Mullineux, G., & Singh, B. (2012b). Visually decomposing vehicle images: Exploring the influence of different aesthetic features on consumer perception of brand. *Design Studies*, *33*(4), 319–341. https://doi.org/10.1016/j.destud.2011.06.006

Rashid, A., Mac Donald, B. J., & Hashmi, M. S. J. (2004). Evaluation of the aesthetics of products and integration of the findings in a proposed intelligent design system. *Journal of Materials Processing Technology*, *153–154*, 380–385. https://doi.org/10.1016/j.jmatprotec.2004.04.014

Reber, R., & Schwarz, N. (2001). The hot fringes of consciousness: Perceptual fluency and affect. *Consciousness & Emotion*, *2*(2), 223–231. https://doi.org/10.1075/ce.2.2.03reb

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing Fluency and Aesthetic Pleasure: Is Beauty in the Perceiver's Processing Experience? *Personality and Social Psychology Review*, *8*(4), 364–382. https://doi.org/10.1207/s15327957pspr0804_3

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of Perceptual Fluency on Affective Judgments. *Psychological Science*, *9*(1), 45–48. https://doi.org/10.1111/1467-9280.00008

Robert W., V., Jr. (1995). *The Place of Product Design and Aesthetics in Consumer Research*. *Advances in Consumer Research Volume 22*, Pages: 641-645. https://www.acrwebsite.org/volumes/7824/volumes/v22/NA-22

Rognoli, V., Bianchini, M., Maffei, S., & Karana, E. (2015). DIY materials. *Materials & Design*, *86*, 692–702. https://doi.org/10.1016/j.matdes.2015.07.020

Rojas, C., & Kang, L. (2001). Aesthetics and Marxism: Chinese Aesthetic Marxists and Their Western Contemporaries. *Chinese Literature: Essays, Articles, Reviews (CLEAR)*, *23*, 164. https://doi.org/10.2307/495509

Royer, F. L. (1981). Detection of symmetry. *Journal of Experimental Psychology: Human Perception and Performance*, *7*(6), 1186–1210. https://doi.org/10.1037/0096-1523.7.6.1186

Saaty, T. L. (1979). *Optimization by the Analytic Hierarchy Process:* Defense Technical Information Center. https://doi.org/10.21236/ADA214804

Saaty, T. L., & Wind, Y. (1980). Marketing applicatons of the analytic hierarchy process. *Management Science*.

Saito, M. (1996). A Comparative Study of Color Preferences in Japan, China and Indonesia, with Emphasis on the Preference for White. *Perceptual and Motor Skills*, *83*(1), 115–128. https://doi.org/10.2466/pms.1996.83.1.115

Saito, Y. (1998). The Aesthetics of Unscenic Nature. *The Journal of Aesthetics and Art Criticism*, 12.

Salvador, F., & Forza, C. (2004). Configuring products to address the customization-responsiveness squeeze: A survey of management issues and opportunities. *International Journal of Production Economics*, *91*(3), 273–291. https://doi.org/10.1016/j.ijpe.2003.09.003

Sangwa, N. R., & Sangwan, K. S. (2018). Leanness assessment of organizational performance: A systematic literature review. *Journal of Manufacturing Technology Management*, *29*(5), 768–788. https://doi.org/10.1108/JMTM-09-2017-0196

Santayana, G. (1896). The Sense of Beauty. *The Sense of Beauty*, 84.

Sarkar, P. (2018). *Understanding the Relationship between Aesthetics and Product Design*. *5*(3), 6.

Sauer, J., & Sonderegger, A. (2009). The influence of prototype fidelity and aesthetics of design in usability tests: Effects on user behaviour, subjective evaluation and emotion. *Applied Ergonomics*, *40*(4), 670–677. https://doi.org/10.1016/j.apergo.2008.06.006

Sauer, J., & Sonderegger, A. (2011). The influence of product aesthetics and user state in usability testing. *Behaviour & Information Technology*, *30*(6), 787–796. https://doi.org/10.1080/0144929X.2010.503352

Schenkman, B. N., & Jönsson, F. U. (2000). Aesthetics and preferences of web pages. *Behaviour & Information Technology*, *19*(5), 367–377. https://doi.org/10.1080/014492900750000063

Schindler, R. M., & Holbrook, M. B. (2003). Nostalgia for early experience as a determinant of consumer preferences. *Psychology and Marketing*, *20*(4), 275–302. https://doi.org/10.1002/mar.10074

Schoormans, J. P. L., & Robben, H. S. J. (1997). The effect of new package design on product attention, categorization and evaluation. *Journal of Economic Psychology*, *18*(2–3), 271–287. https://doi.org/10.1016/S0167-4870(97)00008-1

Scott, C. (2012). *Thomas Aquinas On the Nature and Experience of Beauty*.

Seth, N., Deshmukh, S. G., & Vrat, P. (2005). Service quality models: A review. *International Journal of Quality & Reliability Management*, *22*(9), 913–949. https://doi.org/10.1108/02656710510625211

Sethi, R. (2000). New Product Quality and Product Development Teams. *Journal of Marketing*, *64*(2), 1–14. https://doi.org/10.1509/jmkg.64.2.1.17999

Seva, R. R., Gosiaco, K. G. T., Santos, Ma. C. E. D., & Pangilinan, D. M. L. (2011). Product design enhancement using apparent usability and affective quality. *Applied Ergonomics*, *42*(3), 511–517. https://doi.org/10.1016/j.apergo.2010.09.009

Shank, M. D., & Langmeyer, L. (1994). Does Personality Influence Brand Image? *The Journal of Psychology*, *128*(2), 157–164. https://doi.org/10.1080/00223980.1994.9712719

Sharma, Y. K., Mangla, S. K., Patil, P. P., & Uniyal, S. (2018). Sustainable Food Supply Chain Management Implementation Using DEMATEL Approach. In N. A. Siddiqui, S. M. Tauseef, & K. Bansal (Eds.), *Advances in Health and Environment Safety* (pp. 115–125). Springer Singapore. https://doi.org/10.1007/978-981-10-7122-5_13

Sheller, M. (2004). Automotive Emotions: Feeling the Car. *Theory, Culture & Society*, *21*(4–5), 221–242. https://doi.org/10.1177/0263276404046068

Shin, J., Bhat, C. R., You, D., Garikapati, V. M., & Pendyala, R. M. (2015). Consumer preferences and willingness to pay for advanced vehicle technology options and fuel types. *Transportation Research Part C: Emerging Technologies*, *60*, 511–524. https://doi.org/10.1016/j.trc.2015.10.003

Simmonds, G., & Spence, C. (2017a). Thinking inside the box: How seeing products on, or through, the packaging influences consumer perceptions and purchase behaviour. *Food Quality and Preference*, *62*, 340–351. https://doi.org/10.1016/j.foodqual.2016.11.010

Simmonds, G., & Spence, C. (2017b). Thinking inside the box: How seeing products on, or through, the packaging influences consumer perceptions and purchase behaviour. *Food Quality and Preference*, *62*, 340–351. https://doi.org/10.1016/j.foodqual.2016.11.010

Simonson, A., & Schmitt, B. H. (2014). *Marketing aesthetics: The strategic management of brands, identity, and image*. Free Press. http://www.myilibrary.com?id=899059

Singh, J., & Sarkar, P. (2022). Visual Product Assessment by Using the Eye-Tracking Equipment to Study the Effect of Product Shapes on consumer’s Thinking. In K. C. Popat, S. Kanagaraj, P. S. R. Sreekanth, & V. M. R.

Kumar (Eds.), *Advances in Mechanical Engineering and Material Science* (pp. 149–158). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-0676-3_12
Singh, J., & Sarkar, P. (2023). *Understand and quantify the consumers' cognitive behaviour for the appropriateness features of product aesthetics through the eye-tracking technique*.
Singh, J., & Sarkar, P. (2019, December). *Understanding the gap between the perceptions of consumers and designers about non-visual factors of cars*.
Singh, J., & Sarkar, P. (in communication). Factual analysis of factors influencing consumer cognitive thinking and automobile designing using Fuzzy-AHP. *Journal of Visual Art and Design*.
Singh, P. K., & Sarkar, P. (2019). A framework based on fuzzy AHP-TOPSIS for prioritizing solutions to overcome the barriers in the implementation of ecodesign practices in SMEs. *International Journal of Sustainable Development & World Ecology*, *26*(6), 506–521. https://doi.org/10.1080/13504509.2019.1605547
Singh, P. K., & Sarkar, P. (2020). A framework based on fuzzy Delphi and DEMATEL for sustainable product development: A case of Indian automotive industry. *Journal of Cleaner Production*, *246*, 118991. https://doi.org/10.1016/j.jclepro.2019.118991
Smets, G. J. F., & Overbeeke, C. J. (1995). Expressing tastes in packages. *Design Studies*, *16*(3), 349–365. https://doi.org/10.1016/0142-694X(94)00003-V
Smith, S. M., Ward, T. B., & Finke, R. A. (Eds.). (2009). *The Creative Cognition Approach*. The MIT Press. https://doi.org/10.7551/mitpress/2205.001.0001
Smits, M. W. M. (2019). A quasi-experimental method for testing rural design support within a DRM framework. *Smart and Sustainable Built Environment*, *8*(2), 150–187. https://doi.org/10.1108/SASBE-11-2017-0067
Solomon, R. C. (2002). The Emotions: A Philosophical Exploration. *International Philosophical Quarterly*, *42*(2), 259–261. https://doi.org/10.5840/ipq20024226
Solso, R. (1997). *Cognition and the visual arts*. MIT Press.
Sonderegger, A., & Sauer, J. (2015). The role of non-visual aesthetics in consumer product evaluation. *International Journal of Human-Computer Studies*, *84*, 19–32. https://doi.org/10.1016/j.ijhcs.2015.05.011
Sonderegger, A., Zbinden, G., Uebelbacher, A., & Sauer, J. (2012). The influence of product aesthetics and usability over the course of time: A longitudinal field experiment. *Ergonomics*, *55*(7), 713–730. https://doi.org/10.1080/00140139.2012.672658
Steckler, C. M., & Tracy, J. L. (2014). The Emotional Underpinnings of Social Status. In J. T. Cheng, J. L. Tracy, & C. Anderson (Eds.), *The Psychology of Social Status* (pp. 201–224). Springer New York. https://doi.org/10.1007/978-1-4939-0867-7_10
Steg, L. (2005). Car use: Lust and must. Instrumental, symbolic and affective motives for car use. *Transportation Research Part A: Policy and Practice*, *39*(2–3), 147–162. https://doi.org/10.1016/j.tra.2004.07.001
Sternberg, R. J. (2006). Creating a vision of creativity: The first 25 years. *Psychology of Aesthetics, Creativity, and the Arts*, *S*(1), 2–12. https://doi.org/10.1037/1931-3896.S.1.2
SUMMERS, J., & BLANCO, E. (2013). *ASSESSING DESIGN RES EARCH QUALITY: INVESTIGATING VERIFI CATION AND VALIDATIO N CRITERIA*. 10.
Swift, P. W. (2010). Science Drives Creativity: A Methodology for Quantifying Perceptions. *Design Management Journal (Former Series)*, *8*(2), 51–57. https://doi.org/10.1111/j.1948-7169.1997.tb00160.x
Taliaferro, C. (2013). Aesthetics (Philosophy). In A. L. C. Runehov & L. Oviedo (Eds.), *Encyclopedia of Sciences and Religions* (pp. 25–29). Springer Netherlands. https://doi.org/10.1007/978-1-4020-8265-8_1548
Tanusondjaja, A., Trinh, G., & Romaniuk, J. (2016). Exploring the past Behaviour of New Brand Buyers. *International Journal of Market Research*, *58*(5), 733–747. https://doi.org/10.2501/IJMR-2016-042
Tasaki, K., Kim, M., & Miller, M. D. (1999). The effects of social status on cognitive elaboration and post-message attitude: Focusing on self-construals. *Communication Quarterly*, *47*(2), 196–214. https://doi.org/10.1080/01463379909370134
Tatarkiewicz, W. (1970). Did Aesthetics Progress? *Philosophy and Phenomenological Research*, *31*(1), 47. https://doi.org/10.2307/2105979

Tendahl, M., & Gibbs, R. W. (2008). Complementary perspectives on metaphor: Cognitive linguistics and relevance theory. *Journal of Pragmatics*, *40*(11), 1823–1864. https://doi.org/10.1016/j.pragma.2008.02.001

Tovey, M. (1997). Styling and design: Intuition and analysis in industrial design. *Design Studies*, *18*(1), 5–31. https://doi.org/10.1016/S0142-694X(96)00006-3

Tractinsky, N., Katz, A. S., & Ikar, D. (2000). What is beautiful is usable. *Interacting with Computers*, *13*(2), 127–145. https://doi.org/10.1016/S0953-5438(00)00031-X

Tuch, A. N., Bargas-Avila, J. A., & Opwis, K. (2010). Symmetry and aesthetics in website design: It's a man's business. *Computers in Human Behavior*, *26*(6), 1831–1837. https://doi.org/10.1016/j.chb.2010.07.016

Tuch, A. N., Bargas-Avila, J. A., Opwis, K., & Wilhelm, F. H. (2009). Visual complexity of websites: Effects on users' experience, physiology, performance, and memory. *International Journal of Human-Computer Studies*, *67*(9), 703–715. https://doi.org/10.1016/j.ijhcs.2009.04.002

Tuch, A. N., Presslaber, E. E., Stöcklin, M., Opwis, K., & Bargas-Avila, J. A. (2012). The role of visual complexity and prototypicality regarding first impression of websites: Working towards understanding aesthetic judgments. *International Journal of Human-Computer Studies*, *70*(11), 794–811. https://doi.org/10.1016/j.ijhcs.2012.06.003

Tuch, A. N., Roth, S. P., Hornbæk, K., Opwis, K., & Bargas-Avila, J. A. (2012a). Is beautiful really usable? Toward understanding the relation between usability, aesthetics, and affect in HCI. *Computers in Human Behavior*, *28*(5), 1596–1607. https://doi.org/10.1016/j.chb.2012.03.024

Tuch, A. N., Roth, S. P., Hornbæk, K., Opwis, K., & Bargas-Avila, J. A. (2012b). Is beautiful really usable? Toward understanding the relation between usability, aesthetics, and affect in HCI. *Computers in Human Behavior*, *28*(5), 1596–1607. https://doi.org/10.1016/j.chb.2012.03.024

Ulrich, K. T. (2006). Aesthetics in design. *Design: Creation of Artifacts in Society*.

Uriely, N. (1997). Theories of modern and postmodern tourism. *Annals of Tourism Research*, *24*(4), 982–985. https://doi.org/10.1016/S0160-7383(97)00029-7

van Breemen, E. J. J., & Sudijono, S. (1999). The Role of Shape in Communicating Designers' Aesthetic Intents. *Volume 3: 11th International Conference on Design Theory and Methodology*, 99–108. https://doi.org/10.1115/DETC99/DTM-8752

van Kesteren, I., de Bruijn, S., & Stappers, P. J. (2008). Evaluation of materials selection activities in user-centred design projects. *Journal of Engineering Design*, *19*(5), 417–429. https://doi.org/10.1080/09544820701716248

van Mulken, M., le Pair, R., & Forceville, C. (2010). The impact of perceived complexity, deviation and comprehension on the appreciation of visual metaphor in advertising across three European countries. *Journal of Pragmatics*, *42*(12), 3418–3430. https://doi.org/10.1016/j.pragma.2010.04.030

Veal, A. J. (1993). The concept of lifestyle: A review. *Leisure Studies*, *12*(4), 233–252. https://doi.org/10.1080/02614369300390231

Verhani, V. K., Batra, K., & Pieper, J. (2018). *Industrial_Analysis_Report_-_final.pdf*.

Verma, M., & Wood, W. H. (2001). Form Follows Function: Case-Based Learning Over Product Evolution. *Volume 3: 6th Design for Manufacturing Conference*, 219–229. https://doi.org/10.1115/DETC2001/DFM-21182

Veryzer Jr, R. W. (1993). Aesthetic response and the influence of design principles on product preferences. *Advances in Consumer Research*, *20*(1).

Veryzer, Jr., R. W., & Hutchinson, J. W. (1998a). The Influence of Unity and Prototypicality on Aesthetic Responses to New Product Designs. *Journal of Consumer Research*, *24*(4), 374–385. https://doi.org/10.1086/209516

Veryzer, Jr., R. W., & Hutchinson, J. W. (1998b). The Influence of Unity and Prototypicality on Aesthetic Responses to New Product Designs. *Journal of Consumer Research*, *24*(4), 374–385. https://doi.org/10.1086/209516

Veryzer, R. W., & Borja de Mozota, B. (2005). The Impact of User-Oriented Design on New Product Development: An Examination of Fundamental Relationships*. *Journal of Product Innovation Management*, *22*(2), 128–143. https://doi.org/10.1111/j.0737-6782.2005.00110.x

Vink, P., & Hallbeck, S. (2012). Editorial: Comfort and discomfort studies demonstrate the need for a new model. *Applied Ergonomics*, *43*(2), 271–276. https://doi.org/10.1016/j.apergo.2011.06.001

Visocky O'Grady, J., & Visocky O'Grady, K. (2017). *A designer's research manual: Succeed in design by knowing your clients + understanding what they really need* (Second edition, updated + expanded). Rockport, an imprint of The Quarto Group.

Vyncke, P. (2002). Lifestyle Segmentation: From Attitudes, Interests and Opinions, to Values, Aesthetic Styles, Life Visions and Media Preferences. *European Journal of Communication*, *17*(4), 445–463. https://doi.org/10.1177/02673231020170040301

Waltman, L., van Eck, N. J., & Noyons, E. C. M. (2010). A unified approach to mapping and clustering of bibliometric networks. *Journal of Informetrics*, *4*(4), 629–635. https://doi.org/10.1016/j.joi.2010.07.002

Walton, K. (2007). Aesthetics-What? Why? and Wherefore? *Journal of Aesthetics and Art Criticism*, *65*(2), 147–161. https://doi.org/10.1111/j.1540-594X.2007.00246.x

Wang, J.-S., Cheng, Y.-F., & Chu, Y.-L. (2013). Effect of Celebrity Endorsements on Consumer Purchase Intentions: Advertising Effect and Advertising Appeal as Mediators. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *23*(5), 357–367. https://doi.org/10.1002/hfm.20336

Wang, W.-C., Lin, Y.-H., Lin, C.-L., Chung, C.-H., & Lee, M.-T. (2012). DEMATEL-based model to improve the performance in a matrix organization. *Expert Systems with Applications*, *39*(5), 4978–4986. https://doi.org/10.1016/j.eswa.2011.10.016

Wang, X., Wong, Y. D., Li, K. X., & Yuen, K. F. (2020). This is not me! Technology-identity concerns in consumers' acceptance of autonomous vehicle technology. *Transportation Research Part F: Traffic Psychology and Behaviour*, *74*, 345–360. https://doi.org/10.1016/j.trf.2020.06.005

Washburn, D. (2022). *Symmetries in the Mind: Production, Perception, and Preference for Seven One-Dimensional Patterns*. 13.

Wen, Y., & Sun, H. (2012). The Form Beauty of Product Form Design – The Unity and Variety. *Advanced Materials Research*, *591–593*, 112–114. https://doi.org/10.4028/www.scientific.net/AMR.591-593.112

Wessell, L. P. (1972). Alexander Baumgarten's Contribution to the Development of Aesthetics. *The Journal of Aesthetics and Art Criticism*, *30*(3), 333. https://doi.org/10.2307/428739

Wind, Y., & Saaty, T. L. (1980). Marketing Applications of the Analytic Hierarchy Process. *Management Science*, *26*(7), 641–658.

Wu, H.-H., & Chang, S.-Y. (2015). A case study of using DEMATEL method to identify critical factors in green supply chain management. *Applied Mathematics and Computation*, *256*, 394–403. https://doi.org/10.1016/j.amc.2015.01.041

Yadav, H. C., Jain, R., Shukla, S., Avikal, S., & Mishra, P. K. (2013a). Prioritization of aesthetic attributes of car profile. *International Journal of Industrial Ergonomics*, *43*(4), 296–303. https://doi.org/10.1016/j.ergon.2013.04.008

Yadav, H. C., Jain, R., Shukla, S., Avikal, S., & Mishra, P. K. (2013b). Prioritization of aesthetic attributes of car profile. *International Journal of Industrial Ergonomics*, *43*(4), 296–303. https://doi.org/10.1016/j.ergon.2013.04.008

Yadav, H. C., Jain, R., Singh, A. R., & Mishra, P. K. (2013). Aesthetical design of a car profile: A Kano model-based hybrid approach. *The International Journal of Advanced Manufacturing Technology*, *67*(9–12), 2137–2155. https://doi.org/10.1007/s00170-012-4636-8

Yamamoto, M., & Lambert, D. R. (1994). *The Impact of Product Aesthetics on the Evaluation of Industrial Products*. 16.

Yan, H.-B., Huynh, V.-N., Murai, T., & Nakamori, Y. (2008). Kansei evaluation based on prioritized multi-attribute fuzzy target-oriented decision analysis. *Information Sciences*, *178*(21), 4080–4093. https://doi.org/10.1016/j.ins.2008.06.023

Yang, G. (2007). *Life cycle reliability engineering*. John Wiley & Sons.

You, H., Ryu, T., Oh, K., Yun, M.-H., & Kim, K.-J. (2006). Development of customer satisfaction models for automotive interior materials. *International Journal of Industrial Ergonomics*, *36*(4), 323–330. https://doi.org/10.1016/j.ergon.2005.12.007

Yun, M. H., Han, S. H., Hong, S. W., & Kim, J. (2003). Incorporating user satisfaction into the look-and-feel of mobile phone design. *Ergonomics*, *46*(13–14), 1423–1440. https://doi.org/10.1080/00140130310001610919

Zain, J. M., Tey, M., & Soon, G. Y. (2008). Using Aesthetic Measurement Application (AMA) to Measure Aesthetics of Web Page Interfaces. *2008 Fourth International Conference on Natural Computation*, 96–100. https://doi.org/10.1109/ICNC.2008.764

Zhang, L. (2002). Quantifying Customer Perception of Product Harmony Using Kansei Engineering Method. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *46*(6), 720–724. https://doi.org/10.1177/154193120204600608

Zuniga, M. D., Prieto, P. A., & Fantoni, G. (2014). *QUANTIFYING SHAPE DESCRIPTORS FOR AESTHETIC CONCEPTS*. 8.

