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COMPUTATIONAL OPTIMIZATION AND COMPREHENSIVE ANALYSIS OF SUBWAY INTERIOR DESIGN AND USER PERCEPTION

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Research Paper

Abstract: *As urbanization has developed, the relationship between interior design and user perception in subways has also become a key issue in urban rail transit systems. This paper elaborates on the complexity of train interior design within a subway as related to user perception and defines the necessity of optimization methods, decision support systems, and simulation tools for such a kind of problem. The main purpose of this research is to use quantitative research methods: a fuzzy logic analysis when used together with computer simulation, to determine the relationship between elements in a subway interior and the impressions of users. This study will clarify factors affecting passenger comfort, such as seating design, lighting, and colour schemes, by implementing fuzzy logic. In order to check user perception about subway design, sixty samples were drawn. Key findings indicate that designed seating, in terms of ergonomics, has a significant impact on improving passenger comfort and safety, while adequate space, high-quality materials, and good lighting distribution all dramatically improve passenger comfort and safety. In addition, beautiful interior design and cleanliness somehow positively affect passenger satisfaction. The model and the methodology proposed in this study bring in invaluable insights regarding the removal of biases that could obscure users' perception and thus materialize in a practical way to derive clues for designing subway interiors that suit users' emotions. This, therefore, proves that it is necessary to take into consideration passenger preferences so as to enhance travel experiences and benefit which accrues from the travel.*

Keywords: *Subway Interior Design, User Perception, Travel Experience, Emotional Needs, Relationship between Design and Perception*

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1. Introduction

With the continuous springing up of new cities in China, there has been a fast transformation in living standards. The modern urban landscapes are dominated by features of dense spatial compactness, economic interconnectivity, and high rates of population mobility. These changes have then transformed urban environment and lifestyles into densely populated cities where functionality and connectivity become very important (Angel et al., 2012). However, rapid urbanization and growth in privately owned cars have increased road traffic density and aggravated the situation of environmental pollution. The growing traffic is not only time-consuming but also greatly responsible for air pollution, thus demanding immediate measures towards the sustainability of city transports (Jiang, 2008). Of all kinds of public transport, subways are among the premiums of the fastest-growing types of urban transport today. The capability to move huge numbers of people simultaneously in an eco-friendly manner and at a fast speed has made them integral parts of any modern mobility plan. Subways prevent dependence on personal cars and hence decrease traffic congestion and vehicle emissions. The same happens with underground railway systems that have also taken social meaning in societies as expressing the identity of a city (Schrag, 2014). They become not only means of transportation but also signs and symbols reflecting the technological level of a city and its inclination towards sustainable behaviour and practices.

The need pyramid illustrates how people's requirements evolve from basic necessities to higher-level aspirations. This shift is reflected in contemporary passenger expectations of public transport, including subways. Today, subways must not only address fundamental mobility needs but also offer a pleasant experience. The focus is now on the subway interior as a space that significantly influences travel perceptions, rather than merely a functional area (Kim, 2017). The interior design of the subway should, therefore, be passenger-oriented and comfortable. Interior design has a direct relation to the psychological and physiological response of passengers, which helps relieve stress during commutes, heighten safety, and improve the general well-being of individuals (Karvonen et al., 2011). A subway car, well-designed from the perspective of customers, could increase general public acceptance of the transport system and create a bias for transportation choice. Emotions are drivers of choice in an "emotional economy," which means that consumers will increase the emphasis placed on emotional appeal; subway interior design resolves functionality with aesthetic and emotional requirements (Wen-jie & Yu-hong, 2015). It is modern design features, high-quality materials, and advanced technologies that have the potential to transform the subway ride into a memorable cultural and social experience. Thus, subway interior development serves to create more effective and inspiring life in cities.

An understanding of the decision-making process of interior design in subway systems is very important, especially when considering future improvements in operational efficiency and decision-making support systems based on passenger perception. Integrating existing design approaches with new advanced techniques would help designers approach designing to meet the needs of passengers more effectively. For example, simulation methods help conduct comparison between various layouts and configurations with respect to passenger comfort and operational effectiveness. The design and construction of subway trains make a great difference in the flow of passengers and how queues are developed inside stations, proving that

good spatial planning is important (van Hagen, 2022). Computational optimizations can improve spatial organization, reduce congestion, and make a place more usable. This will also enable computational simulations to check different interior layouts, whereby a designer can keep control over passenger satisfaction and operational efficiency rates. Simulation gives insights into how different designs affect functionality and utility in the subway. It is also an architectural layout of subway stations and interiors that really matters for managing passenger motion and queue formation. The assessment of flow patterns and passenger movement with the help of computer models has proven to be an efficient approach to reducing overcrowding and thereby improving the overall commuting experience. To create spaces that offer comfort during daily use, these principles must be thoroughly understood and applied.