APPENDIX

Appendix of Chapter 4

Appendix 4.1.A. Definition list of aesthetics with source

Defin. no.	Authors	Definition
1	(Heller, 2005)	Aesthetics: a branch of philosophy dealing with the nature of beauty, art, and taste and with the creation and appreciation of beauty.
2	(Charters, 2006)	Aesthetics: In the context of this study, we adopt a narrow definition of aesthetics in which aesthetics can be seen as a synonym for visual beauty.
3	(Bloch, 1995; Hoyer, 1984)	Aesthetics: a particular theory or conception of beauty or art: a particular taste for or approach to what is pleasing to the senses and especially sight.
4	(Benjamin, 1969)	Aesthetics' is a very old concept, rooted in the Greek word aisthesis that can be translated as understanding through sensory perception.
5	(Woodfield, 2001)	Recently, the author has argued that such a definition of aesthetics, i.e. the pleasure attained from sensory perception, is most appropriate in that it clearly separates aesthetic phenomena from other types of experience, such as the construction of meaning and emotional responses.
6	(Martin, 2003)	Aesthetic is not limited to the visual domain - The visual arts have clearly dominated Western art and, as a result, the concept of aesthetics has often been used as synonymous for visual beauty.
7	(Norman, 2002)	If we, however, agree that aesthetics refers to sensory pleasantness in general, things can also be aesthetic or pleasant to listen to, touch, smell, or taste.
8	(Guyer, 2008)	Aesthetics is broader in scope than the philosophy of art, which comprises one of its branches. It deals not only with the nature and value of the arts but also with those responses to natural objects that find expression in the language of the beautiful and the ugly.
9	(de Man, 1982)	To provide more than a general definition of the subject matter of aesthetics is immensely difficult. Indeed, it could be said that self-definition has been the major task of modern aesthetics. We are acquainted with an interesting and puzzling realm of experience: the realm of the beautiful, the ugly, the sublime, and the elegant; of taste, criticism, and fine art; and of contemplation, sensuous enjoyment, and charm.
10	(Backlund et al., 2006)	The term ‘aesthetics’ has a complicated history, sometimes referring to the study of beauty and taste, other times to the experience of art or, more generally, to the philosophy of art. For purposes here, ‘aesthetics’ will be used to refer to the philosophy of art and is therefore primarily concerned with philosophical questions associated with the arts. If so, a naturalized aesthetics is a naturalistic approach to the study of art objects, behavior, and experience.
11	(Frelund, 2018; Wilder, 2021)	In 1798, from German Ästhetisch (mid-18c.) or French esthétique (which is from German), ultimately from Greek aisthetikos "of or for perception by the senses, perceptive," of things, "perceptible," from aisthanesthai "to perceive (by the senses or by the mind), to feel," from PIE *awis-dh-yo-, from root *au- "to perceive."
12	(Mill, 1987)	Aesthetics is a philosophy that explores the intrinsic value and emotional quality of art and its creation. It is closely related to the philosophy of art, which is concerned with the nature of art and the concepts in terms of which individual works of art are interpreted and evaluated.
13	(Simpson, 2020)	Basically "aesthetics" simply means "of beauty" or "pleasing to the eye".
14	(Saito, 2015)	Aesthetics is the pleasure we derive from perceiving an object or experience through our senses. Aesthetic businesses don’t just sell products and services that meet customer needs; they offer experiences that are a pleasure to buy and consume.
15	(Munro and Scruton, 1998)	Aesthetics: a branch of philosophy dealing with the nature of beauty, art, and taste and with the creation and appreciation of beauty. A branch of philosophy dealing with the nature of art and beauty.
16	(Crispin, 2012)	A particular theory or conception of beauty or art.
17	(Dorweiler, 2021)	The term “aesthetic” originated in Greek “aisthitiki” means perception through sensation. ‘Aesthetic’ derives from the Greek term for sensory perception, and so preserves the implication of immediacy carried by the term ‘taste.’ What does aesthetics mean? The root of aesthetics comes from ancient Greek: aisthetikos, pertaining to sense perception; aistheta, perceptible things; aisthenasthai, to perceive; aisthesis, sense perception. Clearly, aesthetics has to do with human perception. This meaning is clarified by considering its negation: anesthetic.
18	(Bo et al., 2018)	In Cambridge Dictionary, aesthetic is “related to the enjoyment or study of beauty”, or “an aesthetical object or a work of art is one that throws great beauty”.

19	(Hekkert, 2014)	In line with the original Greek meaning of the concept, I have defined "aesthetics," or an aesthetic response, as the pleasure – or displeasure – derived from sensory-motor understanding.
20	(Schnurr et al., 2017)	Aesthetic impression may be defined as the sensation that results from the perception of attractiveness (or unattractiveness) in products
21	(Johnson et al., 2014)	We often judge objects, people, and places in terms of beauty and attractiveness, as we might do when inspecting an architectural design, a home decoration, a face, an outfit of clothes, or even the layout of a document or slide presentation.
22	(Walton, 2007)	Aesthetics' is nothing but a loose term lately applied in academic circles to everything that has to do with works of art or with the sense of beauty.
23	(Faste, 1995)	An anesthetic is something that blocks sense perception and makes a person unable to feel anything. Used to diminish pain, it must also necessarily eliminate pleasure. When patients are anesthetized, all sensations are equally eliminated—they feel nothing.
24	(Crilly et al., 2004)	Crozier's "response to function", Cupchik's "cognitive/behavioural response", Lewalski's visual "Y-values" (which are "conducive to purposefulness and functionality"), Baxter's "semantic attractiveness" and Norman's "behavioural level" in design

Appendix of Chapter 5

Appendix: 5.1.A: Survey on non-visual factors of a car.

The aim of this study is to understand what nonvisual factors affect the purchase decision of a prospective buyer of a new car.

Nonvisual factors: nonvisual factors are those factors such as brand value, warranty, reliability that you can feel in your mind and influence your likeness of a car.

Kindly list down the non-visual factors that affect your decision of selecting a car purchasing. Next prioritizing these factors by putting ranking against them (1-highest, 2-next lower, etc.)

Table 5.1.A. Table for inputs from the consumers for non-visual factors

Non-visual factors		
SI.No.	Name of the factors	Rank
1		
2		
3		
4		
┆		
10		

Appendix 5.1.B:

List of all non-visual factors

Table 5.1.B. List of all non-visual factors for rank value as well as the average method

	Rank value method		**Average method**	
S. No.	**Factor**	**Subtotal of values**	**Factor**	**Average weight**
1	Average mileage/ fuel efficient	561	Average mileage/fuel efficient	8.428
2	New technology	379	New technology	5.75
3	Reliability	326	Reliability	6.833
4	Status/ Feeling of prestige	315	Status/Feeling of prestige	6
5	Quality	275	Quality	3.286
6	Design/ form*	256	Design/form*	5.286

7	Ergonomics	262	Ergonomics	4.571
8	Past experience	214	Past experience	4.571
9	Safety	163	Safety	3.625
10	New features	156	New features	3.426
11	Cost/Budget	148	Cost/Budget	1.571
12	Attention	146	Attention	3.111
13	Resale value	106	Resale value	2.25
14	Warranty	102	Warranty	1.556
15	Service center	70	Service center	1.142
16	Brand	62	Brand	0.174
17	Accomplished feeling	24	Accomplished feeling	0.571
18	Power	24	Power	1
19	Culture	10	Culture	1
20	No. of seats	9	No. of seats	0.2

Appendix 5.1.C:

Pareto exercise for nineteen non-visual factors

Table 5.1.C. Pareto exercise for finding the top non-visual factors

Sl no.	Factor	Subtotal	Cumulative	Percentage
1	Average mileage/ fuel efficient	561	561	16%
2	New technology/features	535	1096	30%
3	Reliability	326	1422	39%
4	Status/ Feeling of prestige/Materialistic	315	1737	48%
5	Quality	275	2012	56%
6	Ergonomics	262	2274	63%
7	Design/ form*	256	2530	70%
8	Past experience	214	2744	76%
9	Safety	163	2907	81%
10	Cost/Budget	148	3055	85%
11	Attention	146	3201	89%
12	Resale value	106	3307	92%
13	Warranty	102	3409	94%
14	Service center	70	3479	96%
15	Brand	62	3541	98%
16	Accomplished feeling	24	3565	99%
17	Power	24	3589	99%
18	Culture	10	3599	100%
19	No. of seats	9	3608	100%
		3608		

Appendix 5.1.D: Comparative chart for Fuzzy-AHP

Please provide your input according to the relative importance of each factor with respect to others using this scale.

Goal	Rating scale	Goal

Factor	Equally strong	Intermediate	Moderately strong	Intermediate	Strong	Intermediate	Very strong	Intermediate	Extremely strong	Factor
	1	2	3	4	5	6	7	8	9	
Reliability										Status/feeling of prestige
Reliability										Quality/ warranty
Reliability										Mileage / fuel efficient
Reliability										Unique form
Reliability										New technology/features
Reliability										Past experience
Reliability										Ergonomics
Reliability										Safety features
Status/feeling of prestige										Quality/ warranty
Status/feeling of prestige										Mileage / fuel efficient
⋮										⋮
Ergonomics										Safety features

Table 5.1.D. Fuzzy AHP factors comparison matrix for Designers (D_1)

Goal	Rating scale									Goal
Factor	Equally strong	Intermediate	Moderately strong	Intermediate	Strong	Intermediate	Very strong	Intermediate	Extremely strong	Factor
	1	2	3	4	5	6	7	8	9	
Reliability									9	Status/feeling of prestige
Reliability								8		Quality/ warranty
Reliability					5					Mileage / fuel efficient
Reliability					5					Unique form
Reliability						6				New technology/features
Reliability					5					Past experience
Reliability				4						Ergonomics
Reliability							7			Safety features
Status/feeling of prestige					5					Quality/ warranty
Status/feeling of prestige				4						Mileage / fuel efficient
⋮										⋮

Ergonomics					5					Safety features

Appendix 5.1.E: Comparative chart for Fuzzy-AHP

Table 5.1.E Fuzzy AHP factors comparison matrix for Designers (D_2)

Goal	Rating scale									Goal
Factor	Equally strong	Intermediate	Moderately strong	Intermediate	Strong	Intermediate	Very strong	Intermediate	Extremely strong	Factor
	1	2	3	4	5	6	7	8	9	
Reliability								8		Status/feeling of prestige
Reliability							7			Quality/ warranty
Reliability						6				Mileage / fuel efficient
Reliability					5					Unique form
Reliability					5					New technology/features
Reliability						6				Past experience
Reliability							7			Ergonomics
Reliability							7			Safety features
Status/feeling of prestige						6				Quality/ warranty
Status/feeling of prestige					5					Mileage / fuel efficient
┆										┆
Ergonomics						6				Safety features

Appendix of Chapter 5.2.

Jitender

Mr. Jitender is a PhD research scholar at the Department of Mechanical Engineering at Indian Institute of Technology Ropar. He completed his masters from the Department of Mechanical Engineering at National Institute of Technology, Srinagar. His research interest is in engineering aesthetics.

Appendix 5.2.A: Survey on Visual factors of a car

The aim of this study is to understand what Visual factors affect the purchase decision of a prospective buyer of a new car.
Visual factors: Visual factors are those factors such as color, design, Accessories that you can feel in your mind and influence your likeness of a car.
Kindly list down the Visual factors that affects yours decision of selecting a car purchasing. Next prioritizing these factors by putting ranking against them (1-heighest, 2-next lower, etc.)

Table 5.2.A. Table for inputs from the consumers for non-visual factors

Rank	Visual factor
1	Colour
2	Brand value/name
3	Logo
……..	…..
10	Alloy wheel

Name:	Age:
Education/occupation:	Place:
Signature:	

Appendix 5.2.B, Example of responses to the survey

Table 6.B, Table for inputs from the consumers for non-visual factors

	Participants				
Ranks	1	2	3	-------	86
Rank 1	Shape	Alloy wheel	Brand		Aerodynamic look
Rank 2	Size	Color	Design		Spoilers
Rank 3	Color	Aerodynamic look	Accessories		Alloy wheel
Rank 4	Texture	Front/ back design	Aerodynamics look		Color
Rank 5	Logo	Curves	Texture		Backside look
Rank 6	Navigation system	Height	4 wheel drive		Shape of head lamp/tail
Rank 7	Aerodynamics look	Metal finishing /Glossiness	Color		Tires design
Rank 8	Accessories	Shape of head lamp/tail	Logo		Height
Rank 9	Four wheel drive	Tires design	Shape		Metal finishing /Glossiness
Rank 10	3rd row seats	Spoilers	Size		Brand logo

Appendix 5.2.C:

Table 5.2.C, Calculation for Rank value method, average method, and calculation by using the 80/20 Rule or inverse Pareto Principle for visual factors

		Average method	Rank value method		80/20 Rule or Pareto Principle	
S.No.	Factor	Average weight	Subtotal	Total	Cumulative total	Percentage
1	Color	11.6	713	713	713	19%
2	Brand name/value	8.14	472	472	1185	32%
3	Accessories	8.14	387	387	1572	42%
4	Aerodynamic look	7	354	354	1926	51%
5	Design	6.4	271	271	2197	59%
6	4 wheel drive	4.44	266	266	2463	66%
7	Logo	4.43	253	253	2716	72%
8	GPS	5.29	249	249	2965	79%
9	3 Row seats	3.89	197	197	3162	84%
10	Texture	4	192	192	3354	89%
11	Shape	3.67	133	133	3487	93%
12	Look	2.33	80	80	3567	95%
13	Interior and exterior design	1.86	60	60	3627	97%

14	Cost	1.5	52	52	3679	98%
15	Shoulder lines	4	36	36	3715	99%
16	Design of lights	0.29	13	13	3728	99%
17	Safety	0.5	10	10	3738	100%
18	Alloy wheel	2	8	8	3746	100%
19	Steering position	0.14	5	5	3751	100%
				3751		

A total of nineteen visual factors is identified from open-ended surveys and it is shown in the second column of Table 4. Whereas, in the third column the subtotal of all the multiplications and in the fifth column the average weight of each factor is given.

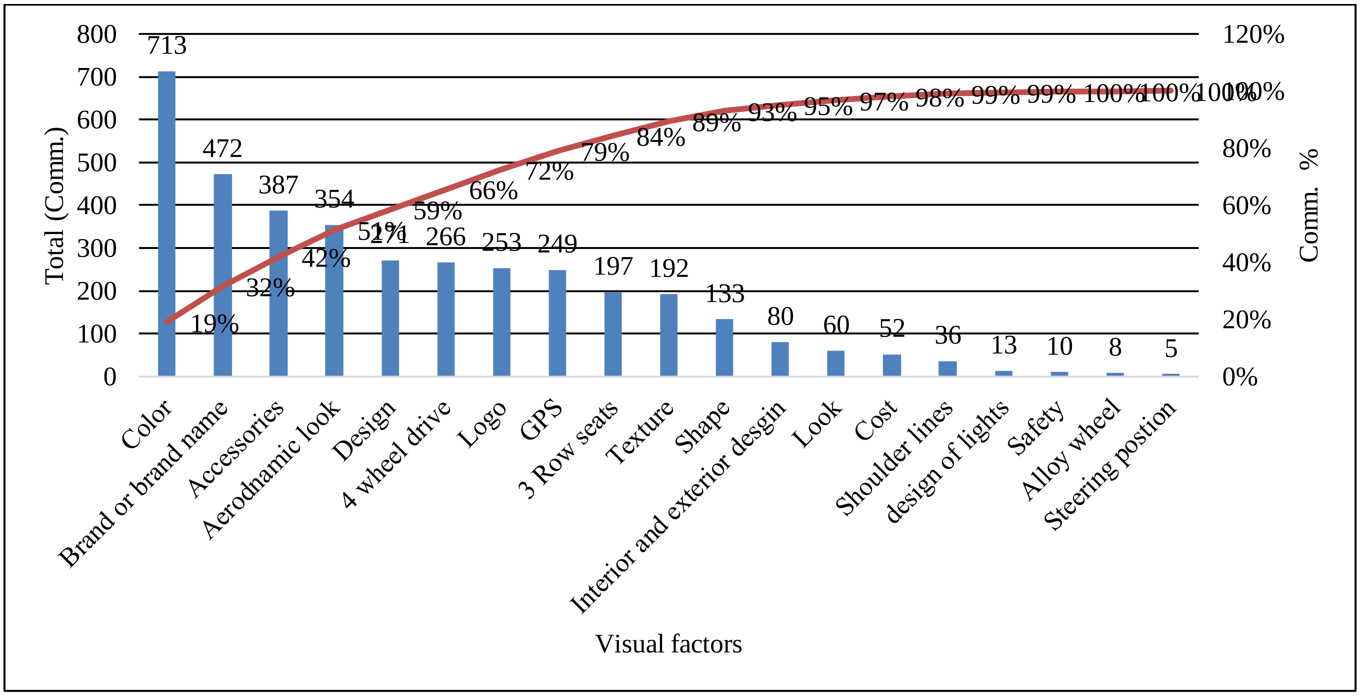


Figure 6.1 shows the total and percentage of each factor with the help of the inverse Pareto principle

Appendix 5.2.D:

Please provide your input according to the relative importance of each factor with respect to others using this scale

Goal										Goal
Factor	Equally strong	Intermed iate	Modera tely strong	Inte rme diat e	Strong	Inte rme diat e	Very strong	Inter media te	Extremel y strong	Factor
	1	2	3	4	5	6	7	8	9	
Colour										Brand
Colour										Design
Colour										Aerodynamic look
Colour										4 wheel drive
Colour										G.P.S
Colour										Logo
Colour										Accessories
Colour										3-row seats
Brand										Design
Brand										Aerodynamic look
¦										¦
Accessories										3-row seats

Table 5.2.D, please provide your input according to the relative importance of each factor with respect to others using this scale which is provide in Table 5.2.6 (designer input-D1)

Goal										Goal
Factor	Equally strong	Intermediate	Moderately strong	Intermediate	Strong	Intermediate	Very strong	Intermediate	Extremely strong	
	1	2	3	4	5	6	7	8	9	
Colour	1									Brand
Colour	1/2									Design
Colour						1/6				Aerodynamic look
Colour		2								4 wheel drive
Colour				1/4						G.P.S
Colour		2								Logo
Colour				1/4						Accessories
Colour							7			3-row seats
Brand					1/5					Design
Brand					1/5					Aerodynamic look
¦										¦
Accessories								8		3-row seats

Table 5.2.E, please provide your input according to the relative importance of each factor with respect to others using this scale which is provide in Table 5.2.6 (designer input-D2)

Goal										Goal
Factor	Equally strong	Intermediate	Moderately strong	Intermediate	Strong	Intermediate	Very strong	Intermediate	Extremely strong	Factor
	1	2	3	4	5	6	7	8	9	
Colour		1/2								Brand
Colour				1/4						Design
Colour					1.5					Aerodynamic look
Colour						1/6				4 wheel drive
Colour						1/6				G.P.S
Colour			3							Logo
Colour			1/3							Accessories
Colour				4						3-row seats
Brand				4						Design
Brand			3							Aerodynamic look
¦										¦
Accessories					5					3-row seats

Appendix of Chapter 5.3.

Appendix 5.3.A: Survey on sub-factors that affects non-visual factors of a car

This study aims to determine the sub-factors that affect a car's non-visual factors at the time of purchase. While purchasing a car, give your feedback below:

1. What do you think, which factor affects the reliability of a car?
2. Which factor will you think affects the status/feeling of the prestige of a car?
3. Which type of factors will affect the fuel efficiency/ mileage of a car?
4. Which factor do you think will affect the design or form of a car?
5. Which factor will affect the warranty/quality of a car?
6. According to you, is there any factor that affects the "New features/technologies" of a car?
7. Which factor will affect the "Safety" of a car?
8. Which factor will affect an "Ergonomics" of a car?
9. What factor will affect the past experience of a car?

Appendix 5.3.B: All the sub-factors in the sequence as received from the respondents

These tables show the list of sub-factor for each non-visual factor with respect to their respective respondents. The responses are divided into parts 1 (1-7 respondents) and Part 2 (8-15 respondents). Respondents are designated by a serial no followed by their age.

Table 5.3.B, List of sub-factor for each non-visual factor (part 1)

Non-visual factors	Sub factor of non-visual						
	R 1/ 35	R 2/29	R 3/ 30	R 4/30	R 5 /31	R 6/30	R 7/32
Reliability	Safety	Airbag, brand value, Seat locking system, brake system	Extra noise, Timely service	No extra accessories in front of the car to avoid opening the airbag	Body material, New technology	Time period for maintenance, airbag, brand value.	Safety, no failure
Ergonomics	Fuel efficiency	Seat adjustment, side mirror placement, and rare view mirror placement	Leg space, the height of the roof,	Leg space, seat adjustment.	Shockers, inside space	Price, review of other, location of the agency, space inside the car.	Seating comfort, leg space, Efficient A.c., smart features in staring wheel
Quality	driving style	Smoothness during driving, seat softness,	Smart technology, safety	Material, insulation.	Comfort, cost	Aerodynamic design, car design.	Look, alloy wheel, smart features, engine

		easy brake, No malfunction					specification, comfort level.
Feeling of status/ prestige	Comfort	Brand, Sllikiness, design, mirror of the car, color, seat cover with a white cloth, interior	Aesthetic quality, engine power, luxury	Look, comfort level, size of the car.	Design of the car, Back sensor, Power breaks	Mileage,	Unique design, New technology, comfort level
Unique form or Design	Aerodyna mics look	Sllikiness of the curve, color	Turning radius, leg space.	Ground clearance, cost, and light design.	Boots space (should be high), Attention secor	Curvy shape of light, front bonnet size (large size).	Design of head and tail light, front grill, aerodynamic look
Past experience	Safety, comfort, fuel efficiency, driving style	Brand value	New technology	Brand value,	Mileage of car, cost-effective (high features in less range)	Space, avg. of car, service quality, customer satisfaction with service staff.	Mileage, comfort level, reliability, look
New technology/fea tures	cost, eco friendly	Hidden need	ABS, Power window, Airbag	Rarer view camera, comfort level,	Engine power(cost-effective)	Safety, price.	ABS, airbag, smart features in the steering wheel, fuel-efficient
Mileage/fuel-efficient	Eco-mode drive	Weight of car, braking type, aerodynamic look	Driver driving style, eco mode drive, weight of a person with car, proper service.	Lubricant oil, power, A.C.	Weight of vehicle, ABS	Size of car, road condition, aerodynamic look, turbo system	Engine specification, aerodynamic look
Safety		Brake, airbag, tire quality, Front mirror (means super hyper phobic mirrors)	ABS, Airbag	Light std. at night time, front mirror, airbag	Airbags, cost	Airbag, locking system price, mirror braking tool provides, braking system.	Airbag, ABS, build quality.

Table 5.3.B, List of sub-factor for each non-visual factor (part 2).

Sub factor of a non-visual factor							
R 8/32	**R 9/30**	**R 10/31**	**R 11/32**	**R 12/31**	**R 13/30**	**R 14/31**	**R 15/35**
Brand value, Build quality, prize	Cost	Past experience, Review from other parodic maintenance	Fuel efficient, Build quality, Economic, Power of engine	Road quality, Shock absorber, Sensor quality, Location of service center	Brand, Public reviews, Engine	Service time period, mileage remains constant over time, Spare part is good	mileage remains constant, service period (consistent performance in the long run), safe
Build quality, seating place, the height of the car, space	Aesthetic s, Brand name, cost.	Space inside toward head, Height of the car from ground, i.e., ground clearance	Seat size, leg space, seat adjustment, staring adjustment, blind space, boot space.	Boot space, seat adjustment	Leg space, seat quality means cushions,	Design of seat	Ease of use

Same as reliability	Same as reliability .	Reliability	Build quality, testing, cost of the car, pickup time, service time, road grip	Build quality, Material used	Build quality, material, Aerodynamic look, structure, brand name	Material, good quality accessories	Engine and interface
Brand value, size of car, ego.	Brand name	Brand value, Economic level.	Comfort zone, high-end features, interiors, size of a car, lighting of the car		Brand, cost, economy	Splendid aesthetics exterior and interior	Brand, good performance
How it looks from the exterior, feeling How it looks from the inside as compared to outside.	Brand value		Look aerodynamic, curves, handles, luxuries, boot shape.	Look, Shape of lights.	Height of car, Curve of car or silhouettes, color	head and taillight design, front grill design	Shape of light
No true nowadays, New brand	Features		Purpose of fulfilment, features, extra feature within range, and not paying extra accessories should be available at all places.	Space, family size, Look	Mileage, comfort zone, post-purchase service	Driving comfort, service cost, availability of parts	mileage
Range of cost.	Cost, Brand value	Economic level	Economy level.	Cost	Easy of excess, safety, Comfort zone	Cost	Smart features, cost
Nothing	Big car, big brand, luxury cars.	Cost of car, economic level.	Power increase millage decrease, size of car, aerodynamic look	Economy level.	Engine power	eco mode drive	driver driving style, maintenance of the car
5-star rating, Brand value	If the cost is high, we did not prefer that car	No factor	Build quality, two airbags, ABS, road condition, aerodynamic look.	Build quality, Shock resistance body	Build quality, interiors, bag, type of rye, high of car, efficiency,	position of seat and steering at the time of the crash, design of the tire	Crash test results

Appendix 5.3.C: Arrangement of 20×20 matrix.

Table 5.3.C List of sub-factors arranged in 20×20 matrix

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}
F_1																				
F_2																				
F_3																				

F_4																				
F_5																				
F_6																				
F_7																				
F_8																				
F_9																				
F_{10}																				
F_{11}																				
F_{12}																				
F_{13}																				
F_{14}																				
F_{15}																				
F_{16}																				
F_{17}																				
F_{18}																				
F_{19}																				
F_{20}																				

Note; F1 (Adjustable driving equipment), F2 (Aerodynamic design), F3 (ABS), F4 (Air-bags), F5 (Brand value), F6 (After-sale services), F7 (Car's build quality) , F8 (Comfortable seat design), F9 (Car cost), F10 (Design/looks of the car), F11 (Design of front grill & bonnet), F12 (Design of headlights), F13 (Eco-mode feature), F14 (Engine performance), F15 (Ground clearance), F16 (Car inside space), F17 (New accessories/feature), F18 (Reliability), F19 (Safety of the car), F20 (Weight of the car).

Appendix 5.3.D: Initial matrix

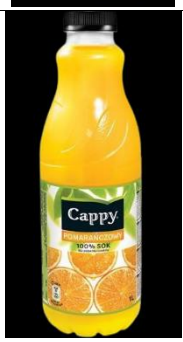
Table 5.3.D, Initial matrix from experts/professionals

	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**F_8**	**F_9**	**F_{10}**	**F_{11}**	**F_{12}**	**F_{13}**	**F_{14}**	**F_{15}**	**F_{16}**	**F_{17}**	**F_{18}**	**F_{19}**	**F_{20}**
F_1	0	1	1	0	3	1	1	4	3	2	0	0	0	0	0	2	2	2	4	2
F_2	0	0	0	0	1	0	1	1	2	3	2	1	0	0	1	1	1	0	2	1
F_3	0	0	0	0	4	0	1	0	2	0	0	0	0	0	0	1	1	1	4	1
F_4	0	0	0	0	4	1	0	2	4	0	0	0	0	0	0	0	1	2	4	1
F_5	3	1	4	4	0	1	3	3	2	4	3	3	4	3	1	3	4	4	4	1
F_6	1	0	0	1	1	0	2	0	2	0	0	0	0	0	0	1	1	1	3	0
F_7	1	1	1	0	3	2	0	2	3	3	3	3	0	0	1	3	2	4	4	4
F_8	4	1	0	2	3	0	2	0	3	1	1	1	1	0	1	3	3	2	2	1
F_9	3	2	2	4	2	2	3	3	0	3	3	3	3	4	1	4	4	4	4	2
F_{10}	2	2	0	0	4	0	3	1	3	0	4	4	0	0	1	3	2	1	1	1
F_{11}	0	2	0	0	3	0	3	1	3	4	0	1	0	0	0	0	0	3	3	2
F_{12}	0	1	0	0	3	0	3	1	3	4	1	0	0	0	0	0	0	1	0	1
F_{13}	0	0	0	0	4	0	0	1	3	0	0	0	0	4	0	0	2	0	0	0
F_{14}	0	0	0	0	3	0	0	0	4	0	0	0	4	0	0	0	1	1	1	1
F_{15}	0	1	0	0	1	0	1	1	1	1	0	0	0	0	0	1	0	2	2	2
F_{16}	2	1	1	0	3	1	3	3	4	3	0	0	0	0	1	0	1	1	1	1
F_{17}	2	1	1	1	4	1	2	3	4	2	0	0	2	1	0	1	0	1	4	1
F_{18}	2	0	1	2	4	1	4	2	4	1	3	1	0	1	2	1	1	0	4	2
F_{19}	4	2	4	4	4	3	4	3	4	1	3	0	0	1	2	1	4	4	0	2
F_{20}	2	1	1	1	1	0	4	1	3	1	2	1	0	1	2	1	1	2	2	0

Appendix of Chapter 6

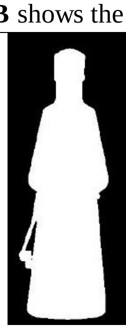
Appendices 6.1.A:

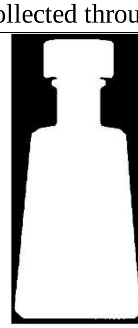
Table 6.1.A lists all the downloaded images downloaded from the PNGWING website.

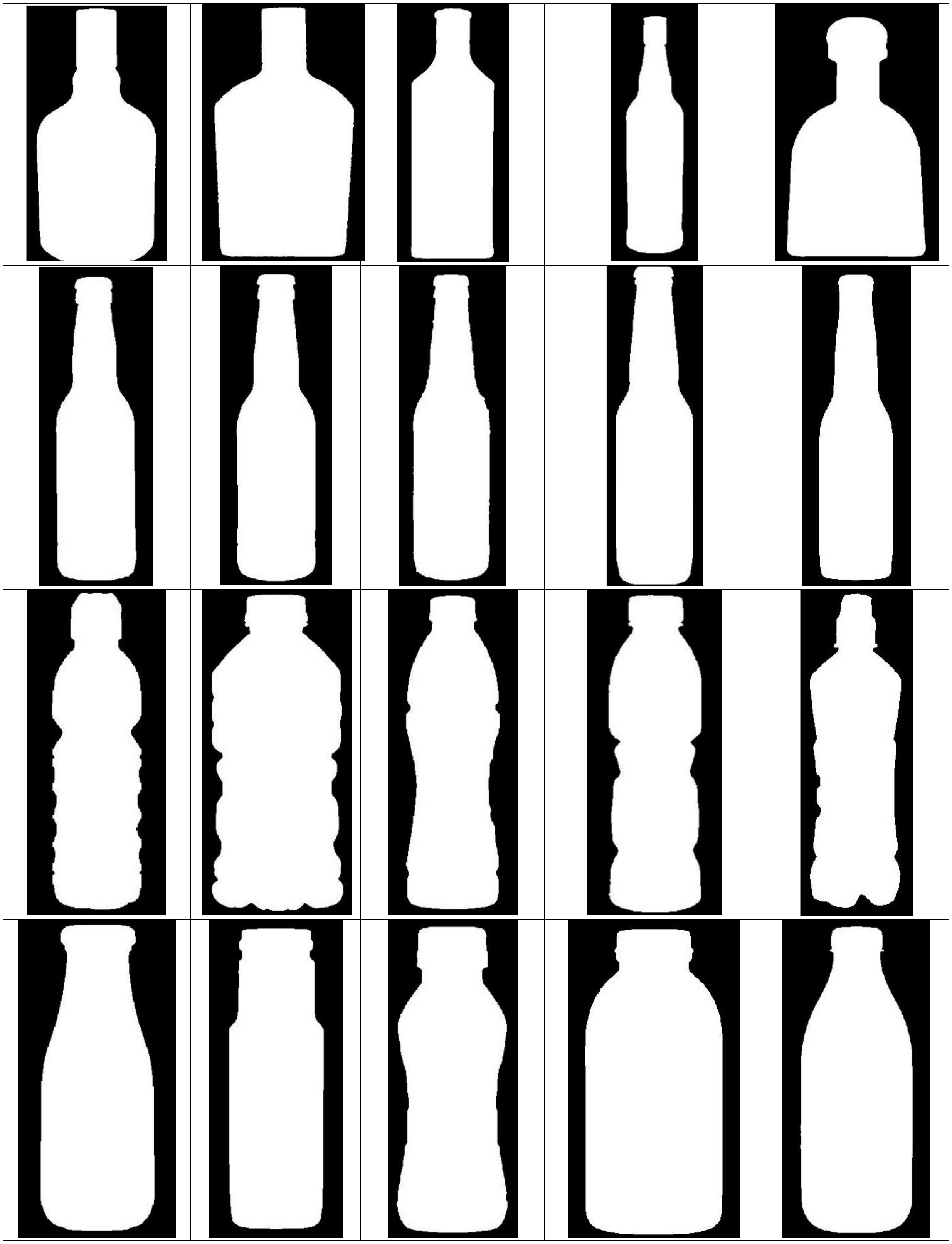


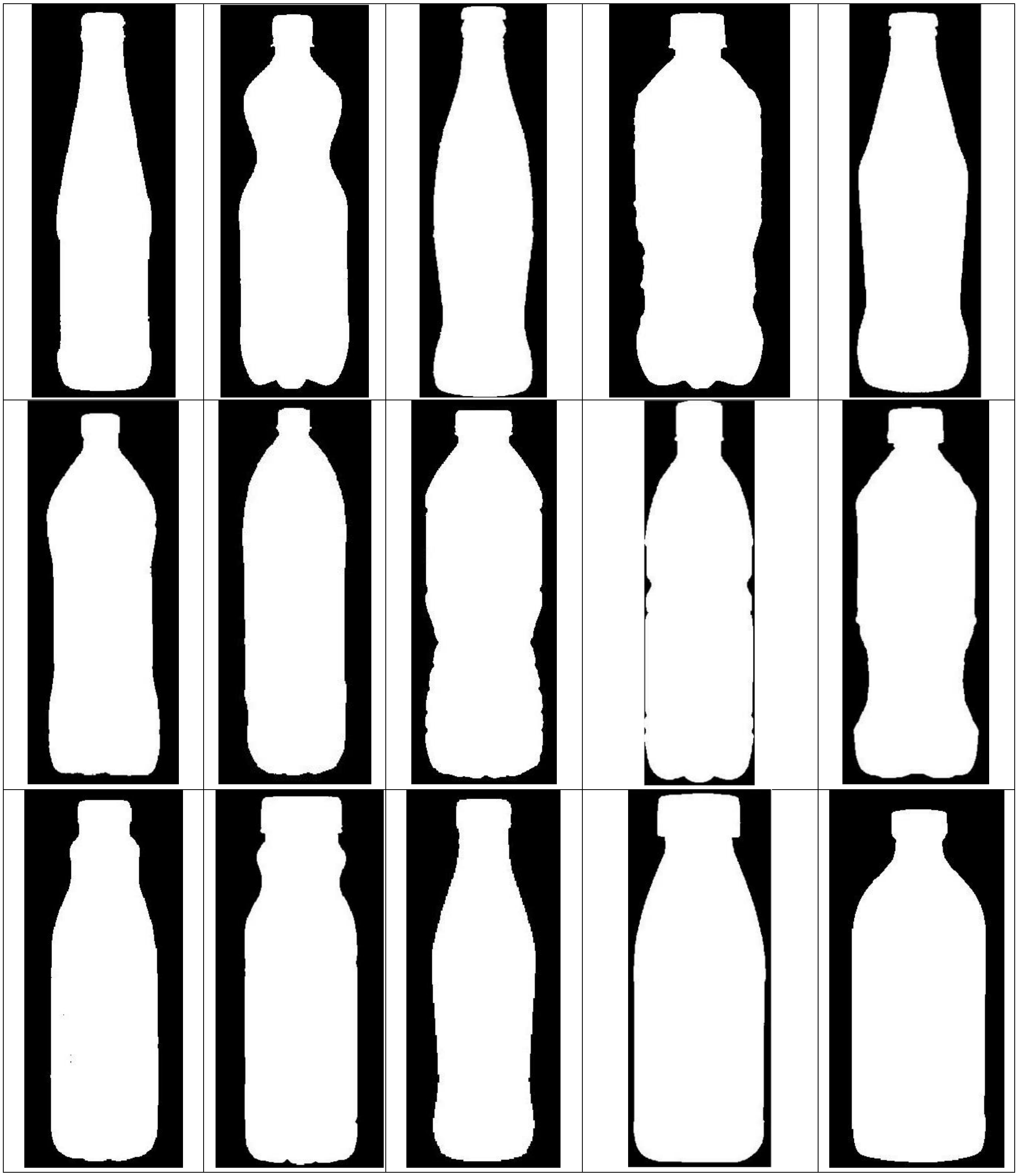
Appendices 6.1.B:

Table 6.1.B shows the list of all the silhouette images collected through MATLAB.





Appendices 6.1.C:

The questionnaire for the design survey is given below.

Out of the following options, fill your choice by mentioning the category of each bottle for the respective images in the answer section.

1. Carbonated drink or soft drink (Mountain dew/Coca-Cola/Pepsi) bottle
2. Juice bottle

3. Energy or Sports drink (Sports/Gatorade/Power) bottle
4. Alcohol (wine/Vodka/ beer) bottle
5. Coffee & Milk (Amul/Starbucks/Shatto milk) bottle
6. Water bottle (Biseleri, Aquafina, Kingfisher)

Appendices 6.1.D:

Table 6.1.D shows the value of pupil diameter size of a human being during the eye-tracking experiment

Product Identification	Whole population pupil diameter	Female pupil diameter	Male pupil diameter
P 2 (G1)	3.06	2.991	3.083
P 5 (G1)	2.91	2.960	2.954
P 8 (G1)	2.87	2.902	2.954
P 10 (G1)	2.93	2.968	2.963
P 15 (G1)	2.90	2.939	2.937
P 17 (G1)	2.87	2.923	2.901
P 1 (G2)	3.06	3.014	3.075
P 6 (G2)	2.95	2.940	3.007
P 7 (G2)	2.93	2.947	2.980
P 11 (G2)	2.91	2.939	2.952
P 14 (G2)	2.89	2.954	2.922
P 18 (G2)	2.89	2.934	2.927
P 3 (G3)	3.04	2.978	3.058
P 4 (G3)	2.97	2.982	3.024
P 9 (G3)	2.90	2.890	2.962
P 12 (G3)	2.85	2.920	2.927
P 13 (G3)	2.89	2.905	2.933
P 16 (G3)	2.90	2.934	2.942

Appendices 6.1E:

Table **6.1E** shows the value of the fixation count of a human being during the eye-tracking.

Product Identification		Female fixation count	Male fixation count	Whole (total) population fixation count
AL (G1)	P 2	20.17	19.24	19.49
CD (G1)	P 5	17.67	20.24	19.56
SD (G1)	P 8	25.00	21.85	22.69
Ju (G1)	P 10	24.50	22.55	23.07
W (G1)	P 15	14.42	20.39	18.80
C/M (G1)	P 17	18.83	18.15	18.33
AL (G2)	P 1	19.00	19.24	19.18
CD (G2)	P 6	19.42	18.61	18.82
SD (G2)	P 7	23.67	23.21	23.33
Ju (G2)	P 11	20.42	20.52	20.49
W (G2)	P 14	13.17	22.39	19.93
C/M (G2)	P 18	18.75	23.09	21.93
AL (G3)	P 3	21.83	18.70	19.53
CD (G3)	P 4	21.08	21.70	21.53
SD (G3)	P 9	26.25	23.58	24.29
Ju (G3)	P 12	17.92	21.15	20.29
W (G3)	P 13	15.08	22.91	20.82
C/M (G3)	P 16	14.67	21.61	19.76

Appendices 6.1F:

Table 8.F shows the value of the Total Fixation Duration during eye-tracking.

Product Identification	Female TFD	Male TFD	Whole population TFD

P 2 (G1)	7.89	7.59	7.67
P 5 (G1)	7.74	7.37	7.46
P 8 (G1)	7.80	7.63	7.68
P 10 (G1)	7.41	7.48	7.47
P 15 (G1)	7.81	7.34	7.46
P 17 (G1)	7.14	6.95	7.09
P 1 (G2)	7.93	7.69	7.75
P 6 (G2)	7.84	7.61	7.67
P 7 (G2)	7.72	7.57	7.60
P 11 (G2)	7.11	7.35	7.32
P 14 (G2)	7.78	7.34	7.45
P 18 (G2)	6.99	7.13	7.19
P 3 (G3)	7.95	7.56	7.66
P 4 (G3)	7.89	7.45	7.56
P 9 (G3)	7.67	7.39	7.48
P 12 (G3)	7.78	7.39	7.49
P 13 (G3)	7.85	7.36	7.49
P 16 (G3)	7.35	7.44	7.41

Appendices 6.1G:

Table 8.G shows the value correlation coefficient after open-ended analysis.

Product Identity (PI)	Pearson's r						
	AL	C/M	Ju	SD	W	CD	
AL (P2)	1.000						G_1
C/M (P17)	-0.305	1.000					
Ju (P10)	-0.572	0.442	1.000				
SD (P8)	-0.491	0.406	0.818	1.000			
W (P15)	-0.605	-0.070	0.823	0.772	1.000		
CD (P5)	-0.331	-0.516	-0.473	-0.550	-0.135	1.000	
Product Identity (PI)	Pearson's r						
	AL	C/M	Ju	SD	W	CD	
AL (P_1)	1.000						G_2
C/M (P_{18})	-0.280	1.000					
Ju (P_{11})	-0.514	0.498	1.000				
SD (P_7)	-0.188	0.004	0.673	1.000			
W (P_{14})	-0.429	-0.423	-0.037	-0.129	1.000		
CD (P_6)	-0.057	-0.479	-0.558	-0.315	-0.100	1.000	
Product Identity (PI)	Pearson's r						
	AL	C/M	Ju	SD	W	CD	
AL (P_3)	1.000						G_3
C/M (P_{16})	-0.296	1.000					
Ju (P_{12})	-0.280	-0.201	1.000				
SD (P_9)	-0.298	-0.078	0.864	1.000			
W (P_{13})	-0.288	-0.409	0.156	0.018	1.000		
CD (P_4)	-0.273	-0.318	-0.374	-0.381	-0.102	1.000	

Appendices 6.1.H:

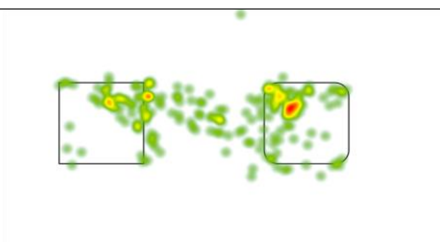
Table 6.1.H shows the value correlation coefficient after eye-tracking analysis

Product Identity (PI)	Pearson's r						
	AL	C/M	Ju	SD	W	CD	
AL (P2)	1.000						
C/M (P17)	-0.423	1.000					
Ju (P10)	-0.425	0.612	1.000				G_1
SD (P8)	-0.456	0.253	0.688	1.000			
W (P15)	-0.733	-0.006	0.122	0.236	1.000		
CD (P5)	-0.353	-0.401	-0.599	-0.474	0.435	1.000	
	AL	C/M	Ju	SD	W	CD	
AL (P_1)	1.000						
C/M (P_{18})	-0.382	1.000					
Ju (P_{11})	-0.366	0.445	1.000				G_2
SD (P_7)	-0.462	0.899	0.523	1.000			
W (P_{14})	-0.477	-0.379	-0.324	-0.311	1.000		
CD (P_6)	-0.225	-0.527	-0.243	-0.463	0.184	1.000	
	AL	C/M	Ju	SD	W	CD	
AL (P_3)	1.000						
C/M (P_{16})	-0.227	1.000					
Ju (P_{12})	-0.278	-0.305	1.000				G_3
SD (P_9)	-0.317	-0.426	0.892	1.000			
W (P_{13})	-0.396	-0.405	-0.150	0.099	1.000		
CD (P_4)	-0.143	-0.347	-0.424	-0.389	0.301	1.000	

Appendix of Chapter 6.2

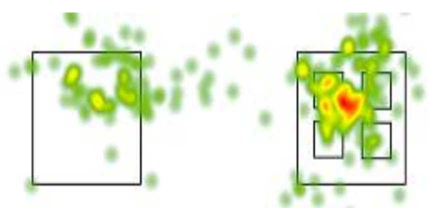
Appendix 6.2.A:

Table 6.2.A, Shows the images each stimulus which is used in Phase I study

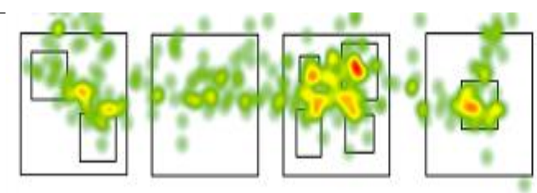


1(A) **1(B)**

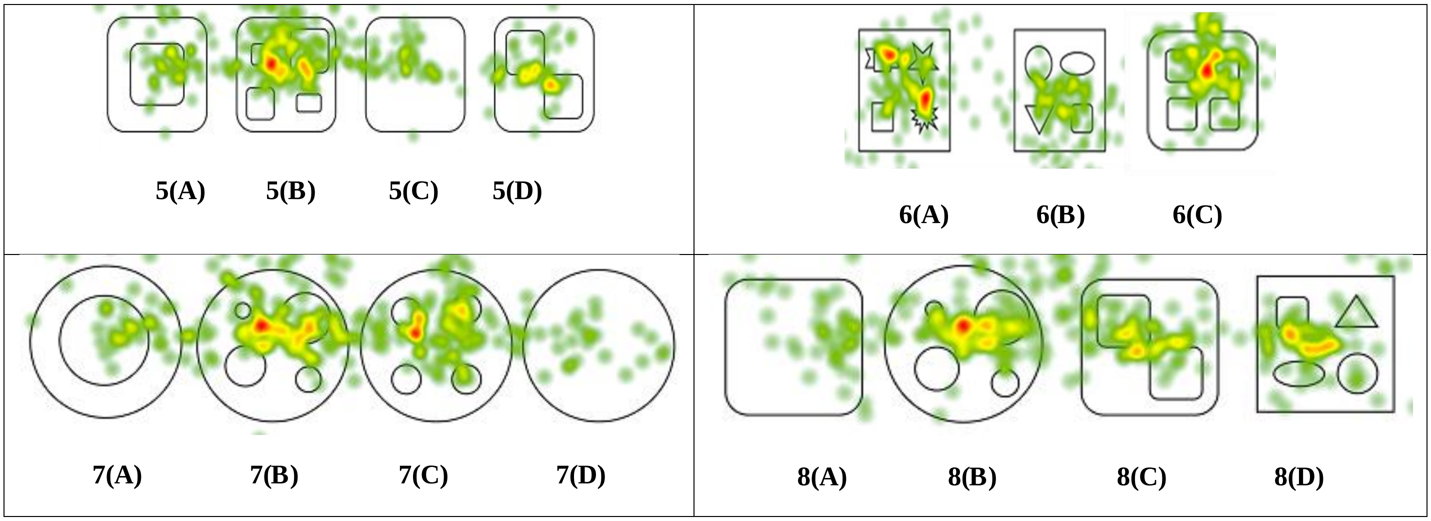
2(A) **2(B)**



3(A) **3(B)**



4(A) **4(B)** **4(C)** **4(D)**



Appendix 6.2.B: represents the rating scale for participants:

Table 6.2.B, measure the aesthetic preference for the given stimuli, please provide your kind inputs.