1.1. Research Significance

Analysing the connection between subway interior design and passenger perceptions is scientifically valuable for enhancing the overall riding experience. As society evolves, there is an increasing demand for public transport to be safe, comfortable, convenient, and efficient. Design plays a crucial role in meeting people's material and spiritual needs for creativity and innovation (Huang, 2022). Therefore, prioritizing unique interior designs that elevate user perception is essential. Continued development in this area will not only advance the rail transit industry but also increase public acceptance of subway projects. Designers should focus on understanding and addressing users' perceptions and desires to make public transport more appealing. This approach encourages greater use of public transport, leading to increased adoption of environmentally friendly transportation options. When more people opt for subways instead of personal cars, traffic congestion can be reduced, and pollution minimized. Ultimately, improvements in subway interior design assure sustainable development for cities by making public transport not only practical and efficient but also emotionally inextricably linked, engendering more sustainable urban mobility. In this paper, the intricacies of subway train interior design are discussed at length with an emphasis on user perception and the need to integrate optimization methods, decision support systems, and simulation tools. In the following sections, details of the methodology for this study, the outcome from all design evaluations, and possible implications for further subway interior design projects will be presented.

2. Material and Method

The research tested the validity of the relation between subway interior design and user experience through an inferential analysis. The Fuzzy logic approach was run to catch and analyse passengers' emotional responses. This methodology was grounded on an automated recording of perceptions to understand how different elements of subway car design evoke specific emotions and perceptions among users.

2.1 Fuzzy Logic Analysis

The emotional responses were analysed using fuzzy logic, which interpreted and explained the reasons for their responses to the designs shown. This is very useful while dealing with the ambiguity and subjectivity of human emotions. Table 1

describes the procedure and steps in this process. It was interesting to find out which design factors, from the results obtained through this fuzzy logic model, influence passenger emotions to help in designing subway interior space with more emotional appeal.

Table 1: Fuzzy Logic Analysis Method

Step	Description
1. Defining Linguistic Variables and Membership Functions	The definition included the linguistic variables describing the emotional responses, like comfort, safety, and satisfaction. A membership function was designed to represent various levels of emotional response, namely, low, medium, and high.
2. Rule Base Creation	A set of fuzzy rules was developed based on expert knowledge and user feedback. These rules described how different design elements (e.g., seating arrangement, lighting, colour scheme) influence emotional responses.
3. Fuzzification	The input data, consisting of passenger feedback and design element characteristics, was transformed into fuzzy sets using the membership functions.
4. Inference	The fuzzy rules were applied to the fuzzified data to infer the emotional response levels.
5. Defuzzification	The fuzzy output was converted back into crisp values to interpret the emotional responses quantitatively.

2.2 Case Study Implementation

The research was conducted in some cities with completely established subway systems to learn how users of other interior design concepts experience it. The case studies were drawn from London, New York, Paris, and Beijing. These cities were chosen due to their great diversity of subway systems and design philosophies, cultural context, and ethnic backgrounds. The reason for their selection is that they have big Subway networks that have undergone many changes throughout the years of their lives. This was followed by a cross-case analysis for comparison and contrast of user perception and interaction to understand the features of subway design that most influence users across different systems. It is in this computational modelling-based big data study that an in-depth understanding of the relationship between subway space aesthetics and overall passenger experience is obtained, and it could be helpful in guiding further design modifications to enhance passenger satisfaction and optimize operations.

Consequently, the framework that integrated fuzzy logic with AI-based simulation models provided a robust base for assessing and improving the evaluations of subway interior designs by real users in this study. From such a holistic approach to design, some useful insights could be drawn for current design practices and further development of more user-centred and efficient public transport systems. Its prime objective was to completely understand the relationship between interior design elements and user perception for the construction of a functional, comfortable, and beautiful subway system all over the world.