Please indicate your preference by ticking one circle per line for the Overall aesthetics for the image						
1	2	3	4	5	6	7
Least aesthetically pleasing	Somewhat aesthetically pleasing	Slightly aesthetically pleasing	Neither/Nor aesthetically pleasing	Slightly higher aesthetically pleasing	Somewhat highly aesthetically pleasing	Extreme most aesthetically pleasing

Appendix 6.2.C:

Table 6.2.C Lists of factors and their level

Stimuli	Camera button or switch,	Flash, and Location of Light	Lenses frame shapes and location	Lenses frame colour	Decorated line shapes	Decorated lines colours	Body shape	Body dimensions in ratios	Body colors (R, G, B)	Body elements (Grip shapes)	Grip colour	Af assist illuminated lamp and logo location and their dimensions
1	Button/Switch with sharp edges	With flash, left light	Right side of front section	Black N0	In Top of camera lense	255, 229, 29	Rectangle with sharp corner	1 : 1	232, 47, 68	square shape	Black N0	Right Side Top lamp and logo dimensions in proportion 1:1
2	Button/Switch with sharp edges	With flash, left light	Right (large)	White N10	In Top and bottom of small area	RGB 75, 224, 208	Rectangle with soft edges	1 : 1.414	146, 224, 63	Golden rectangle shape	White N10	Left Side Top lamp and logo dimensions in proportion 1:1.414
3	Button/Switch with sharp edges	With flash, left light	Centre	RGB 75, 224, 208	In top and bottom large area	White N10	Rectangle with more round or soft edges	1 : 1.618	83, 113, 232	Thin line shape	RGB 75, 224, 208	Right Side Bottom lamp and logo dimensions in proportion 1:1618
4	Button/Switch with sharp edges	With flash, left light	Centre right	146, 224, 63	Top large area	N 0	Rectangle with sharp edge hood	1 : 1.732	White N10	D shape with golden rectangle	146, 224, 63	Left side Bottom lamp and logo dimensions in proportion 1:1.732

										proportion		
5	Button/Switch with sharp edges	With flash, left light	Centre right (large)	255, 229, 29	Top and small area	146, 224, 63	Rectangle with soft round edge hood	1 : 2	Black N0	Square with one side filet	255, 229, 29	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
6	Button/Switch with sharp edges	Without flash	Right side of front section	White N10	In top and bottom large area	N 0	Rectangle with soft round edge hood	1 : 1	146, 224, 63	Thin line shape	146, 224, 63	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
7	Button/Switch with sharp edges	Without flash	Right (large)	RGB 75, 224, 208	Top large area	146, 224, 63	Rectangle with sharp corner	1 : 1.414	83, 113, 232	D shape with golden rectangle proportion	255, 229, 29	Right Side Top lamp and logo dimensions in proportion 1:1
8	Button/Switch with sharp edges	Without flash	Centre	146, 224, 63	Top and small area	255, 229, 29	Rectangle with soft edges	1 : 1.618	White N10	Square with one side filet	Black N0	Left Side Top lamp and logo dimensions in proportion 1:1.414
9	Button/Switch with sharp edges	Without flash	Centre right	255, 229, 29	In Top of camera lense	RGB 75, 224, 208	Rectangle with more round or soft edges	1 : 1.732	Black N0	square shape	White N10	Right Side Bottom lamp and logo dimensions in proportion 1:1618
10	Button/Switch with sharp edges	Without flash	Centre right (large)	Black N0	In Top and bottom of small area	White N10	Rectangle with sharp edge hood	1 : 2	232, 47, 68	Golden rectangle shape	RGB 75, 224, 208	Left side Bottom lamp and logo dimensions in proportion 1:1.732
11	Button/Switch with sharp edges	With flash, the right light	Right side of front section	RGB 75, 224, 208	Top small area	RGB 75, 224, 208	Rectangle with sharp edge hood	1 : 1.732	232, 47, 68	Thin line shape	255, 229, 29	Left Side Top lamp and logo dimensions in proportion 1:1.414
12	Button/Switch with sharp edges	With flash, the right light	Right (large)	146, 224, 63	In Top of camera lense	White N10	Rectangle with soft round edge hood	1 : 2	146, 224, 63	D shape with golden rectangle proportion	Black N0	Right Side Bottom lamp and logo dimensions in proportion 1:1618
13	Button/Switch with sharp edges	With flash, the right light	Centre	255, 229, 29	In Top and bottom of small area	N 0	Rectangle with sharp corner	1 : 1	83, 113, 232	Square with one side filet	White N10	Left side Bottom lamp and logo dimensions in proportion 1:1.732
14	Button/Switch with sharp edges	With flash, the right light	Centre right	Black N0	In top and bottom large area	146, 224, 63	Rectangle with soft edges	1 : 1.414	White N10	square shape	RGB 75, 224, 208	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
15	Button/Switch with sharp edges	With flash, the right light	Centre right (large)	White N10	Top large area	255, 229, 29	Rectangle with more round or	1 : 1.618	Black N0	Golden rectangle shape	146, 224, 63	Right Side Top lamp and logo dimensions in proportion 1:1

							soft edges					
16	Button/Switch with sharp edges	Without flash	Right side of front section	146, 224, 63	In Top and bottom of small area	146, 224, 63	Rectangle with more round or soft edges	1 : 2	83, 113, 232	square shape	146, 224, 63	Left Side Top lamp and logo dimensions in proportion 1:1.414
17	Button/Switch with sharp edges	Without flash	Right (large)	255, 229, 29	In top and bottom large area	255, 229, 29	Rectangle with sharp edge hood	1 : 1	White N10	Golden rectangle shape	255, 229, 29	Right Side Bottom lamp and logo dimensions in proportion 1:1618
18	Button/Switch with sharp edges	Without flash	Centre	Black N0	Top large area	RGB 75, 224, 208	Rectangle with soft round edge hood	1 : 1.414	Black N0	Thin line shape	Black N0	Left side Bottom lamp and logo dimensions in proportion 1:1.732
19	Button/Switch with sharp edges	Without flash	Centre right	White N10	Top and small area	White N10	Rectangle with sharp corner	1 : 1.618	232, 47, 68	D shape with golden rectangle proportion	White N10	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
20	Button/Switch with sharp edges	Without flash	Centre right (large)	RGB 75, 224, 208	In Top of camera lense	N 0	Rectangle with soft edges	1 : 1.732	146, 224, 63	Square with one side filet	RGB 75, 224, 208	Right Side Top lamp and logo dimensions in proportion 1:1
21	Button/Switch with sharp edges	With flash and the centre light	Right side of front section	255, 229, 29	Top large area	White N10	Rectangle with soft edges	1 : 1.732	83, 113, 232	Golden rectangle shape	Black N0	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
22	Button/Switch with sharp edges	With flash and the centre light	Right (large)	Black N0	Top and small area	N 0	Rectangle with more round or soft edges	1 : 2	White N10	Thin line shape	White N10	Right Side Top lamp and logo dimensions in proportion 1:1
23	Button/Switch with sharp edges	With flash and the centre light	Centre	White N10	In Top of camera lense	146, 224, 63	Rectangle with sharp edge hood	1 : 1	Black N0	D shape with golden rectangle proportion	RGB 75, 224, 208	Left Side Top lamp and logo dimensions in proportion 1:1.414
24	Button/Switch with sharp edges	With flash and the centre light	Centre right	RGB 75, 224, 208	In Top and bottom of small area	255, 229, 29	Rectangle with soft round edge hood	1 : 1.414	232, 47, 68	Square with one side filet	146, 224, 63	Right Side Bottom lamp and logo dimensions in proportion 1:1618
25	Button/Switch with sharp edges	With flash and the centre light	Centre right (large)	146, 224, 63	In top and bottom large area	RGB 75, 224, 208	Rectangle with sharp corner	1 : 1.618	146, 224, 63	square shape	255, 229, 29	Left side Bottom lamp and logo dimensions in proportion 1:1.732
26	Button/Switch with soft round edges	With flash, left light	Right side of front section	Black N0	Top large area	146, 224, 63	Rectangle with sharp	1 : 1.618	146, 224, 63	Square with one	White N10	Right Side Bottom lamp and logo dimensions in

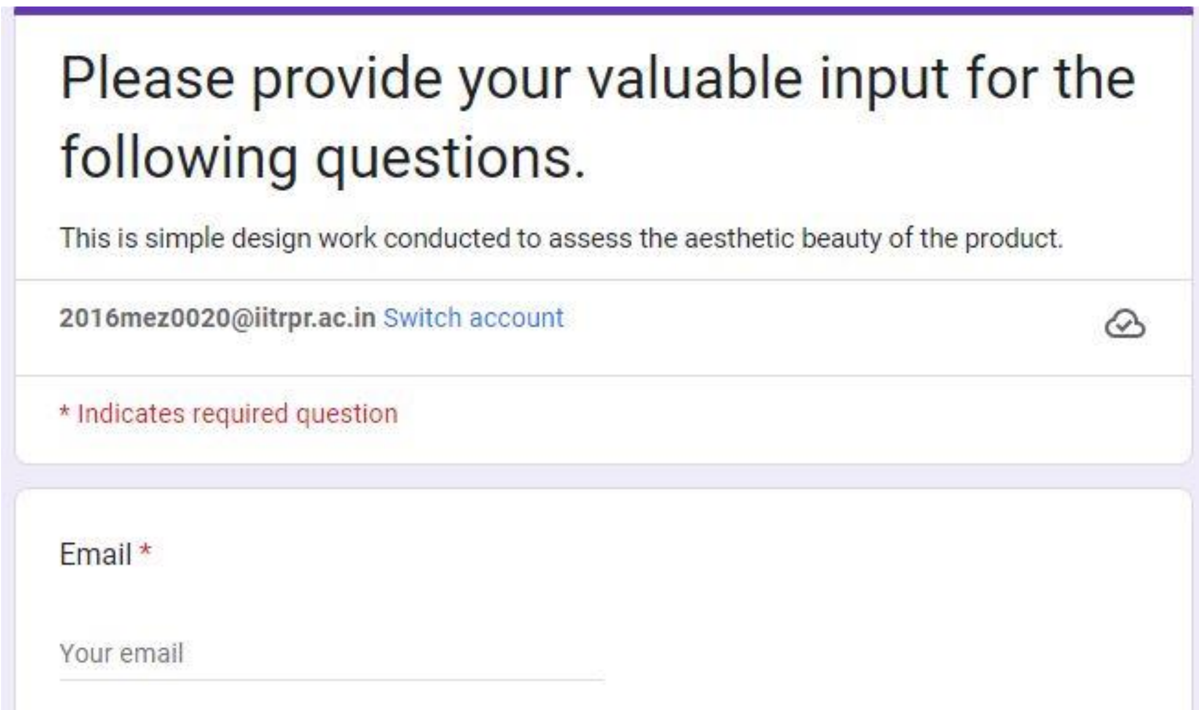
							edge hood			side filet		proportion 1:1618
27	Button/Switch with soft round edges	With flash, left light	Right (large)	White N10	Top and small area	255, 229, 29	Rectangle with soft round edge hood	1 : 1.732	83, 113, 232	square shape	RGB 75, 224, 208	Left side Bottom lamp and logo dimensions in proportion 1:1.732
28	Button/Switch with soft round edges	With flash, left light	Centre	RGB 75, 224, 208	In Top of camera lense	RGB 75, 224, 208	Rectangle with sharp corner	1 : 2	White N10	Golden rectangle shape	146, 224, 63	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
29	Button/Switch with soft round edges	With flash, left light	Centre right	146, 224, 63	In Top and bottom of small area	White N10	Rectangle with soft edges	1 : 1	Black N0	Thin line shape	255, 229, 29	Right Side Top lamp and logo dimensions in proportion 1:1
30	Button/Switch with soft round edges	With flash, left light	Centre right (large)	255, 229, 29	In top and bottom large area	N 0	Rectangle with more round or soft edges	1 : 1.414	232, 47, 68	D shape with golden rectangle proportion	Black N0	Left Side Top lamp and logo dimensions in proportion 1:1.414
31	Button/Switch with soft round edges	Without flash	Right side of front section	White N10	In Top of camera lense	White N10	Rectangle with more round or soft edges	1 : 1.414	White N10	Square with one side filet	255, 229, 29	Left side Bottom lamp and logo dimensions in proportion 1:1.732
32	Button/Switch with soft round edges	Without flash	Right (large)	RGB 75, 224, 208	In Top and bottom of small area	N 0	Rectangle with sharp edge hood	1 : 1.618	Black N0	square shape	Black N0	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
33	Button/Switch with soft round edges	Without flash	Centre	146, 224, 63	In top and bottom large area	146, 224, 63	Rectangle with soft round edge hood	1 : 1.732	232, 47, 68	Golden rectangle shape	White N10	Right Side Top lamp and logo dimensions in proportion 1:1
34	Button/Switch with soft round edges	Without flash	Centre right	255, 229, 29	Top large area	255, 229, 29	Rectangle with sharp corner	1 : 2	146, 224, 63	Thin line shape	RGB 75, 224, 208	Left Side Top lamp and logo dimensions in proportion 1:1.414
35	Button/Switch with soft round edges	Without flash	Centre right (large)	Black N0	Top and small area	RGB 75, 224, 208	Rectangle with soft edges	1 : 1	83, 113, 232	D shape with golden rectangle proportion	146, 224, 63	Right Side Bottom lamp and logo dimensions in proportion 1:1618
36	Button/Switch with soft round edges	With flash, the right light	Right side of front section	RGB 75, 224, 208	In top and bottom large area	255, 229, 29	Rectangle with soft edges	1 : 2	Black N0	D shape with golden rectangle proportion	White N10	Left side Bottom lamp and logo dimensions in proportion 1:1.732
37	Button/Switch with soft round edges	With flash, the right light	Right (large)	146, 224, 63	Top large area	RGB 75, 224, 208	Rectangle with more round or	1 : 1	232, 47, 68	Square with one	RGB 75,	Centre (Just near with camera lense) lamp and logo

							soft edges			side filet	224, 208	dimensions in proportion 1:2
38	Button/Switch with soft round edges	With flash, the right light	Centre	255, 229, 29	Top and small area	White N10	Rectangle with sharp edge hood	1 : 1.414	146, 224, 63	square shape	146, 224, 63	Right Side Top lamp and logo dimensions in proportion 1:1
39	Button/Switch with soft round edges	With flash, the right light	Centre right	Black N0	In Top of camera lense	N 0	Rectangle with soft round edge hood	1 : 1.618	83, 113, 232	Golden rectangle shape	255, 229, 29	Left Side Top lamp and logo dimensions in proportion 1:1.414
40	Button/Switch with soft round edges	With flash, the right light	Centre right (large)	White N10	In Top and bottom of small area	146, 224, 63	Rectangle with sharp corner	1 : 1.732	White N10	Thin line shape	Black N0	Right Side Bottom lamp and logo dimensions in proportion 1:1618
41	Button/Switch with soft round edges	Without flash	Right side of front section	146, 224, 63	Top and small area	N 0	Rectangle with sharp corner	1 : 1.414	Black N0	Golden rectangle shape	RGB 75, 224, 208	Right Side Bottom lamp and logo dimensions in proportion 1:1618
42	Button/Switch with soft round edges	Without flash	Right (large)	255, 229, 29	In Top of camera lense	146, 224, 63	Rectangle with soft edges	1 : 1.618	232, 47, 68	Thin line shape	146, 224, 63	Left side Bottom lamp and logo dimensions in proportion 1:1.732
43	Button/Switch with soft round edges	Without flash	Centre	Black N0	In Top and bottom of small area	255, 229, 29	Rectangle with more round or soft edges	1 : 1.732	146, 224, 63	D shape with golden rectangle proportion	255, 229, 29	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
44	Button/Switch with soft round edges	Without flash	Centre right	White N10	In top and bottom large area	RGB 75, 224, 208	Rectangle with sharp edge hood	1 : 2	83, 113, 232	Square with one side filet	Black N0	Right Side Top lamp and logo dimensions in proportion 1:1
45	Button/Switch with soft round edges	Without flash	Centre right (large)	RGB 75, 224, 208	Top large area	White N10	Rectangle with soft round edge hood	1 : 1	White N10	square shape	White N10	Left Side Top lamp and logo dimensions in proportion 1:1.414
46	Button/Switch with soft round edges	With flash and the centre light	Right side of front section	255, 229, 29	In Top and bottom of small area	RGB 75, 224, 208	Rectangle with soft round edge hood	1 : 1.618	White N10	D shape with golden rectangle proportion	RGB 75, 224, 208	Right Side Top lamp and logo dimensions in proportion 1:1
47	Button/Switch with soft round edges	With flash and the centre light	Right (large)	Black N0	In top and bottom large area	White N10	Rectangle with sharp corner	1 : 1.732	Black N0	Square with one side filet	146, 224, 63	Left Side Top lamp and logo dimensions in proportion 1:1.414
48	Button/Switch with soft round edges	With flash and the centre light	Centre	White N10	Top large area	N 0	Rectangle with soft edges	1 : 2	232, 47, 68	square shape	255, 229, 29	Right Side Bottom lamp and logo dimensions in proportion 1:1618

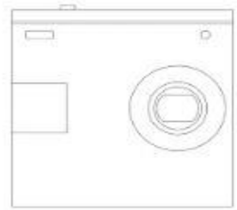
49	Button/Switch with soft round edges	With flash and the centre light	Centre right	RGB 75, 224, 208	Top and small area	146, 224, 63	Rectangle with more round or soft edges	1 : 1	146, 224, 63	Golden rectangle shape	Black N0	Left side Bottom lamp and logo dimensions in proportion 1:1.732
50	Button/Switch with soft round edges	With flash and the centre light	Centre right (large)	146, 224, 63	In Top of camera lenses	255, 229, 29	Rectangle with sharp edge hood	1 : 1.414	83, 113, 232	Thin line shape	White N10	Centre (Just near with camera lenses) lamp and logo dimensions in proportion 1:2

Appendix 6.2.D.A

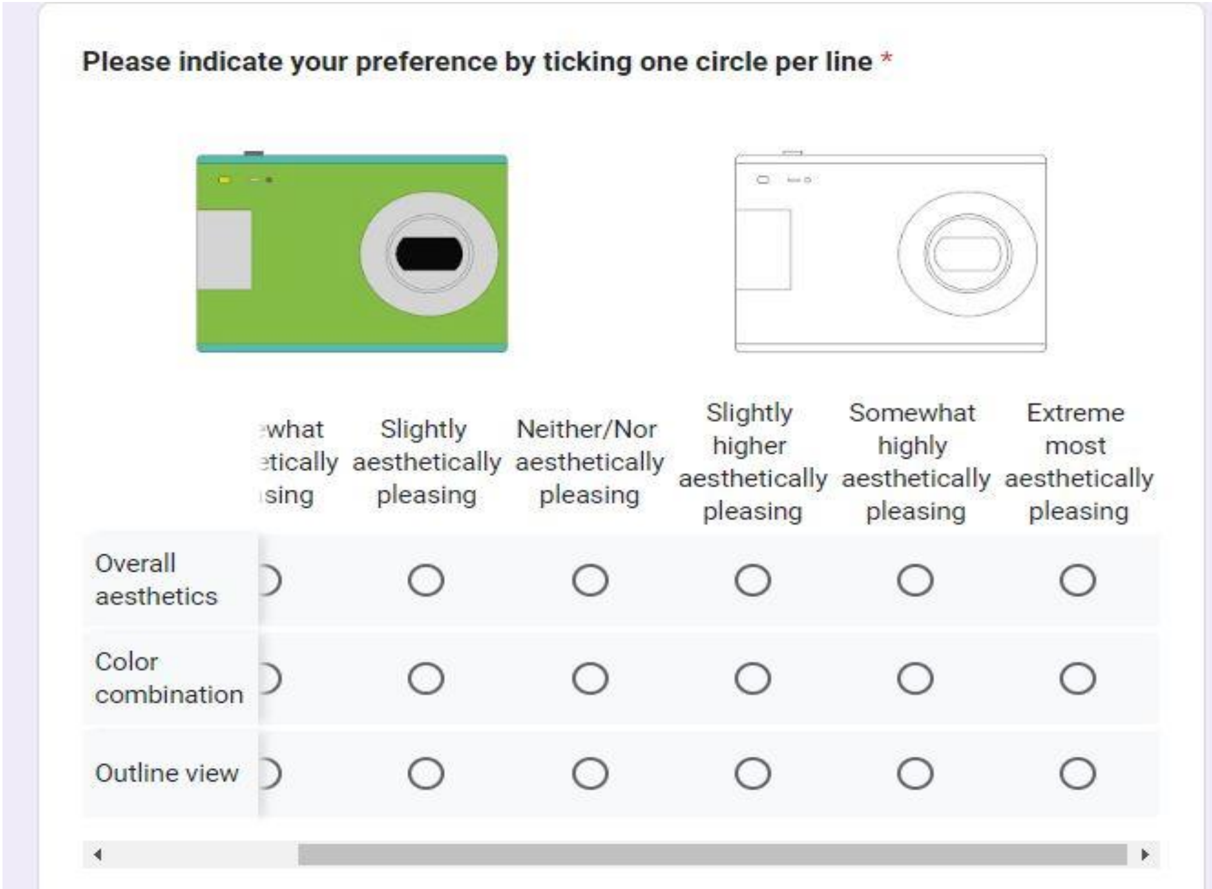
In this appendix, we shows the some design samples out of 50 design samples, which were used for eyetracking and open-ended survey for the aesthetic preference.



Please indicate your preference by ticking one circle per line



	Least thetically leasing	Somewhat aesthetically pleasing	Slightly aesthetically pleasing	Neither/Nor aesthetically pleasing	Slightly higher aesthetically pleasing	Somewh highly aesthetic pleasin
Overall aesthetics	○	○	○	○	○	○
Color combination	○	○	○	○	○	○
Outline view	○	○	○	○	○	○

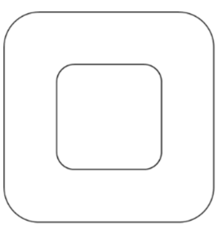


Please indicate your preference by ticking one circle per line *

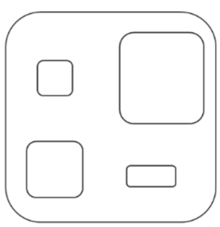
	·what ·tically ·sing	Slightly aesthetically pleasing	Neither/Nor aesthetically pleasing	Slightly higher aesthetically pleasing	Somewhat highly aesthetically pleasing	Extreme most aesthetically pleasing
Overall aesthetics	○	○	○	○	○	○
Color combination	○	○	○	○	○	○
Outline view	○	○	○	○	○	○

Appendix 6.2.D.B

In this appendix, we shows the some design samples out of 8 logical element images which were used for eyetracking and open-ended survey for the aesthetic preference.



A

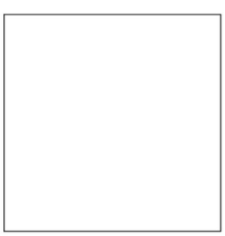


B

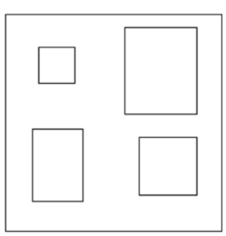
Please provide your valuable input for the following questions

Email Id…………………

Please indicate your preference by ticking one circle per line



A



B

	Least ·thetically ·leasing	Somewhat aesthetically pleasing	Slightly aesthetically pleasing	Neither/Nor aesthetically pleasing	Slightly higher aesthetically pleasing	Somewh· highly aesthetic· pleasin·
Overall aesthetics	○	○	○	○	○	○
Color combination	○	○	○	○	○	○
Outline view	○	○	○	○	○	○

Appendix 6.2.E.

Table 6.2.E: Indicate the response of participants for different stimuli's

Image	Overall aesthetics	Color combination	Outline view
1	4.14	3.93	4.86
2	4.79	4.43	4.36
3	4.64	4.71	4.57
4	4.21	4	4.14
5	3.86	2.93	4.29
6	4.36	4.29	4.36
7	4.79	4.5	4.71
8	4.71	4.64	4.79
9	4.21	4.29	4.5
10	3.57	3.21	4.21
11	4.07	3.79	4
12	3.57	3.64	3.64
13	3.36	3.57	4.14
14	3.79	3.5	3.93
15	3.71	3.29	3.71
16	4	4	4.23
17	3.46	3.38	3.77
18	4.07	3.93	4.64
19	4.29	3.71	4.57
20	4.46	4.38	4.85
21	4.69	3.85	4.62
22	5.14	4.79	5.29
23	3.07	3.36	3.57
24	4	3.57	4.14
25	3.86	3.5	4.14
26	3.57	3.14	3.86
27	4	4.07	4
28	4.21	4.36	4.21
29	3.93	3.86	4
30	3.79	3.57	4.21
31	4.79	4.86	5
32	4.93	5.21	5
33	4.29	4.29	4.43
34	4.5	4.71	4.64
35	3.86	3.57	4
36	3.57	3.21	3.86
37	3.93	4.14	3.93
38	4	3.93	4.36
39	3.5	3	4
40	4.57	4	4.5
41	4	4.29	4.29
42	3.71	3.36	3.79
43	4.29	4	4.21
44	4.14	4.07	4.29
45	3.57	3.43	3.79
46	3.93	3.71	4.21
47	3.43	3.36	4
48	4.07	3.79	4.21
49	4.57	4.29	4.79
50	4	3.71	4.21

Appendix 6.2.F

Table 6.2.F, shows the list of beauty, contrast, contrast/total time proportion, and pureness

S. No.	Pureness %	Proportion (sec^{-1})	Contrast	Contrast /Total Time	Overall aesthetics preference	Beauty
1	3.38	0.06	497.97	0.71	4.14	0.29
2	3.71	0.06	463.92	0.76	4.79	0.29
3	4.21	0.05	451.28	0.81	4.64	0.26
4	4.52	0.05	457.66	0.86	4.21	0.26
5	4.87	0.05	396.55	0.80	3.86	0.30
6	4.62	0.04	480.90	0.90	4.36	0.21
7	4.64	0.06	390.24	0.78	4.79	0.36
8	5.46	0.03	537.42	1.19	4.71	0.14
9	5.47	0.05	399.86	0.92	4.21	0.30
10	5.56	0.05	380.45	0.85	3.57	0.33
11	4.45	0.05	460.13	0.89	4.07	0.25
12	5.37	0.05	351.23	0.79	3.57	0.34
13	5.12	0.05	419.25	0.85	3.36	0.30
14	5.10	0.05	422.18	0.87	3.79	0.29
15	5.39	0.04	456.92	1.04	3.71	0.21
16	5.19	0.04	467.27	0.97	4.00	0.21
17	5.32	0.04	421.43	0.98	3.46	0.22
18	5.56	0.05	366.01	0.87	4.07	0.32
19	5.22	0.05	404.07	0.89	4.29	0.29
20	5.73	0.05	370.27	0.90	4.46	0.32
21	5.45	0.05	349.34	0.78	4.69	0.35
22	5.48	0.05	332.00	0.79	5.14	0.35
23	5.67	0.06	320.39	0.80	3.07	0.43
24	4.98	0.06	341.48	0.81	4.00	0.37
25	5.46	0.06	296.77	0.77	3.86	0.43
26	5.38	0.05	350.41	0.84	3.57	0.32
27	6.05	0.05	303.34	0.81	4.00	0.37
28	6.31	0.06	278.00	0.79	4.21	0.48
29	6.35	0.06	282.94	0.75	3.93	0.51
30	5.81	0.06	274.27	0.70	3.79	0.50
31	3.64	0.05	505.58	0.81	4.79	0.22
32	4.64	0.04	490.39	1.03	4.93	0.18
33	4.63	0.04	566.63	1.20	4.29	0.15
34	5.45	0.04	446.97	1.03	4.50	0.21
35	5.32	0.05	411.97	0.93	3.86	0.29
36	5.62	0.05	345.26	0.81	3.57	0.35
37	5.73	0.06	317.14	0.78	3.93	0.44
38	5.66	0.05	378.91	0.85	4.00	0.33
39	6.01	0.05	359.87	0.89	3.50	0.34
40	5.64	0.05	357.80	0.93	4.57	0.30
41	4.63	0.06	385.85	0.78	4.00	0.36
42	5.91	0.05	341.09	0.87	3.71	0.34
43	5.42	0.04	420.24	1.03	4.29	0.21
44	4.41	0.05	489.01	0.91	4.14	0.24
45	4.98	0.05	407.77	0.84	3.57	0.30
46	4.64	0.04	516.49	0.95	3.93	0.20
47	5.06	0.05	389.63	0.82	3.43	0.31
48	4.72	0.06	383.77	0.75	4.07	0.38
49	5.08	0.06	334.97	0.69	4.57	0.44
50	4.73	0.06	330.72	0.72	4.00	0.39

BIOGRAPHY

About the candidate (JITENDER)

Jitender is a Ph.D. candidate in the Department of Mechanical Engineering at Indian Institute of Technology Ropar, Punjab, INDIA. He is a postgraduate in Mechanical System Design from National Institute of Technology Srinagar, Jammu and Kashmir, INDIA. His research interests are primarily in the field of Product aesthetic design and development, Sustainability, Human computer Interaction, Manufacturing and Multi-Criteria Decision Making.

About the supervisor (Dr. Prabir Sarkar)

Dr. Prabir Sarkar is an Associate Professor in the Department of Mechanical Engineering at the Indian Institute of Technology Ropar. Before joining IIT Ropar, he was working as an Associate Researcher at the National Institute of Standards and Technology (NIST), U.S. Department of Commerce Gaithersburg, USA. He completed his Ph.D. from the Indian Institute of Science (IISc), Bangalore in Design Creativity. He did his Master of Design also from IISc on Product Design and Engineering. He worked for Bharat Earth Movers Limited (BEML) in the Research and Development division after completing his masters. His research group in the Design Research Laboratory and Sustainable Design and Manufacturing Laboratory are engaged in research in Ecodesign, biomimicry, engineering aesthetics, sustainable machining, and design creativity. He has authored more than 80 peer-reviewed journal and conference publications. Currently, he is also working on developing products for rural applications. He is an editorial board member of the Journal of Engineering, Design and Technology, Emerald and is a reviewer of several journals and conferences. Dr. Sarkar secured jointly funding of more than 100 crores from various external funding agencies.

APPENDIX

Appendix of Chapter 4

Appendix 4.1.A. Definition list of aesthetics with source

Defin. no.	Authors	Definition
1	(Heller, 2005)	Aesthetics: a branch of philosophy dealing with the nature of beauty, art, and taste and with the creation and appreciation of beauty.
2	(Charters, 2006)	Aesthetics: In the context of this study, we adopt a narrow definition of aesthetics in which aesthetics can be seen as a synonym for visual beauty.
3	(Bloch, 1995; Hoyer, 1984)	Aesthetics: a particular theory or conception of beauty or art: a particular taste for or approach to what is pleasing to the senses and especially sight.
4	(Benjamin, 1969)	Aesthetics' is a very old concept, rooted in the Greek word aisthesis that can be translated as understanding through sensory perception.
5	(Woodfield, 2001)	Recently, the author has argued that such a definition of aesthetics, i.e. the pleasure attained from sensory perception, is most appropriate in that it clearly separates aesthetic phenomena from other types of experience, such as the construction of meaning and emotional responses.
6	(Martin, 2003)	Aesthetic is not limited to the visual domain - The visual arts have clearly dominated Western art and, as a result, the concept of aesthetics has often been used as synonymous for visual beauty.
7	(Norman, 2002)	If we, however, agree that aesthetics refers to sensory pleasantness in general, things can also be aesthetic or pleasant to listen to, touch, smell, or taste.
8	(Guyer, 2008)	Aesthetics is broader in scope than the philosophy of art, which comprises one of its branches. It deals not only with the nature and value of the arts but also with those responses to natural objects that find expression in the language of the beautiful and the ugly.
9	(de Man, 1982)	To provide more than a general definition of the subject matter of aesthetics is immensely difficult. Indeed, it could be said that self-definition has been the major task of modern aesthetics. We are acquainted with an interesting and puzzling realm of experience: the realm of the beautiful, the ugly, the sublime, and the elegant; of taste, criticism, and fine art; and of contemplation, sensuous enjoyment, and charm.
10	(Backlund et al., 2006)	The term 'aesthetics' has a complicated history, sometimes referring to the study of beauty and taste, other times to the experience of art or, more generally, to the philosophy of art. For purposes here, 'aesthetics' will be used to refer to the philosophy of art and is therefore primarily concerned with philosophical questions associated with the arts. If so, a naturalized aesthetics is a naturalistic approach to the study of art objects, behavior, and experience.
11	(Frelund, 2018; Wilder, 2021)	In 1798, from German Ästhetisch (mid-18c.) or French esthétique (which is from German), ultimately from Greek aisthetikos "of or for perception by the senses, perceptive," of things, "perceptible," from aisthanesthai "to perceive (by the senses or by the mind), to feel," from PIE *awis-dh-yo-, from root *au- "to perceive."
12	(Mill, 1987)	Aesthetics is a philosophy that explores the intrinsic value and emotional quality of art and its creation. It is closely related to the philosophy of art, which is concerned with the nature of art and the concepts in terms of which individual works of art are interpreted and evaluated.
13	(Simpson, 2020)	Basically "aesthetics" simply means "of beauty" or "pleasing to the eye".
14	(Saito, 2015)	Aesthetics is the pleasure we derive from perceiving an object or experience through our senses. Aesthetic businesses don't just sell products and services that meet customer needs; they offer experiences that are a pleasure to buy and consume.
15	(Munro and Scruton, 1998)	Aesthetics: a branch of philosophy dealing with the nature of beauty, art, and taste and with the creation and appreciation of beauty. A branch of philosophy dealing with the nature of art and beauty.
16	(Crispin, 2012)	A particular theory or conception of beauty or art.
17	(Dorweiler, 2021)	The term "aesthetic" originated in Greek "aisthitiki" means perception through sensation. 'Aesthetic' derives from the Greek term for sensory perception, and so preserves the implication of immediacy carried by the term 'taste.' What does aesthetics mean? The root of aesthetics comes from ancient Greek: aisthetikos, pertaining to sense perception; aistheta, perceptible things; aisthenasthai, to perceive; aisthesis, sense perception. Clearly, aesthetics has to do with human perception. This meaning is clarified by considering its negation: anesthetic.
18	(Bo et al., 2018)	In Cambridge Dictionary, aesthetic is "related to the enjoyment or study of beauty", or "an aesthetical object or a work of art is one that throws great beauty".
19	(Hekkert, 2014)	In line with the original Greek meaning of the concept, I have defined "aesthetics," or an aesthetic response, as the pleasure – or displeasure – derived from sensory-motor understanding.
20	(Schnurr et al., 2017)	Aesthetic impression may be defined as the sensation that results from the perception of attractiveness (or unattractiveness) in products
21	(Johnson et al., 2014)	We often judge objects, people, and places in terms of beauty and attractiveness, as we might do when inspecting an architectural design, a home decoration, a face, an outfit of clothes, or even the layout of a document or slide presentation.

22	(Walton, 2007)	Aesthetics' is nothing but a loose term lately applied in academic circles to everything that has to do with works of art or with the sense of beauty.
23	(Faste, 1995)	An anesthetic is something that blocks sense perception and makes a person unable to feel anything. Used to diminish pain, it must also necessarily eliminate pleasure. When patients are anesthetized, all sensations are equally eliminated—they feel nothing.
24	(Crilly et al., 2004)	Crozier's "response to function", Cupchik's "cognitive/behavioural response", Lewalski's visual "Y-values" (which are "conducive to purposefulness and functionality"), Baxter's "semantic attractiveness" and Norman's "behavioural level" in design

Appendix of Chapter 5

Appendix: 5.1.A: Survey on non-visual factors of a car.

The aim of this study is to understand what nonvisual factors affect the purchase decision of a prospective buyer of a new car.

Nonvisual factors: nonvisual factors are those factors such as brand value, warranty, reliability that you can feel in your mind and influence your likeness of a car.

Kindly list down the non-visual factors that affect your decision of selecting a car purchasing. Next prioritizing these factors by putting ranking against them (1-highest, 2-next lower, etc.)

Table 5.1.A. Table for inputs from the consumers for non-visual factors

Non-visual factors		
SI.No.	Name of the factors	Rank
1		
2		
3		
4		
¦		
10		

Appendix 5.1.B:

List of all non-visual factors

Table 5.1.B. List of all non-visual factors for rank value as well as the average method

	Rank value method		**Average method**	
S. No.	**Factor**	**Subtotal of values**	**Factor**	**Average weight**
1	Average mileage/ fuel efficient	561	Average mileage/fuel efficient	8.428
2	New technology	379	New technology	5.75
3	Reliability	326	Reliability	6.833
4	Status/ Feeling of prestige	315	Status/Feeling of prestige	6
5	Quality	275	Quality	3.286
6	Design/ form*	256	Design/form*	5.286
7	Ergonomics	262	Ergonomics	4.571
8	Past experience	214	Past experience	4.571
9	Safety	163	Safety	3.625
10	New features	156	New features	3.426
11	Cost/Budget	148	Cost/Budget	1.571
12	Attention	146	Attention	3.111
13	Resale value	106	Resale value	2.25
14	Warranty	102	Warranty	1.556
15	Service center	70	Service center	1.142
16	Brand	62	Brand	0.174
17	Accomplished feeling	24	Accomplished feeling	0.571
18	Power	24	Power	1
19	Culture	10	Culture	1

20	No. of seats	9	No. of seats	0.2

Appendix 5.1.C:

Pareto exercise for nineteen non-visual factors

Table 5.1.C. Pareto exercise for finding the top non-visual factors

Sl no.	Factor	Subtotal	Cumulative	Percentage
1	Average mileage/ fuel efficient	561	561	16%
2	New technology/features	535	1096	30%
3	Reliability	326	1422	39%
4	Status/ Feeling of prestige/Materialistic	315	1737	48%
5	Quality	275	2012	56%
6	Ergonomics	262	2274	63%
7	Design/ form*	256	2530	70%
8	Past experience	214	2744	76%
9	Safety	163	2907	81%
10	Cost/Budget	148	3055	85%
11	Attention	146	3201	89%
12	Resale value	106	3307	92%
13	Warranty	102	3409	94%
14	Service center	70	3479	96%
15	Brand	62	3541	98%
16	Accomplished feeling	24	3565	99%
17	Power	24	3589	99%
18	Culture	10	3599	100%
19	No. of seats	9	3608	100%
		3608		

Appendix 5.1.D: Comparative chart for Fuzzy-AHP

Please provide your input according to the relative importance of each factor with respect to others using this scale.

Goal	Rating scale									Goal
Factor	Equally strong	Intermediate	Moderately strong	Intermediate	Strong	Intermediate	Very strong	Intermediate	Extremely strong	Factor
	1	2	3	4	5	6	7	8	9	
Reliability										Status/feeling of prestige
Reliability										Quality/ warranty
Reliability										Mileage / fuel efficient
Reliability										Unique form
Reliability										New technology/features
Reliability										Past experience
Reliability										Ergonomics
Reliability										Safety features
Status/feeling of prestige										Quality/ warranty
Status/feeling of prestige										Mileage / fuel efficient
⋮										⋮

Ergonomics										Safety features

Table 5.1.D. Fuzzy AHP factors comparison matrix for Designers (D_1)

Goal	Rating scale									Goal
Factor	Equally strong	Intermediate	Moderately strong	Intermediate	Strong	Intermediate	Very strong	Intermediate	Extremely strong	Factor
	1	2	3	4	5	6	7	8	9	
Reliability									9	Status/feeling of prestige
Reliability								8		Quality/ warranty
Reliability					5					Mileage / fuel efficient
Reliability					5					Unique form
Reliability						6				New technology/features
Reliability					5					Past experience
Reliability				4						Ergonomics
Reliability							7			Safety features
Status/feeling of prestige					5					Quality/ warranty
Status/feeling of prestige				4						Mileage / fuel efficient
⁞										⁞
Ergonomics					5					Safety features

Appendix 5.1.E: Comparative chart for Fuzzy-AHP

Table 5.1.E Fuzzy AHP factors comparison matrix for Designers (D_2)

Goal	Rating scale									Goal
Factor	Equally strong	Intermediate	Moderately strong	Intermediate	Strong	Intermediate	Very strong	Intermediate	Extremely strong	Factor
	1	2	3	4	5	6	7	8	9	
Reliability								8		Status/feeling of prestige
Reliability							7			Quality/ warranty
Reliability						6				Mileage / fuel efficient
Reliability					5					Unique form
Reliability					5					New technology/features
Reliability						6				Past experience
Reliability							7			Ergonomics
Reliability							7			Safety features
Status/feeling of prestige						6				Quality/ warranty
Status/feeling of prestige					5					Mileage / fuel efficient

¦										¦
Ergonomics						6				Safety features

Appendix of Chapter 5.2.

Jitender

Mr. Jitender is a PhD research scholar at the Department of Mechanical Engineering at Indian Institute of Technology Ropar. He completed his masters from the Department of Mechanical Engineering at National Institute of Technology, Srinagar. His research interest is in engineering aesthetics.

Appendix 5.2.A: Survey on Visual factors of a car

The aim of this study is to understand what Visual factors affect the purchase decision of a prospective buyer of a new car.

Visual factors: Visual factors are those factors such as color, design, Accessories that you can feel in your mind and influence your likeness of a car.

Kindly list down the Visual factors that affects yours decision of selecting a car purchasing. Next prioritizing these factors by putting ranking against them (1-heighest, 2-next lower, etc.)

Table 5.2.A. Table for inputs from the consumers for non-visual factors

Rank	Visual factor
1	Colour
2	Brand value/name
3	Logo
……..	…..
10	Alloy wheel

Name:	Age:
Education/occupation:	Place:
Signature:	

Appendix 5.2.B, Example of responses to the survey

Table 6.B, Table for inputs from the consumers for non-visual factors

	Participants				
Ranks	1	2	3	-------	86
Rank 1	Shape	Alloy wheel	Brand		Aerodynamic look
Rank 2	Size	Color	Design		Spoilers
Rank 3	Color	Aerodynamic look	Accessories		Alloy wheel
Rank 4	Texture	Front/ back design	Aerodynamics look		Color
Rank 5	Logo	Curves	Texture		Backside look
Rank 6	Navigation system	Height	4 wheel drive		Shape of head lamp/tail
Rank 7	Aerodynamics look	Metal finishing /Glossiness	Color		Tires design
Rank 8	Accessories	Shape of head lamp/tail	Logo		Height
Rank 9	Four wheel drive	Tires design	Shape		Metal finishing /Glossiness
Rank 10	3rd row seats	Spoilers	Size		Brand logo

Appendix 5.2.C:

Table 5.2.C, Calculation for Rank value method, average method, and calculation by using the 80/20 Rule or inverse Pareto Principle for visual factors

		Average method	Rank value method		80/20 Rule or Pareto Principle	
S.No.	Factor	Average weight	Subtotal	Total	Cumulative total	Percentage
1	Color	11.6	713	713	713	19%
2	Brand name/value	8.14	472	472	1185	32%
3	Accessories	8.14	387	387	1572	42%
4	Aerodynamic look	7	354	354	1926	51%
5	Design	6.4	271	271	2197	59%
6	4 wheel drive	4.44	266	266	2463	66%
7	Logo	4.43	253	253	2716	72%
8	GPS	5.29	249	249	2965	79%
9	3 Row seats	3.89	197	197	3162	84%
10	Texture	4	192	192	3354	89%
11	Shape	3.67	133	133	3487	93%
12	Look	2.33	80	80	3567	95%
13	Interior and exterior design	1.86	60	60	3627	97%
14	Cost	1.5	52	52	3679	98%
15	Shoulder lines	4	36	36	3715	99%
16	Design of lights	0.29	13	13	3728	99%
17	Safety	0.5	10	10	3738	100%
18	Alloy wheel	2	8	8	3746	100%
19	Steering position	0.14	5	5	3751	100%
				3751		

A total of nineteen visual factors is identified from open-ended surveys and it is shown in the second column of Table 4. Whereas, in the third column the subtotal of all the multiplications and in the fifth column the average weight of each factor is given.