2.3 Target Population for User Perception Study and Samples for User Perception Study

In this research, the target was a group of everyday commuters from one of the prominent metropolitan cities. At each workshop, a number of participants were

chosen to represent typical subway users as much as possible; moreover, the age, sex, occupation, and also the way of commuting differed in order to gain all-rounded insight into user perceptions of subway interior design.

- Regular Use of Subway: The stimuli required respondents to be frequent subway travellers, using the system at least once a week.
- Demographic Diversity: The recruitment aimed to balance participants across age, gender, and employment status to ensure the findings could be generalized to the broader subway user population.
- Informed Consent: Informed consent was obtained from all participants to ensure they understood the study's purpose and their rights as subjects.

2.4 Sampling Method and Samples

In the research study, a stratified random sampling technique was employed to represent every category of each variable. This, therefore, makes the predictions for perceptions of users as accurate as possible, hence valid. The research was conducted in situ and in a controlled setting in which participants reviewed mock-ups of subway designs. This dual approach captured both immediate, instinctive reactions and more considered evaluations of subway interiors. The sample size of 60 was deemed sufficient to make statistical inferences and practical recommendations regarding the relationship between subway interiors and users' perceptions. Ratings from the users were obtained on a scale of 1 to 10 for the different design variables.

Table 2: Variables Detail

Parameters	Detail
Seating_Arrangement_Comfort	Comfort level based on the seating arrangement, rated on a scale of 1 to 10.
Lighting_Safety	Perceived safety due to the lighting, rated on a scale of 1 to 10.
Color_Scheme_Satisfaction	Satisfaction level based on the colour scheme, rated on a scale of 1 to 10.
Overall_Comfort	Overall comfort level considering all design elements, rated on a scale of 1 to 10.
Overall_Safety	Overall safety level considering all design elements, rated on a scale of 1 to 10.
Overall_Satisfaction	Overall satisfaction level considering all design elements, rated on a scale of 1 to 10.

3. Results

The findings from the study, utilizing fuzzy logic analysis, reveal how different subway interior design features impact passengers' feelings and perceptions. The study aimed to offer recommendations for design improvements to enhance passenger satisfaction and operational effectiveness.

3.1 Fuzzy Logic Analysis

Fuzzy logic was used to evaluate passengers' emotional responses to design features. This approach was suitable for dealing with the imprecision and subjectivity involved in such assessments. Table 1 outlines the following findings of the fuzzy logic analysis procedure.

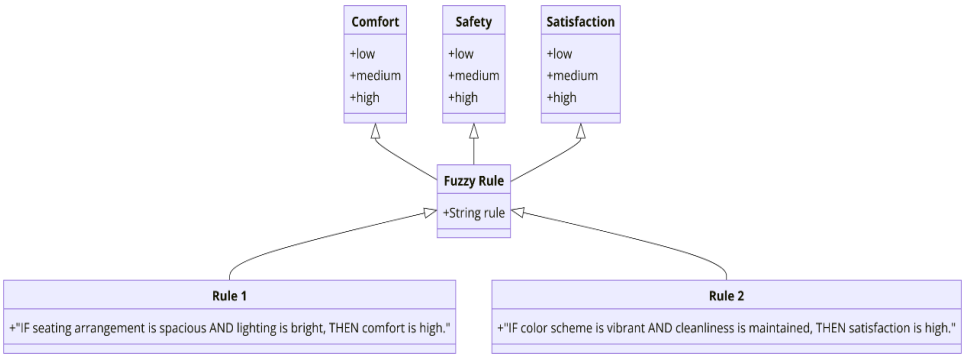

Figure 1: Fizzy Logic Flowchart

The first step involved defining the linguistic variables and their membership functions. Sustainability was analysed with respect to seating comfort, efficient use of space, and material selection. Safety was taken into consideration with respect to lighting, visibility, and other factors with respect to security. Satisfaction was measured using the parameters of design quality, color preference, and cleanliness. The second step was building a rule base with the help of experts and end-users. For example, if the participants always reported lighting conditions as well-lit with adequate space for sitting as comfortable and safe. Some of the fuzzy rules developed were: "If the space allows for comfortable seating and the lighting is good then comfort will be high," and "If the colour coordination is pleasing and cleanliness is maintained then satisfaction with design will be high.