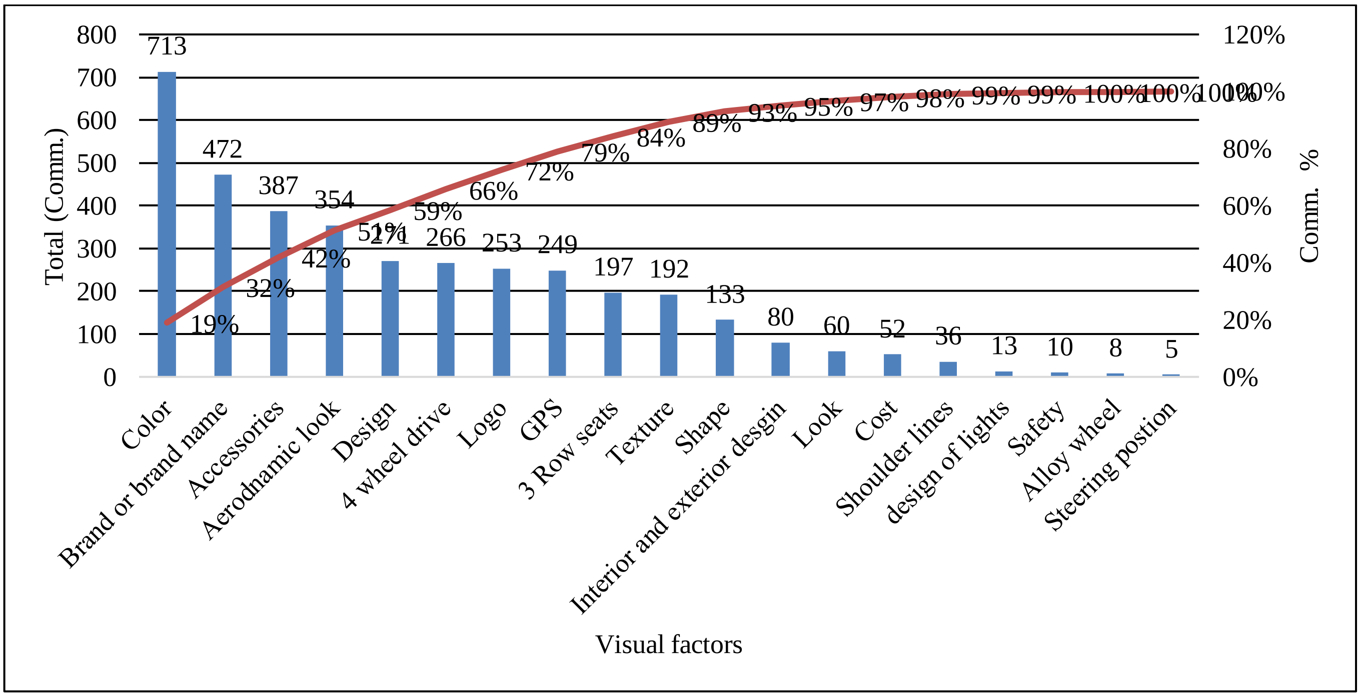


Figure 6.1 shows the total and percentage of each factor with the help of the inverse Pareto principle

Appendix 5.2.D:

Please provide your input according to the relative importance of each factor with respect to others using this scale

Goal										Goal
Factor	Equally strong	Intermed iate	Modera tely strong	Inte rme diat e	Strong	Inte rme diat e	Very strong	Inter media te	Extremel y strong	Factor
	1	2	3	4	5	6	7	8	9	
Colour										Brand

Colour										Design
Colour										Aerodynamic look
Colour										4 wheel drive
Colour										G.P.S
Colour										Logo
Colour										Accessories
Colour										3-row seats
Brand										Design
Brand										Aerodynamic look
⁞										⁞
Accessories										3-row seats

Table 5.2.D, please provide your input according to the relative importance of each factor with respect to others using this scale which is provide in Table 5.2.6 (designer input-D1)

Goal										Goal
Factor	Equally strong	Intermediate	Moderately strong	Intermed iate	Stron g	Interm ediate	Very stron g	Inter medi ate	Extremely strong	
	1	2	3	4	5	6	7	8	9	
Colour	1									Brand
Colour	1/2									Design
Colour						1/6				Aerodynamic look
Colour		2								4 wheel drive
Colour				1/4						G.P.S
Colour		2								Logo
Colour				1/4						Accessories
Colour							7			3-row seats
Brand					1/5					Design
Brand					1/5					Aerodynamic look
⁞										⁞
Accessor ies								8		3-row seats

Table 5.2.E, please provide your input according to the relative importance of each factor with respect to others using this scale which is provide in Table 5.2.6 (designer input-D2)

Goal										Goal
Factor	Equally strong	Intermediat e	Moderately strong	Intermedi ate	Strong	Interm ediate	Very stron g	Intermedi ate	Extremel y strong	Factor
	1	2	3	4	5	6	7	8	9	
Colour		1/2								Brand
Colour				1/4						Design
Colour					1.5					Aerodyna mic look
Colour						1/6				4 wheel drive
Colour						1/6				G.P.S
Colour			3							Logo
Colour			1/3							Accessorie s
Colour				4						3-row seats
Brand				4						Design
Brand			3							Aerodyna mic look
⁞										⁞
Accesso ries					5					3-row seats

Appendix of Chapter 5.3.

Appendix 5.3.A: Survey on sub-factors that affects non-visual factors of a car

This study aims to determine the sub-factors that affect a car's non-visual factors at the time of purchase. While purchasing a car, give your feedback below:

1. What do you think, which factor affects the reliability of a car?
2. Which factor will you think affects the status/feeling of the prestige of a car?
3. Which type of factors will affect the fuel efficiency/ mileage of a car?
4. Which factor do you think will affect the design or form of a car?
5. Which factor will affect the warranty/quality of a car?
6. According to you, is there any factor that affects the "New features/technologies" of a car?
7. Which factor will affect the "Safety" of a car?
8. Which factor will affect an "Ergonomics" of a car?
9. What factor will affect the past experience of a car?

Appendix 5.3.B: All the sub-factors in the sequence as received from the respondents

These tables show the list of sub-factor for each non-visual factor with respect to their respective respondents. The responses are divided into parts 1 (1-7 respondents) and Part 2 (8-15 respondents). Respondents are designated by a serial no followed by their age.

Table 5.3.B, List of sub-factor for each non-visual factor (part 1)

Non-visual factors	Sub factor of non-visual					
	R 1/ 35	R 2/29	R 3/ 30	R 4/30	R 5 /31	R 6/30	R 7/32
Reliability	Safety	Airbag, brand value, Seat locking system, brake system	Extra noise, Timely service	No extra accessories in front of the car to avoid opening the airbag	Body material, New technology	Time period for maintenance, airbag, brand value.	Safety, no failure
Ergonomics	Fuel efficiency	Seat adjustment, side mirror placement, and rare view mirror placement	Leg space, the height of the roof,	Leg space, seat adjustment.	Shockers, inside space	Price, review of other, location of the agency, space inside the car.	Seating comfort, leg space, Efficient A.c., smart features in staring wheel
Quality	driving style	Smoothness during driving, seat softness, easy	Smart technology, safety	Material, insulation.	Comfort, cost	Aerodynamic design, car design.	Look, alloy wheel, smart features, engine specification

		brake, No malfunction					, comfort level.
Feeling of status/ prestige	Comfort	Brand, Sllikiness, design, mirror of the car, color, seat cover with a white cloth, interior	Aesthetic quality, engine power, luxury	Look, comfort level, size of the car.	Design of the car, Back sensor, Power breaks	Mileage,	Unique design, New technology, comfort level
Unique form or Design	Aerodyna mics look	Sllikiness of the curve, color	Turning radius, leg space.	Ground clearance, cost, and light design.	Boots space (should be high), Attention secor	Curvy shape of light, front bonnet size (large size).	Design of head and tail light, front grill, aerodynamic look
Past experience	Safety, comfort, fuel efficiency, driving style	Brand value	New technology	Brand value,	Mileage of car, cost-effective (high features in less range)	Space, avg. of car, service quality, customer satisfaction with service staff.	Mileage, comfort level, reliability, look
New technology/fe atures	cost, eco friendly	Hidden need	ABS, Power window, Airbag	Rarer view camera, comfort level,	Engine power(cost-effective)	Safety, price.	ABS, airbag, smart features in the steering wheel, fuel-efficient
Mileage/fuel-efficient	Eco-mode drive	Weight of car, braking type, aerodynamic look	Driver driving style, eco mode drive, weight of a person with car, proper service.	Lubricant oil, power, A.C.	Weight of vehicle, ABS	Size of car, road condition, aerodynamic look, turbo system	Engine specification , aerodynamic look
Safety		Brake, airbag, tire quality, Front mirror (means super hyper phobic mirrors)	ABS, Airbag	Light std. at night time, front mirror, airbag	Airbags, cost	Airbag, locking system price, mirror braking tool provides, braking system.	Airbag, ABS, build quality.

Table 5.3.B, List of sub-factor for each non-visual factor (part 2).

Sub factor of a non-visual factor							
R 8/32	**R 9/30**	**R 10/31**	**R 11/32**	**R 12/31**	**R 13/30**	**R 14/31**	**R 15/35**
Brand value, Build quality, prize	Cost	Past experience, Review from other parodic maintenance	Fuel efficient, Build quality, Economic, Power of engine	Road quality, Shock absorber, Sensor quality, Location of service center	Brand, Public reviews, Engine	Service time period, mileage remains constant over time, Spare part is good	mileage remains constant, service period (consistent performanc e in the long run), safe
Build quality, seating place, the height of the car, space	Aesthetic s, Brand name, cost.	Space inside toward head, Height of the car from ground, i.e., ground clearance	Seat size, leg space, seat adjustment, staring adjustment, blind space, boot space.	Boot space, seat adjustment	Leg space, seat quality means cushions,	Design of seat	Ease of use
Same as reliability	Same as reliabilit y.	Reliability	Build quality, testing, cost of the car, pickup time, service time, road grip	Build quality, Material used	Build quality, material, Aerodynami c look, structure, brand name	Material, good quality accessorie s	Engine and interface

Brand value, size of car, ego.	Brand name	Brand value, Economic level.	Comfort zone, high-end features, interiors, size of a car, lighting of the car		Brand, cost, economy	Splendid aesthetics exterior and interior	Brand, good performance
How it looks from the exterior, feeling How it looks from the inside as compared to outside.	Brand value		Look aerodynamic, curves, handles, luxuries, boot shape.	Look, Shape of lights.	Height of car, Curve of car or silhouettes, color	head and taillight design, front grill design	Shape of light
No true nowadays , New brand	Features		Purpose of fulfilment, features, extra feature within range, and not paying extra accessories should be available at all places.	Space, family size, Look	Mileage, comfort zone, post-purchase service	Driving comfort, service cost, availability of parts	mileage
Range of cost.	Cost, Brand value	Economic level	Economy level.	Cost	Easy of excess, safety, Comfort zone	Cost	Smart features, cost
Nothing	Big car, big brand, luxury cars.	Cost of car, economic level.	Power increase millage decrease, size of car, aerodynamic look	Economy level.	Engine power	eco mode drive	driver driving style, maintenance of the car
5-star rating, Brand value	If the cost is high, we did not prefer that car	No factor	Build quality, two airbags, ABS, road condition, aerodynamic look.	Build quality, Shock resistance body	Build quality, interiors, bag, type of rye, high of car, efficiency,	position of seat and steering at the time of the crash, design of the tire	Crash test results

Appendix 5.3.C: Arrangement of 20×20 matrix.

Table 5.3.C List of sub-factors arranged in 20×20 matrix

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}
F_1																				
F_2																				
F_3																				
F_4																				
F_5																				
F_6																				
F_7																				
F_8																				
F_9																				
F_{10}																				
F_{11}																				
F_{12}																				
F_{13}																				
F_{14}																				
F_{15}																				

F_{16}																				
F_{17}																				
F_{18}																				
F_{19}																				
F_{20}																				

Note; F1 (Adjustable driving equipment), F2 (Aerodynamic design), F3 (ABS), F4 (Air-bags), F5 (Brand value), F6 (After-sale services), F7 (Car's build quality) , F8 (Comfortable seat design), F9 (Car cost), F10 (Design/looks of the car), F11 (Design of front grill & bonnet), F12 (Design of headlights), F13 (Eco-mode feature), F14 (Engine performance), F15 (Ground clearance), F16 (Car inside space), F17 (New accessories/feature), F18 (Reliability), F19 (Safety of the car), F20 (Weight of the car).

Appendix 5.3.D: Initial matrix

Table 5.3.D, Initial matrix from experts/professionals

	F_1	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**	**F_8**	**F_9**	**F_{10}**	**F_{11}**	**F_{12}**	**F_{13}**	**F_{14}**	**F_{15}**	**F_{16}**	**F_{17}**	**F_{18}**	**F_{19}**	**F_{20}**
F_1	0	1	1	0	3	1	1	4	3	2	0	0	0	0	0	2	2	2	4	2
F_2	0	0	0	0	1	0	1	1	2	3	2	1	0	0	1	1	1	0	2	1
F_3	0	0	0	0	4	0	1	0	2	0	0	0	0	0	0	1	1	1	4	1
F_4	0	0	0	0	4	1	0	2	4	0	0	0	0	0	0	0	1	2	4	1
F_5	3	1	4	4	0	1	3	3	2	4	3	3	4	3	1	3	4	4	4	1
F_6	1	0	0	1	1	0	2	0	2	0	0	0	0	0	0	1	1	1	3	0
F_7	1	1	1	0	3	2	0	2	3	3	3	3	0	0	1	3	2	4	4	4
F_8	4	1	0	2	3	0	2	0	3	1	1	1	1	0	1	3	3	2	2	1
F_9	3	2	2	4	2	2	3	3	0	3	3	3	3	4	1	4	4	4	4	2
F_{10}	2	2	0	0	4	0	3	1	3	0	4	4	0	0	1	3	2	1	1	1
F_{11}	0	2	0	0	3	0	3	1	3	4	0	1	0	0	0	0	0	3	3	2
F_{12}	0	1	0	0	3	0	3	1	3	4	1	0	0	0	0	0	0	1	0	1
F_{13}	0	0	0	0	4	0	0	1	3	0	0	0	0	4	0	0	2	0	0	0
F_{14}	0	0	0	0	3	0	0	0	4	0	0	0	4	0	0	0	1	1	1	1
F_{15}	0	1	0	0	1	0	1	1	1	1	0	0	0	0	0	1	0	2	2	2
F_{16}	2	1	1	0	3	1	3	3	4	3	0	0	0	0	1	0	1	1	1	1
F_{17}	2	1	1	1	4	1	2	3	4	2	0	0	2	1	0	1	0	1	4	1
F_{18}	2	0	1	2	4	1	4	2	4	1	3	1	0	1	2	1	1	0	4	2
F_{19}	4	2	4	4	4	3	4	3	4	1	3	0	0	1	2	1	4	4	0	2
F_{20}	2	1	1	1	1	0	4	1	3	1	2	1	0	1	2	1	1	2	2	0

Appendix of Chapter 6

Appendices 6.1.A:

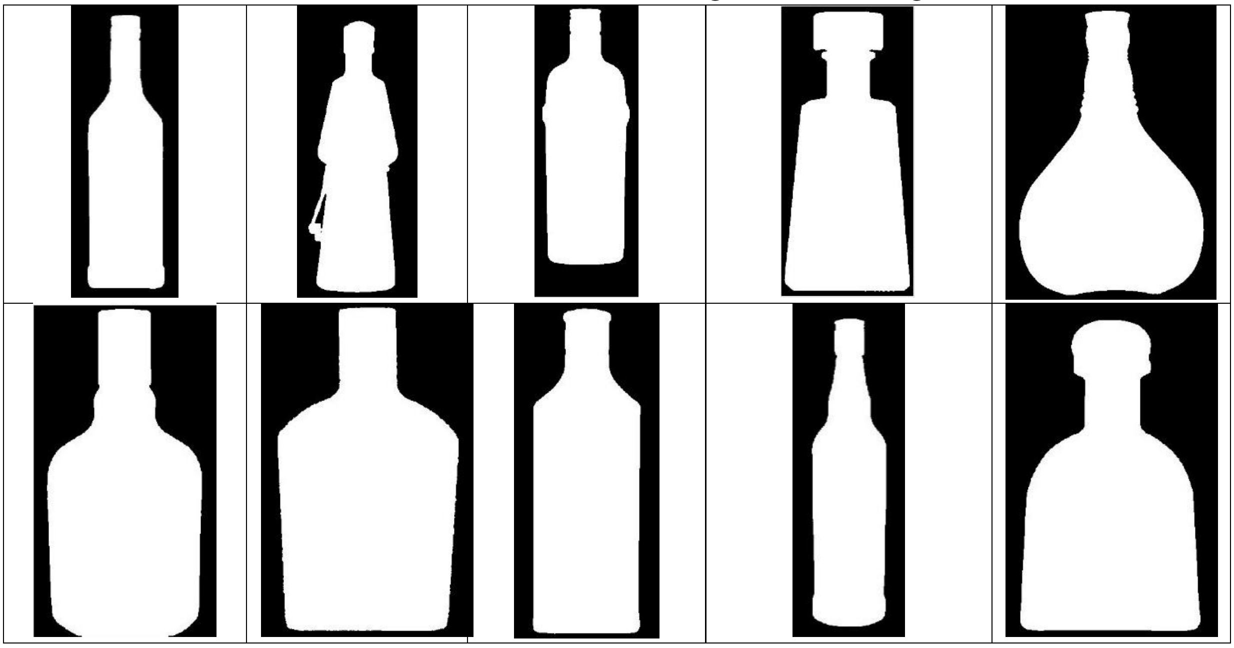
Table 6.1.A lists all the downloaded images downloaded from the PNGWING website.

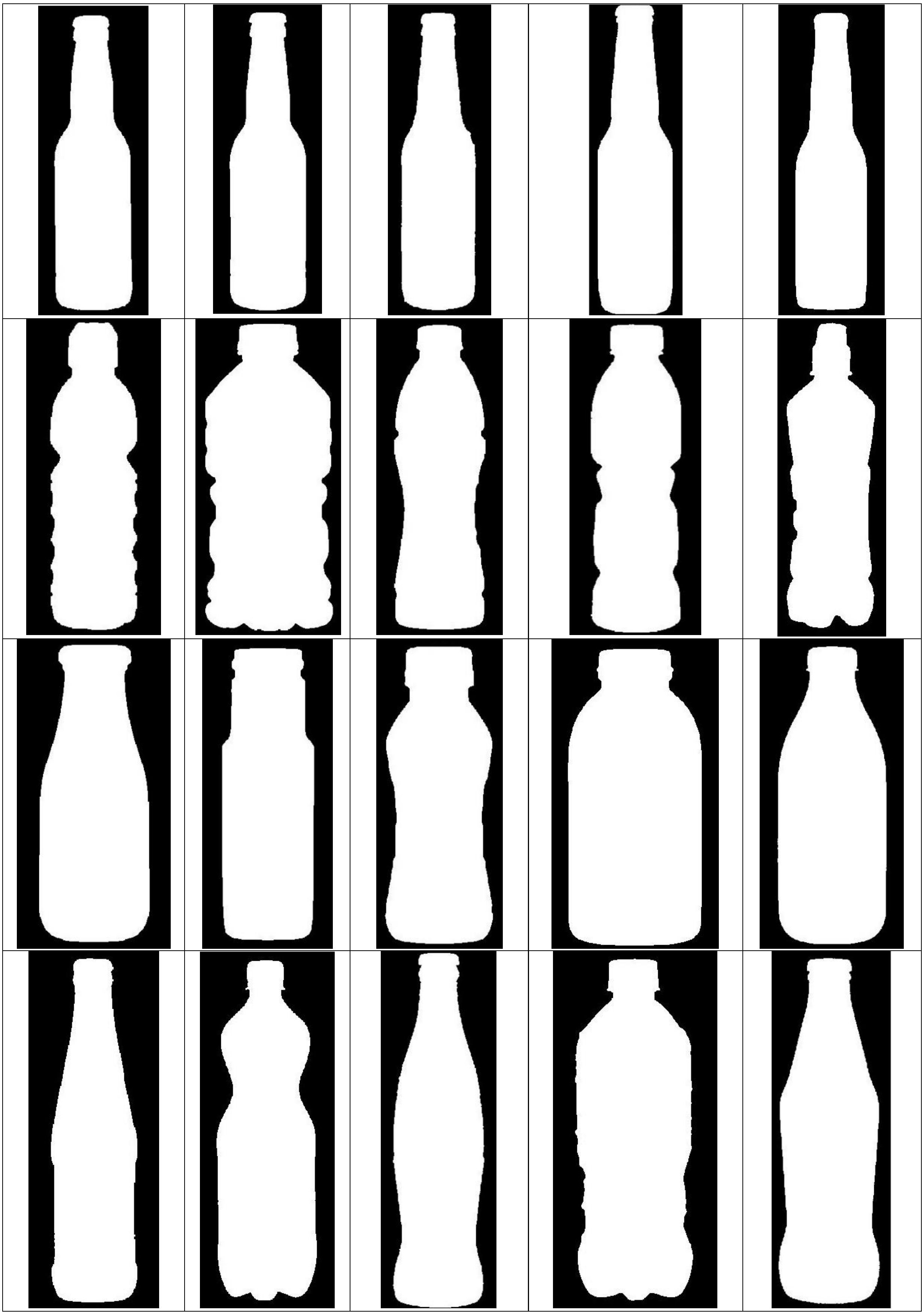
				

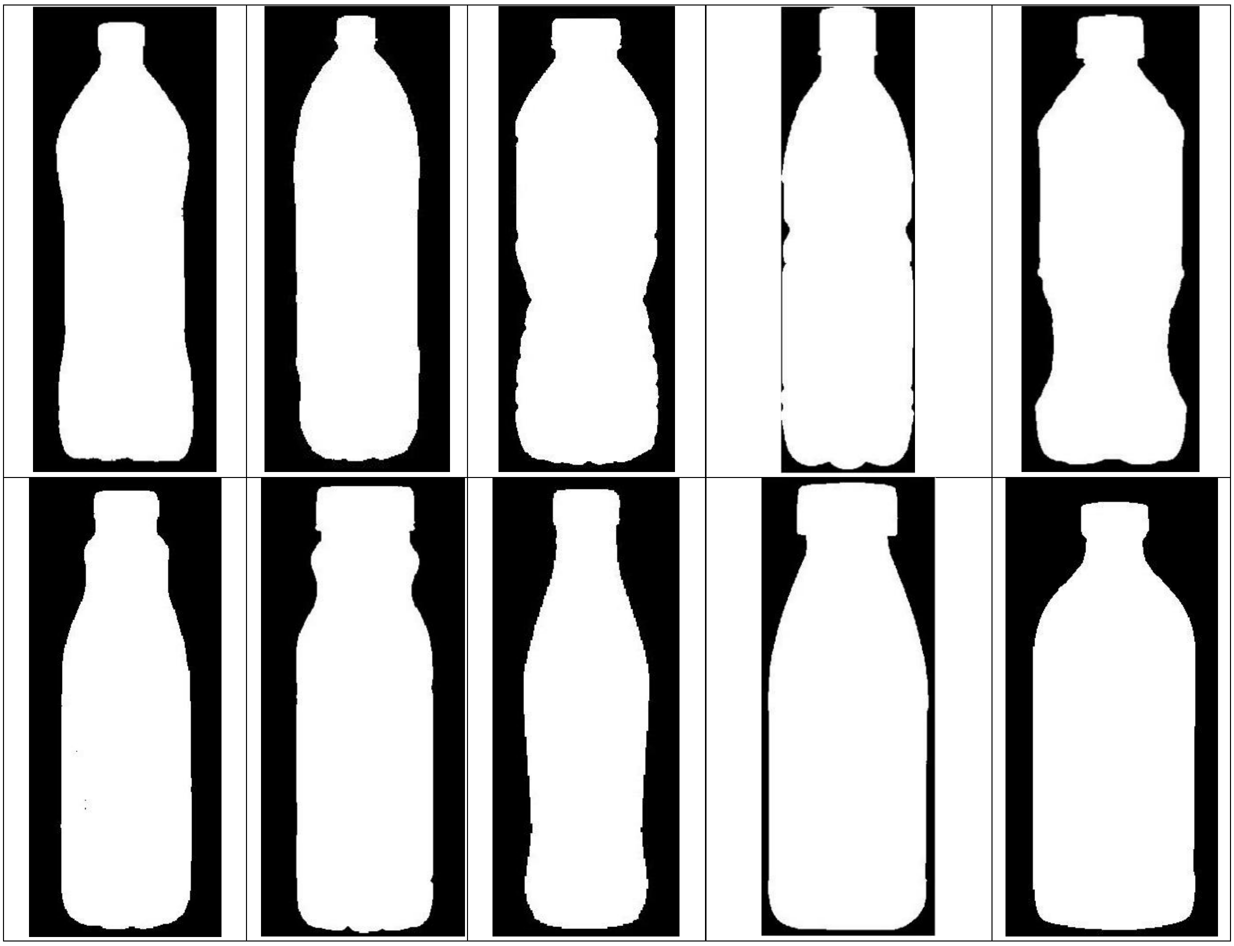

Grand Old Parr
GENTLEMAN JACK
BOMBAY SAPPHIRE
Dewar's White Label
DonJulio
Bud
STRONGBOW
Corona Extra
POWER ADE
GATORADE
Vanilla
frappuccino
250ml
COLD & CRAFTED
DOUBLESHOT
COFFEE SMOOTHIE
STARBUCKS COLD BREW COFFEE
Fanta
Coca-Cola
pepsi
Sprite

Appendices 6.1.B:

Table 6.1.B shows the list of all the silhouette images collected through MATLAB.







Appendices 6.1.C:

The questionnaire for the design survey is given below.

Out of the following options, fill your choice by mentioning the category of each bottle for the respective images in the answer section.

1. Carbonated drink or soft drink (Mountain dew/Coca-Cola/Pepsi) bottle
2. Juice bottle
3. Energy or Sports drink (Sports/Gatorade/Power) bottle
4. Alcohol (wine/Vodka/ beer) bottle
5. Coffee & Milk (Amul/Starbucks/Shatto milk) bottle
6. Water bottle (Biseleri, Aquafina, Kingfisher)

Appendices 6.1.D:

Table 6.1.D shows the value of pupil diameter size of a human being during the eye-tracking experiment

Product Identification	Whole population pupil diameter	Female pupil diameter	Male pupil diameter
P 2 (G1)	3.06	2.991	3.083
P 5 (G1)	2.91	2.960	2.954
P 8 (G1)	2.87	2.902	2.954
P 10 (G1)	2.93	2.968	2.963
P 15 (G1)	2.90	2.939	2.937
P 17 (G1)	2.87	2.923	2.901
P 1 (G2)	3.06	3.014	3.075
P 6 (G2)	2.95	2.940	3.007
P 7 (G2)	2.93	2.947	2.980
P 11 (G2)	2.91	2.939	2.952
P 14 (G2)	2.89	2.954	2.922
P 18 (G2)	2.89	2.934	2.927

P 3 (G3)	3.04	2.978	3.058
P 4 (G3)	2.97	2.982	3.024
P 9 (G3)	2.90	2.890	2.962
P 12 (G3)	2.85	2.920	2.927
P 13 (G3)	2.89	2.905	2.933
P 16 (G3)	2.90	2.934	2.942

Appendices 6.1E:

Table **6.1E** shows the value of the fixation count of a human being during the eye-tracking.

Product Identification		Female fixation count	Male fixation count	Whole (total) population fixation count
AL (G1)	P 2	20.17	19.24	19.49
CD (G1)	P 5	17.67	20.24	19.56
SD (G1)	P 8	25.00	21.85	22.69
Ju (G1)	P 10	24.50	22.55	23.07
W (G1)	P 15	14.42	20.39	18.80
C/M (G1)	P 17	18.83	18.15	18.33
AL (G2)	P 1	19.00	19.24	19.18
CD (G2)	P 6	19.42	18.61	18.82
SD (G2)	P 7	23.67	23.21	23.33
Ju (G2)	P 11	20.42	20.52	20.49
W (G2)	P 14	13.17	22.39	19.93
C/M (G2)	P 18	18.75	23.09	21.93
AL (G3)	P 3	21.83	18.70	19.53
CD (G3)	P 4	21.08	21.70	21.53
SD (G3)	P 9	26.25	23.58	24.29
Ju (G3)	P 12	17.92	21.15	20.29
W (G3)	P 13	15.08	22.91	20.82
C/M (G3)	P 16	14.67	21.61	19.76

Appendices 6.1F:

Table 8.F shows the value of the Total Fixation Duration during eye-tracking.

Product Identification	Female TFD	Male TFD	Whole population TFD
P 2 (G1)	7.89	7.59	7.67
P 5 (G1)	7.74	7.37	7.46
P 8 (G1)	7.80	7.63	7.68
P 10 (G1)	7.41	7.48	7.47
P 15 (G1)	7.81	7.34	7.46
P 17 (G1)	7.14	6.95	7.09
P 1 (G2)	7.93	7.69	7.75
P 6 (G2)	7.84	7.61	7.67
P 7 (G2)	7.72	7.57	7.60
P 11 (G2)	7.11	7.35	7.32
P 14 (G2)	7.78	7.34	7.45
P 18 (G2)	6.99	7.13	7.19
P 3 (G3)	7.95	7.56	7.66
P 4 (G3)	7.89	7.45	7.56
P 9 (G3)	7.67	7.39	7.48
P 12 (G3)	7.78	7.39	7.49
P 13 (G3)	7.85	7.36	7.49
P 16 (G3)	7.35	7.44	7.41

Appendices 6.1G:

Table 8.G shows the value correlation coefficient after open-ended analysis.

Product Identity (PI)	Pearson's r						
	AL	C/M	Ju	SD	W	CD	

AL (P2)	1.000						G1
C/M (P17)	-0.305	1.000					
Ju (P10)	-0.572	0.442	1.000				
SD (P8)	-0.491	0.406	0.818	1.000			
W (P15)	-0.605	-0.070	0.823	0.772	1.000		
CD (P5)	-0.331	-0.516	-0.473	-0.550	-0.135	1.000	
Product Identity (PI)	Pearson's r						G2
	AL	C/M	Ju	SD	W	CD	
AL (P_1)	1.000						
C/M (P_{18})	-0.280	1.000					
Ju (P_{11})	-0.514	0.498	1.000				
SD (P_7)	-0.188	0.004	0.673	1.000			
W (P_{14})	-0.429	-0.423	-0.037	-0.129	1.000		
CD (P_6)	-0.057	-0.479	-0.558	-0.315	-0.100	1.000	
Product Identity (PI)	Pearson's r						G3
	AL	C/M	Ju	SD	W	CD	
AL (P_3)	1.000						
C/M (P_{16})	-0.296	1.000					
Ju (P_{12})	-0.280	-0.201	1.000				
SD (P_9)	-0.298	-0.078	0.864	1.000			
W (P_{13})	-0.288	-0.409	0.156	0.018	1.000		
CD (P_4)	-0.273	-0.318	-0.374	-0.381	-0.102	1.000	

Appendices 6.1.H:

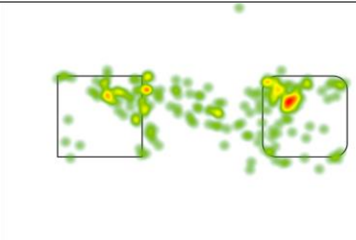
Table 6.1.H shows the value correlation coefficient after eye-tracking analysis

Product Identity (PI)	Pearson's r						
	AL	C/M	Ju	SD	W	CD	
AL (P2)	1.000						G1
C/M (P17)	-0.423	1.000					
Ju (P10)	-0.425	0.612	1.000				
SD (P8)	-0.456	0.253	0.688	1.000			
W (P15)	-0.733	-0.006	0.122	0.236	1.000		
CD (P5)	-0.353	-0.401	-0.599	-0.474	0.435	1.000	
	AL	C/M	Ju	SD	W	CD	G2
AL (P_1)	1.000						
C/M (P_{18})	-0.382	1.000					
Ju (P_{11})	-0.366	0.445	1.000				
SD (P_7)	-0.462	0.899	0.523	1.000			
W (P_{14})	-0.477	-0.379	-0.324	-0.311	1.000		
CD (P_6)	-0.225	-0.527	-0.243	-0.463	0.184	1.000	
	AL	C/M	Ju	SD	W	CD	G3
AL (P_3)	1.000						
C/M (P_{16})	-0.227	1.000					
Ju (P_{12})	-0.278	-0.305	1.000				
SD (P_9)	-0.317	-0.426	0.892	1.000			
W (P_{13})	-0.396	-0.405	-0.150	0.099	1.000		
CD (P_4)	-0.143	-0.347	-0.424	-0.389	0.301	1.000	

Appendix of Chapter 6.2

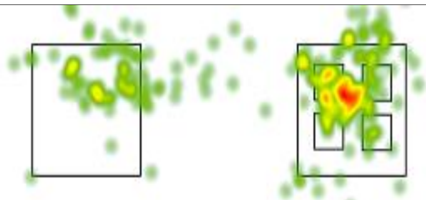
Appendix 6.2.A:

Table 6.2.A, Shows the images each stimulus which is used in Phase I study



1(A) 1(B)

2(A) 2(B)

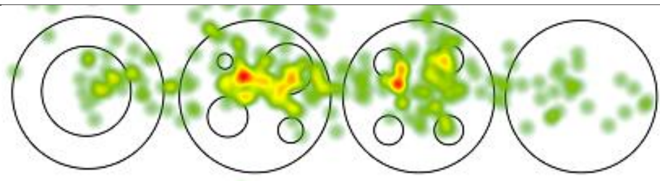


3(A) 3(B)

4(A) 4(B) 4(C) 4(D)

5(A) 5(B) 5(C) 5(D)

6(A) 6(B) 6(C)



7(A) 7(B) 7(C) 7(D)

8(A) 8(B) 8(C) 8(D)

Appendix 6.2.B: represents the rating scale for participants:

Table 6.2.B, measure the aesthetic preference for the given stimuli, please provide your kind inputs.

Please indicate your preference by ticking one circle per line for the Overall aesthetics for the image						
1	2	3	4	5	6	7
Least aesthetically pleasing	Somewhat aesthetically pleasing	Slightly aesthetically pleasing	Neither/Nor aesthetically pleasing	Slightly higher aesthetically pleasing	Somewhat highly aesthetically pleasing	Extreme most aesthetically pleasing

Appendix 6.2.C:

Table 6.2.C Lists of factors and their level

Stimuli	Camera button or switch,	Flash, and Location of Light	Lenses frame shapes and location	Lenses frame colour	Decorated line shapes	Decorated lines colours	Body shape	Body dimensions in ratios	Body colors (R, G, B)	Body elements (Grip shapes)	Grip colour	Af assist illuminated lamp and logo location and their dimensions
1	Button/Switch with sharp edges	With flash, left light	Right side of front section	Black N0	In Top of camera lense	255, 229, 29	Rectangle with sharp corner	1 : 1	232, 47, 68	square shape	Black N0	Right Side Top lamp and logo dimensions in proportion 1:1

2	Button/Switch with sharp edges	With flash, left light	Right (large)	White N10	In Top and bottom of small area	RGB 75, 224, 208	Rectangle with soft edges	1 : 1.414	146, 224, 63	Golden rectangle shape	White N10	Left Side Top lamp and logo dimensions in proportion 1:1.414
3	Button/Switch with sharp edges	With flash, left light	Centre	RGB 75, 224, 208	In top and bottom large area	White N10	Rectangle with more round or soft edges	1 : 1.618	83, 113, 232	Thin line shape	RGB 75, 224, 208	Right Side Bottom lamp and logo dimensions in proportion 1:1618
4	Button/Switch with sharp edges	With flash, left light	Centre right	146, 224, 63	Top large area	N 0	Rectangle with sharp edge hood	1 : 1.732	White N10	D shape with golden rectangle proportion	146, 224, 63	Left side Bottom lamp and logo dimensions in proportion 1:1.732
5	Button/Switch with sharp edges	With flash, left light	Centre right (large)	255, 229, 29	Top and small area	146, 224, 63	Rectangle with soft round edge hood	1 : 2	Black N0	Square with one side filet	255, 229, 29	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
6	Button/Switch with sharp edges	Without flash	Right side of front section	White N10	In top and bottom large area	N 0	Rectangle with soft round edge hood	1 : 1	146, 224, 63	Thin line shape	146, 224, 63	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
7	Button/Switch with sharp edges	Without flash	Right (large)	RGB 75, 224, 208	Top large area	146, 224, 63	Rectangle with sharp corner	1 : 1.414	83, 113, 232	D shape with golden rectangle proportion	255, 229, 29	Right Side Top lamp and logo dimensions in proportion 1:1
8	Button/Switch with sharp edges	Without flash	Centre	146, 224, 63	Top and small area	255, 229, 29	Rectangle with soft edges	1 : 1.618	White N10	Square with one side filet	Black N0	Left Side Top lamp and logo dimensions in proportion 1:1.414
9	Button/Switch with sharp edges	Without flash	Centre right	255, 229, 29	In Top of camera lense	RGB 75, 224, 208	Rectangle with more round or soft edges	1 : 1.732	Black N0	square shape	White N10	Right Side Bottom lamp and logo dimensions in proportion 1:1618
10	Button/Switch with sharp edges	Without flash	Centre right (large)	Black N0	In Top and bottom of small area	White N10	Rectangle with sharp edge hood	1 : 2	232, 47, 68	Golden rectangle shape	RGB 75, 224, 208	Left side Bottom lamp and logo dimensions in proportion 1:1.732
11	Button/Switch with sharp edges	With flash, the right light	Right side of front section	RGB 75, 224, 208	Top small area	RGB 75, 224, 208	Rectangle with sharp edge hood	1 : 1.732	232, 47, 68	Thin line shape	255, 229, 29	Left Side Top lamp and logo dimensions in proportion 1:1.414
12	Button/Switch with sharp edges	With flash, the right light	Right (large)	146, 224, 63	In Top of camera lense	White N10	Rectangle with soft round edge hood	1 : 2	146, 224, 63	D shape with golden rectangle proportion	Black N0	Right Side Bottom lamp and logo dimensions in proportion 1:1618
13	Button/Switch with sharp edges	With flash, the right light	Centre	255, 229, 29	In Top and bottom of small area	N 0	Rectangle with sharp corner	1 : 1	83, 113, 232	Square with one side filet	White N10	Left side Bottom lamp and logo dimensions in proportion 1:1.732

14	Button/Switch with sharp edges	With flash, the right light	Centre right	Black N0	In top and bottom large area	146, 224, 63	Rectangle with soft edges	1 : 1.414	White N10	square shape	RGB 75, 224, 208	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
15	Button/Switch with sharp edges	With flash, the right light	Centre right (large)	White N10	Top large area	255, 229, 29	Rectangle with more round or soft edges	1 : 1.618	Black N0	Golden rectangle shape	146, 224, 63	Right Side Top lamp and logo dimensions in proportion 1:1
16	Button/Switch with sharp edges	Without flash	Right side of front section	146, 224, 63	In Top and bottom of small area	146, 224, 63	Rectangle with more round or soft edges	1 : 2	83, 113, 232	square shape	146, 224, 63	Left Side Top lamp and logo dimensions in proportion 1:1.414
17	Button/Switch with sharp edges	Without flash	Right (large)	255, 229, 29	In top and bottom large area	255, 229, 29	Rectangle with sharp edge hood	1 : 1	White N10	Golden rectangle shape	255, 229, 29	Right Side Bottom lamp and logo dimensions in proportion 1:1618
18	Button/Switch with sharp edges	Without flash	Centre	Black N0	Top large area	RGB 75, 224, 208	Rectangle with soft round edge hood	1 : 1.414	Black N0	Thin line shape	Black N0	Left side Bottom lamp and logo dimensions in proportion 1:1.732
19	Button/Switch with sharp edges	Without flash	Centre right	White N10	Top and small area	White N10	Rectangle with sharp corner	1 : 1.618	232, 47, 68	D shape with golden rectangle proportion	White N10	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
20	Button/Switch with sharp edges	Without flash	Centre right (large)	RGB 75, 224, 208	In Top of camera lense	N 0	Rectangle with soft edges	1 : 1.732	146, 224, 63	Square with one side filet	RGB 75, 224, 208	Right Side Top lamp and logo dimensions in proportion 1:1
21	Button/Switch with sharp edges	With flash and the centre light	Right side of front section	255, 229, 29	Top large area	White N10	Rectangle with soft edges	1 : 1.732	83, 113, 232	Golden rectangle shape	Black N0	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
22	Button/Switch with sharp edges	With flash and the centre light	Right (large)	Black N0	Top and small area	N 0	Rectangle with more round or soft edges	1 : 2	White N10	Thin line shape	White N10	Right Side Top lamp and logo dimensions in proportion 1:1
23	Button/Switch with sharp edges	With flash and the centre light	Centre	White N10	In Top of camera lense	146, 224, 63	Rectangle with sharp edge hood	1 : 1	Black N0	D shape with golden rectangle proportion	RGB 75, 224, 208	Left Side Top lamp and logo dimensions in proportion 1:1.414
24	Button/Switch with sharp edges	With flash and the centre light	Centre right	RGB 75, 224, 208	In Top and bottom of small area	255, 229, 29	Rectangle with soft round edge hood	1 : 1.414	232, 47, 68	Square with one side filet	146, 224, 63	Right Side Bottom lamp and logo dimensions in proportion 1:1618
25	Button/Switch with sharp edges	With flash and the centre light	Centre right (large)	146, 224, 63	In top and bottom large area	RGB 75, 224, 208	Rectangle with sharp corner	1 : 1.618	146, 224, 63	square shape	255, 229, 29	Left side Bottom lamp and logo dimensions in proportion 1:1.732

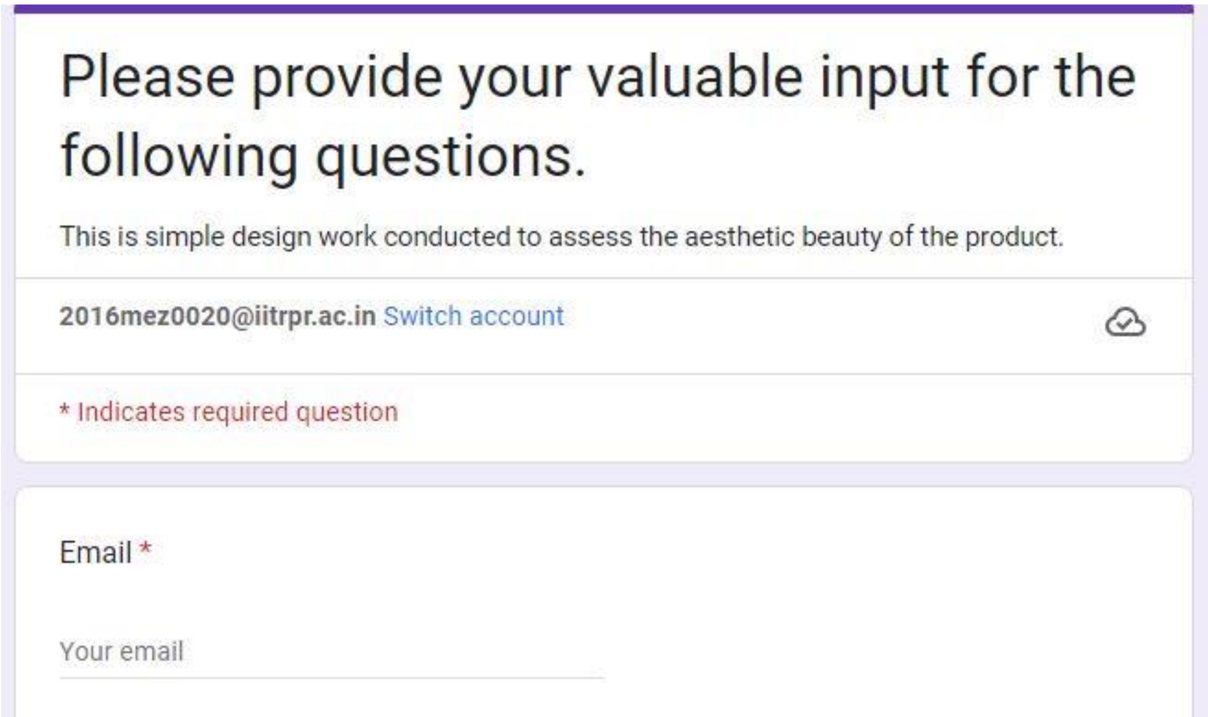
26	Button/Switch with soft round edges	With flash, left light	Right side of front section	Black N0	Top large area	146, 224, 63	Rectangle with sharp edge hood	1 : 1.618	146, 224, 63	Square with one side filet	White N10	Right Side Bottom lamp and logo dimensions in proportion 1:1618
27	Button/Switch with soft round edges	With flash, left light	Right (large)	White N10	Top and small area	255, 229, 29	Rectangle with soft round edge hood	1 : 1.732	83, 113, 232	square shape	RGB 75, 224, 208	Left side Bottom lamp and logo dimensions in proportion 1:1.732
28	Button/Switch with soft round edges	With flash, left light	Centre	RGB 75, 224, 208	In Top of camera lense	RGB 75, 224, 208	Rectangle with sharp corner	1 : 2	White N10	Golden rectangle shape	146, 224, 63	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
29	Button/Switch with soft round edges	With flash, left light	Centre right	146, 224, 63	In Top and bottom of small area	White N10	Rectangle with soft edges	1 : 1	Black N0	Thin line shape	255, 229, 29	Right Side Top lamp and logo dimensions in proportion 1:1
30	Button/Switch with soft round edges	With flash, left light	Centre right (large)	255, 229, 29	In top and bottom large area	N 0	Rectangle with more round or soft edges	1 : 1.414	232, 47, 68	D shape with golden rectangle proportion	Black N0	Left Side Top lamp and logo dimensions in proportion 1:1.414
31	Button/Switch with soft round edges	Without flash	Right side of front section	White N10	In Top of camera lense	White N10	Rectangle with more round or soft edges	1 : 1.414	White N10	Square with one side filet	255, 229, 29	Left side Bottom lamp and logo dimensions in proportion 1:1.732
32	Button/Switch with soft round edges	Without flash	Right (large)	RGB 75, 224, 208	In Top and bottom of small area	N 0	Rectangle with sharp edge hood	1 : 1.618	Black N0	square shape	Black N0	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
33	Button/Switch with soft round edges	Without flash	Centre	146, 224, 63	In top and bottom large area	146, 224, 63	Rectangle with soft round edge hood	1 : 1.732	232, 47, 68	Golden rectangle shape	White N10	Right Side Top lamp and logo dimensions in proportion 1:1
34	Button/Switch with soft round edges	Without flash	Centre right	255, 229, 29	Top large area	255, 229, 29	Rectangle with sharp corner	1 : 2	146, 224, 63	Thin line shape	RGB 75, 224, 208	Left Side Top lamp and logo dimensions in proportion 1:1.414
35	Button/Switch with soft round edges	Without flash	Centre right (large)	Black N0	Top and small area	RGB 75, 224, 208	Rectangle with soft edges	1 : 1	83, 113, 232	D shape with golden rectangle proportion	146, 224, 63	Right Side Bottom lamp and logo dimensions in proportion 1:1618
36	Button/Switch with soft round edges	With flash, the right light	Right side of front section	RGB 75, 224, 208	In top and bottom large area	255, 229, 29	Rectangle with soft edges	1 : 2	Black N0	D shape with golden rectangle proportion	White N10	Left side Bottom lamp and logo dimensions in proportion 1:1.732
37	Button/Switch with soft round edges	With flash, the right light	Right (large)	146, 224, 63	Top large area	RGB 75, 224, 208	Rectangle with more round or soft edges	1 : 1	232, 47, 68	Square with one side filet	RGB 75, 224, 208	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2