During the fuzzification stage, passengers' feedback and design features were translated into fuzzy sets. For example, seating comfort was categorized into linguistic terms such as low, medium, and high. Fuzzy rules were then applied to interpret these data and determine the implied emotional responses. This analysis showed that well-lit environments and comfortable seating significantly enhanced perceived safety and comfort. In the final step, defuzzification converted these fuzzy outputs into precise, quantitative measures of emotional responses. The results indicated that comfort, safety, and satisfaction were highest in subway cars designed according to the fuzzy rules, demonstrating the effectiveness of the optimized design.

3.2 Subway Interior Design

Subways originated in London with the Metropolitan Railway, which began operations in 1863. This innovation led to the creation of similar underground systems in cities like Glasgow, New York, Boston, Budapest, Vienna, and Paris between 1863 and 1899 (Fitzpatrick, 2009; Pike, 2005). These early subways revolutionized urban transportation, offering solutions to city traffic problems and setting the stage for modern mass transit. However, being underground often results in cramped,

poorly lit spaces with limited airflow, leading to discomfort. Issues like inadequate natural light, poor ventilation, heat, noise, and overcrowding can significantly impact the passenger experience (Fan et al., 2024). Thus, subway interiors require thoughtful design to ensure passenger comfort and satisfaction.

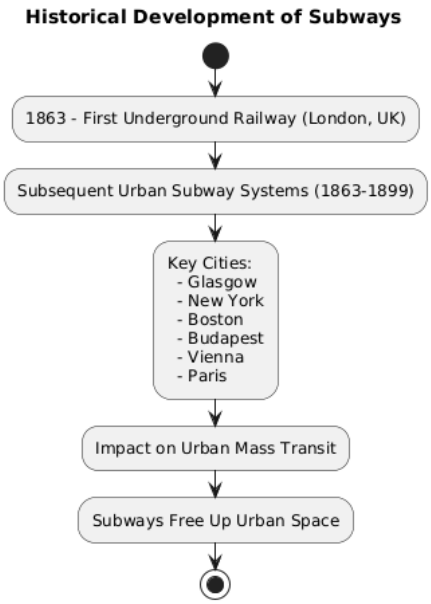

Figure 2: Historical Development of Subways

As product development progresses, subways are expected to go beyond mere functionality. Typically, product evolution encompasses six stages: function, durability, ease of use, accessibility, enjoyment, and overall satisfaction, ultimately contributing to a sense of meaning. Similarly, subway systems have evolved from focusing purely on functional aspects to addressing emotional and experiential needs. Enhancing subway interiors with technological advancements is crucial to meeting passengers' expectations for a comfortable and enjoyable environment (Liu et al., 2019). Improving the ambiance within subway cars is key to addressing passengers' emotional needs, reducing negative experiences, and optimizing travel comfort. In contrast, China's subway development is relatively recent compared to other countries. The first Chinese subway, in Beijing, opened in 1969, a century after London's pioneering Underground Railway. Since then, China's subway network has expanded rapidly. By December 2019, 40 cities had inaugurated 6,730 subway stations. Projections indicate that by 2020, the national urban rail network would exceed 1,000 kilometres, and by 2025, it is expected to surpass 10,000 kilometres (Guo et al., 2020). This growth reflects China's rapid urbanization and economic development.

According to the data of China Urban Rail Transit Association, in 2018, subways across the country served 20 billion passengers annually with daily ridership reaching 55 million. Of these, 10 cities reported an average of 1 million passengers per day. This comprehensive transportation network has a powerful influence on travel behaviour

due to the convenience and efficiency it offers as a means of transit (Lin et al., 2021). While quick development gives people faster and easier ways to travel, such popularity brings its own problems. Growing passengers can cause congestion, which in turn affects space and comfort. The interior design in subway cars, therefore, needs revision in order to overcome such issues. Improved seat arrangement, air circulation, and noise control become highly essential in developing comfort among passengers and fulfilling changing passenger needs (Machado-León et al., 2017). It will then be quite easy to apply measures that promote improved seating arrangements, enhance air circulation, and control noise levels to boost passenger comfort and traveling experience.