38	Button/Switch with soft round edges	With flash, the right light	Centre	255, 229, 29	Top and small area	White N10	Rectangle with sharp edge hood	1 : 1.414	146, 224, 63	square shape	146, 224, 63	Right Side Top lamp and logo dimensions in proportion 1:1
39	Button/Switch with soft round edges	With flash, the right light	Centre right	Black N0	In Top of camera lense	N 0	Rectangle with soft round edge hood	1 : 1.618	83, 113, 232	Golden rectangle shape	255, 229, 29	Left Side Top lamp and logo dimensions in proportion 1:1.414
40	Button/Switch with soft round edges	With flash, the right light	Centre right (large)	White N10	In Top and bottom of small area	146, 224, 63	Rectangle with sharp corner	1 : 1.732	White N10	Thin line shape	Black N0	Right Side Bottom lamp and logo dimensions in proportion 1:1618
41	Button/Switch with soft round edges	Without flash	Right side of front section	146, 224, 63	Top and small area	N 0	Rectangle with sharp corner	1 : 1.414	Black N0	Golden rectangle shape	RGB 75, 224, 208	Right Side Bottom lamp and logo dimensions in proportion 1:1618
42	Button/Switch with soft round edges	Without flash	Right (large)	255, 229, 29	In Top of camera lense	146, 224, 63	Rectangle with soft edges	1 : 1.618	232, 47, 68	Thin line shape	146, 224, 63	Left side Bottom lamp and logo dimensions in proportion 1:1.732
43	Button/Switch with soft round edges	Without flash	Centre	Black N0	In Top and bottom of small area	255, 229, 29	Rectangle with more round or soft edges	1 : 1.732	146, 224, 63	D shape with golden rectangle proportion	255, 229, 29	Centre (Just near with camera lense) lamp and logo dimensions in proportion 1:2
44	Button/Switch with soft round edges	Without flash	Centre right	White N10	In top and bottom large area	RGB 75, 224, 208	Rectangle with sharp edge hood	1 : 2	83, 113, 232	Square with one side filet	Black N0	Right Side Top lamp and logo dimensions in proportion 1:1
45	Button/Switch with soft round edges	Without flash	Centre right (large)	RGB 75, 224, 208	Top large area	White N10	Rectangle with soft round edge hood	1 : 1	White N10	square shape	White N10	Left Side Top lamp and logo dimensions in proportion 1:1.414
46	Button/Switch with soft round edges	With flash and the centre light	Right side of front section	255, 229, 29	In Top and bottom of small area	RGB 75, 224, 208	Rectangle with soft round edge hood	1 : 1.618	White N10	D shape with golden rectangle proportion	RGB 75, 224, 208	Right Side Top lamp and logo dimensions in proportion 1:1
47	Button/Switch with soft round edges	With flash and the centre light	Right (large)	Black N0	In top and bottom large area	White N10	Rectangle with sharp corner	1 : 1.732	Black N0	Square with one side filet	146, 224, 63	Left Side Top lamp and logo dimensions in proportion 1:1.414
48	Button/Switch with soft round edges	With flash and the centre light	Centre	White N10	Top large area	N 0	Rectangle with soft edges	1 : 2	232, 47, 68	square shape	255, 229, 29	Right Side Bottom lamp and logo dimensions in proportion 1:1618
49	Button/Switch with soft round edges	With flash and the centre light	Centre right	RGB 75, 224, 208	Top and small area	146, 224, 63	Rectangle with more round or soft edges	1 : 1	146, 224, 63	Golden rectangle shape	Black N0	Left side Bottom lamp and logo dimensions in proportion 1:1.732
50	Button/Switch with soft round edges	With flash and the	Centre right (large)	146, 224, 63	In Top of camera lenses	255, 229, 29	Rectangle with sharp	1 : 1.414	83, 113, 232	Thin line shape	White N10	Centre (Just near with camera lenses) lamp and logo

		centre light					edge hood					dimensions in proportion 1:2

Appendix 6.2.D.A

In this appendix, we shows the some design samples out of 50 design samples, which were used for eyetracking and open-ended survey for the aesthetic preference.



Please provide your valuable input for the following questions.

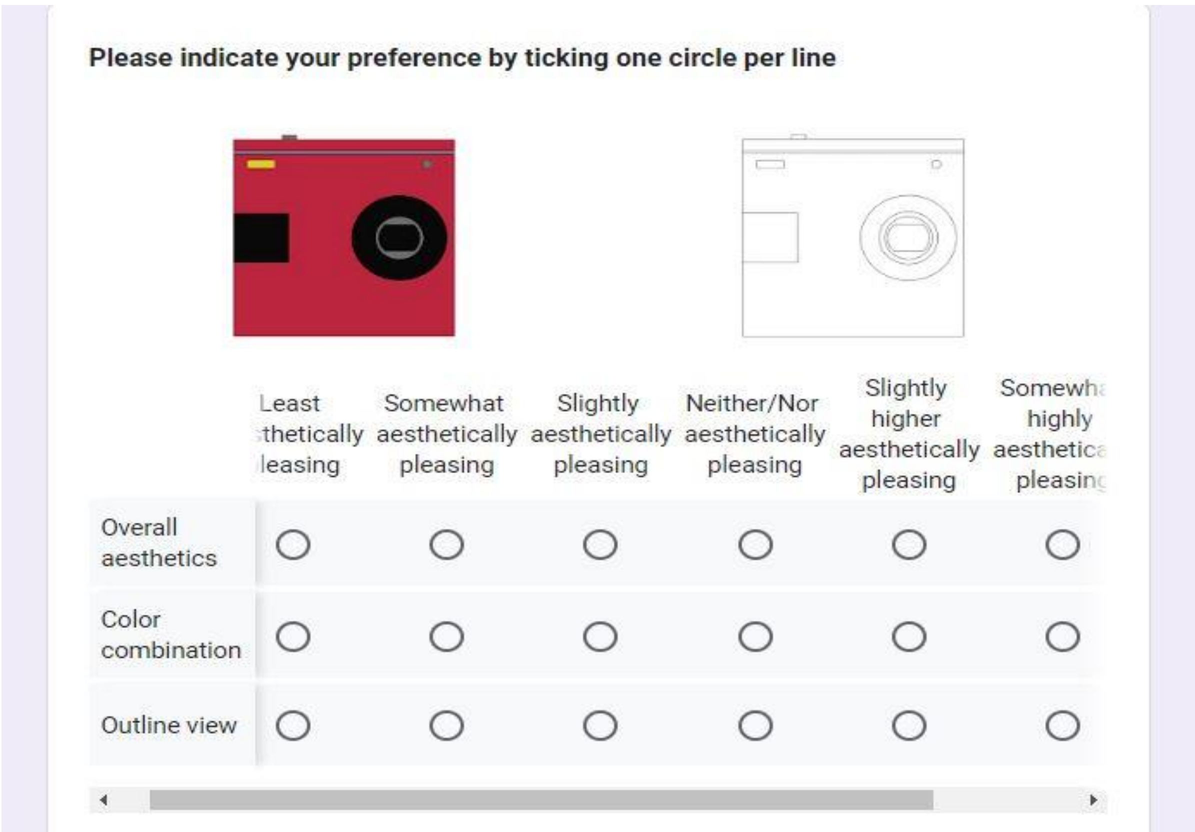
This is simple design work conducted to assess the aesthetic beauty of the product.

2016mez0020@iitrpr.ac.in Switch account

* Indicates required question

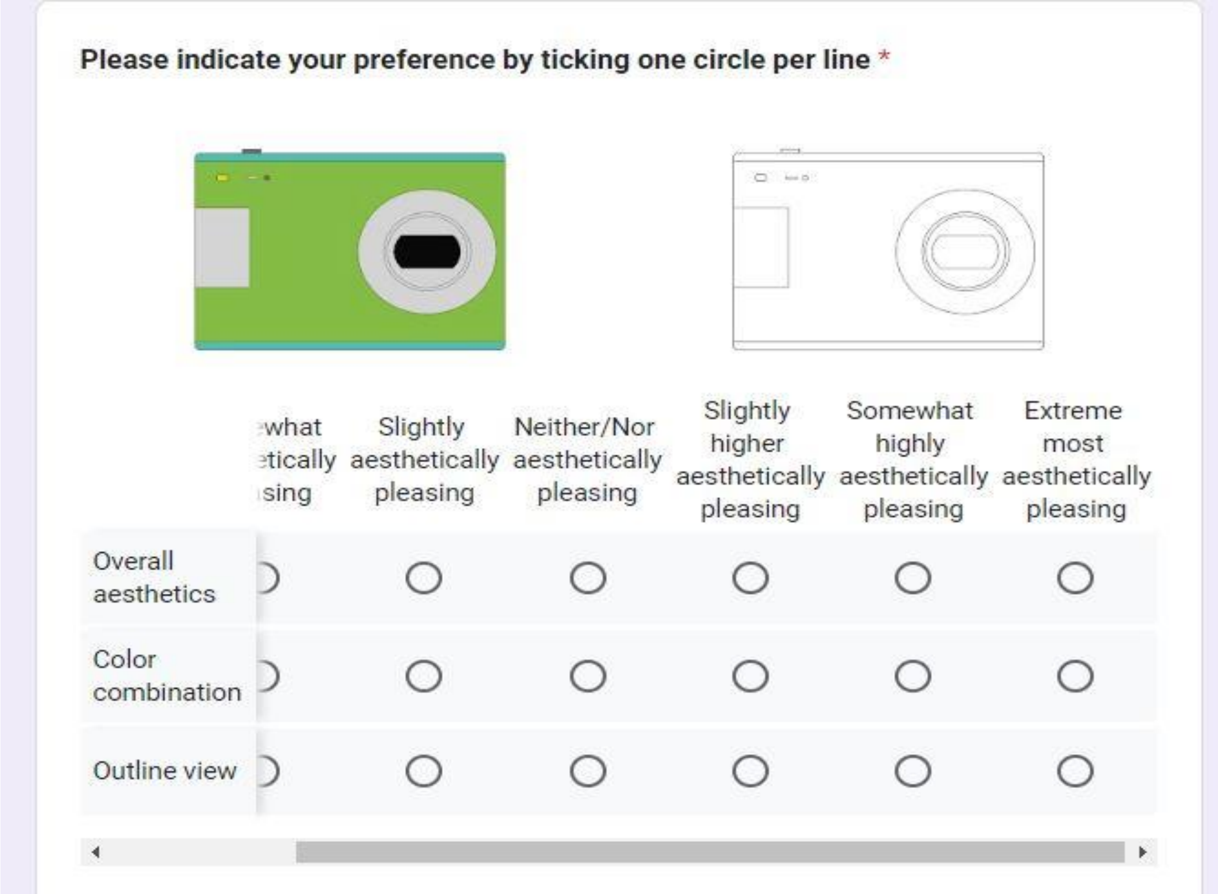
Email *

Your email



Please indicate your preference by ticking one circle per line

	Least aesthetically pleasing	Somewhat aesthetically pleasing	Slightly aesthetically pleasing	Neither/Nor aesthetically pleasing	Slightly higher aesthetically pleasing	Somewhat highly aesthetically pleasing
Overall aesthetics	○	○	○	○	○	○
Color combination	○	○	○	○	○	○
Outline view	○	○	○	○	○	○

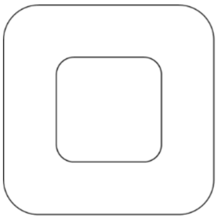


Please indicate your preference by ticking one circle per line *

	…what …tically …sing	Slightly aesthetically pleasing	Neither/Nor aesthetically pleasing	Slightly higher aesthetically pleasing	Somewhat highly aesthetically pleasing	Extreme most aesthetically pleasing
Overall aesthetics	○	○	○	○	○	○
Color combination	○	○	○	○	○	○
Outline view	○	○	○	○	○	○

Appendix 6.2.D.B

In this appendix, we shows the some design samples out of 8 logical element images which were used for eyetracking and open-ended survey for the aesthetic preference.



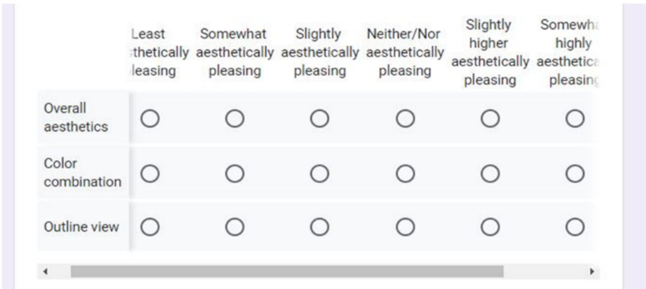
A

B

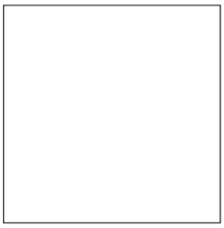
Please provide your valuable input for the following questions

Email Id…………………

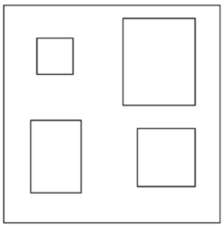
Please indicate your preference by ticking one circle per line



	Least …thetically …leasing	Somewhat aesthetically pleasing	Slightly aesthetically pleasing	Neither/Nor aesthetically pleasing	Slightly higher aesthetically pleasing	Somewh… highly aesthetic… pleasin…
Overall aesthetics	○	○	○	○	○	○
Color combination	○	○	○	○	○	○
Outline view	○	○	○	○	○	○



A



B

Appendix 6.2.E.

Table 6.2.E: Indicate the response of participants for different stimuli's

Image	Overall aesthetics	Color combination	Outline view
1	4.14	3.93	4.86
2	4.79	4.43	4.36
3	4.64	4.71	4.57

4	4.21	4	4.14
5	3.86	2.93	4.29
6	4.36	4.29	4.36
7	4.79	4.5	4.71
8	4.71	4.64	4.79
9	4.21	4.29	4.5
10	3.57	3.21	4.21
11	4.07	3.79	4
12	3.57	3.64	3.64
13	3.36	3.57	4.14
14	3.79	3.5	3.93
15	3.71	3.29	3.71
16	4	4	4.23
17	3.46	3.38	3.77
18	4.07	3.93	4.64
19	4.29	3.71	4.57
20	4.46	4.38	4.85
21	4.69	3.85	4.62
22	5.14	4.79	5.29
23	3.07	3.36	3.57
24	4	3.57	4.14
25	3.86	3.5	4.14
26	3.57	3.14	3.86
27	4	4.07	4
28	4.21	4.36	4.21
29	3.93	3.86	4
30	3.79	3.57	4.21
31	4.79	4.86	5
32	4.93	5.21	5
33	4.29	4.29	4.43
34	4.5	4.71	4.64
35	3.86	3.57	4
36	3.57	3.21	3.86
37	3.93	4.14	3.93
38	4	3.93	4.36
39	3.5	3	4
40	4.57	4	4.5
41	4	4.29	4.29
42	3.71	3.36	3.79
43	4.29	4	4.21
44	4.14	4.07	4.29
45	3.57	3.43	3.79
46	3.93	3.71	4.21
47	3.43	3.36	4
48	4.07	3.79	4.21
49	4.57	4.29	4.79
50	4	3.71	4.21

Appendix 6.2.F

Table 6.2.F, shows the list of beauty, contrast, contrast/total time proportion, and pureness

S. No.	Pureness %	Proportion (sec^{-1})	Contrast	Contrast /Total Time	Overall aesthetics preference	Beauty
1	3.38	0.06	497.97	0.71	4.14	0.29
2	3.71	0.06	463.92	0.76	4.79	0.29
3	4.21	0.05	451.28	0.81	4.64	0.26
4	4.52	0.05	457.66	0.86	4.21	0.26
5	4.87	0.05	396.55	0.80	3.86	0.30
6	4.62	0.04	480.90	0.90	4.36	0.21
7	4.64	0.06	390.24	0.78	4.79	0.36
8	5.46	0.03	537.42	1.19	4.71	0.14
9	5.47	0.05	399.86	0.92	4.21	0.30
10	5.56	0.05	380.45	0.85	3.57	0.33
11	4.45	0.05	460.13	0.89	4.07	0.25

12	5.37	0.05	351.23	0.79	3.57	0.34
13	5.12	0.05	419.25	0.85	3.36	0.30
14	5.10	0.05	422.18	0.87	3.79	0.29
15	5.39	0.04	456.92	1.04	3.71	0.21
16	5.19	0.04	467.27	0.97	4.00	0.21
17	5.32	0.04	421.43	0.98	3.46	0.22
18	5.56	0.05	366.01	0.87	4.07	0.32
19	5.22	0.05	404.07	0.89	4.29	0.29
20	5.73	0.05	370.27	0.90	4.46	0.32
21	5.45	0.05	349.34	0.78	4.69	0.35
22	5.48	0.05	332.00	0.79	5.14	0.35
23	5.67	0.06	320.39	0.80	3.07	0.43
24	4.98	0.06	341.48	0.81	4.00	0.37
25	5.46	0.06	296.77	0.77	3.86	0.43
26	5.38	0.05	350.41	0.84	3.57	0.32
27	6.05	0.05	303.34	0.81	4.00	0.37
28	6.31	0.06	278.00	0.79	4.21	0.48
29	6.35	0.06	282.94	0.75	3.93	0.51
30	5.81	0.06	274.27	0.70	3.79	0.50
31	3.64	0.05	505.58	0.81	4.79	0.22
32	4.64	0.04	490.39	1.03	4.93	0.18
33	4.63	0.04	566.63	1.20	4.29	0.15
34	5.45	0.04	446.97	1.03	4.50	0.21
35	5.32	0.05	411.97	0.93	3.86	0.29
36	5.62	0.05	345.26	0.81	3.57	0.35
37	5.73	0.06	317.14	0.78	3.93	0.44
38	5.66	0.05	378.91	0.85	4.00	0.33
39	6.01	0.05	359.87	0.89	3.50	0.34
40	5.64	0.05	357.80	0.93	4.57	0.30
41	4.63	0.06	385.85	0.78	4.00	0.36
42	5.91	0.05	341.09	0.87	3.71	0.34
43	5.42	0.04	420.24	1.03	4.29	0.21
44	4.41	0.05	489.01	0.91	4.14	0.24
45	4.98	0.05	407.77	0.84	3.57	0.30
46	4.64	0.04	516.49	0.95	3.93	0.20
47	5.06	0.05	389.63	0.82	3.43	0.31
48	4.72	0.06	383.77	0.75	4.07	0.38
49	5.08	0.06	334.97	0.69	4.57	0.44
50	4.73	0.06	330.72	0.72	4.00	0.39

BIOGRAPHY

About the candidate (JITENDER)

Jitender is a Ph.D. candidate in the Department of Mechanical Engineering at Indian Institute of Technology Ropar, Punjab, INDIA. He is a postgraduate in Mechanical System Design from National Institute of Technology Srinagar, Jammu and Kashmir, INDIA. His research interests are primarily in the field of Product aesthetic design and development, Sustainability, Human computer Interaction, Manufacturing and Multi-Criteria Decision Making.

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Dr. Prabir Sarkar is an Associate Professor in the Department of Mechanical Engineering at the Indian Institute of Technology Ropar. Before joining IIT Ropar, he was working as an Associate Researcher at the National Institute of Standards and Technology (NIST), U.S. Department of Commerce Gaithersburg, USA. He completed his Ph.D. from the Indian Institute of Science (IISc), Bangalore in Design Creativity. He did his Master of Design also from IISc on Product Design and Engineering. He worked for Bharat Earth Movers Limited (BEML) in the Research and Development division after completing his masters. His research group in the Design Research Laboratory and Sustainable Design and Manufacturing Laboratory are engaged in research in Ecodesign, biomimicry, engineering aesthetics, sustainable machining, and design creativity. He has authored more than 80 peer-reviewed journal and conference publications. Currently, he is also working on developing products for rural applications. He is an editorial board member of the Journal of Engineering, Design and Technology, Emerald and is a reviewer of several journals and conferences. Dr. Sarkar secured jointly funding of more than 100 crores from various external funding agencies.