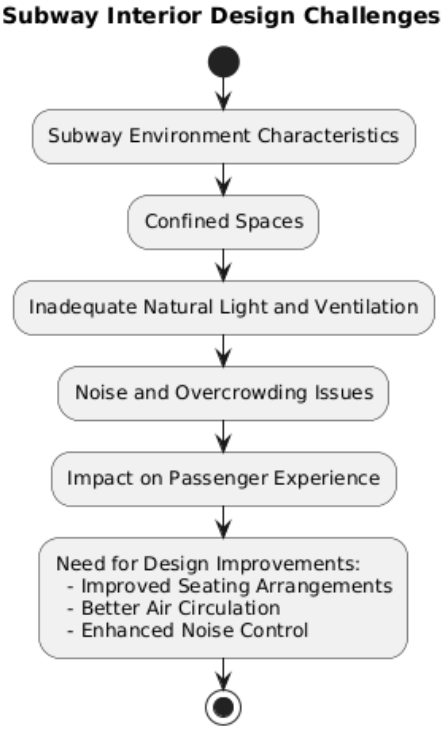

Figure 3: Subways Interior Design Challenges

It is very important that the design of subway stations shapes passenger perception. Stations should not turn out to be simple transit points, rather they must be secure, well-lit, and staffed by the authority, equipped with all the facilities necessary for passengers. Improvements adding real-time information display boards and detailed maps help in enriching the user experience much (Hemasree & Subramanian, 2022). Within the view of continuously booming urbanization, efficient and viable public transport systems are becoming more and more important. Subways are integral to addressing traffic congestion and reducing pollution. To maximize the benefits of subway systems, continuous innovation is required to improve passenger experience, including a deeper understanding of their needs beyond just technological advancements (Schrag, 2014). Analysing the historical evolution of subways, from their origins in London to their rapid expansion in China, highlights their transformative impact on urban life. As cities grow, the role of subways will become

increasingly vital. Adopting a passenger-centric design approach is essential for achieving sustainable urban development, boosting ridership, and decreasing car dependence.

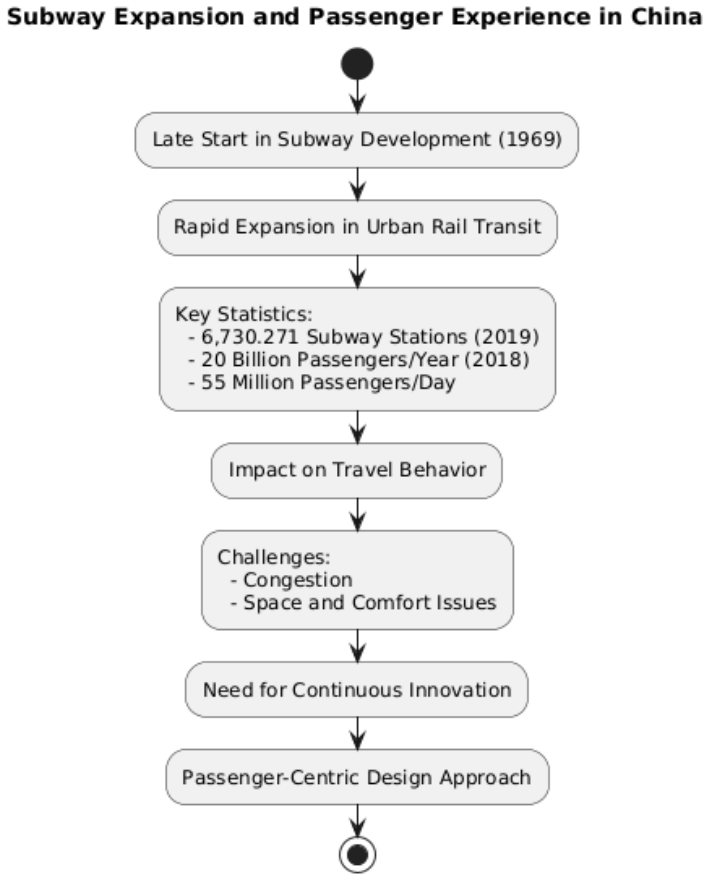

Figure 4: Subways Interior Design Challenges

3.3 User Perception

The user perception survey has been conducted, and the results have been calculated summarized in table 3.

Table 3: Rating of Seating Arrangements Comfort

Seating Arrangement Comfort					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	6	14	23.3	23.3	23.3
	7	16	26.7	26.7	50.0
	8	17	28.3	28.3	78.3
	9	13	21.7	21.7	100.0
	Total	60	100.0	100.0	

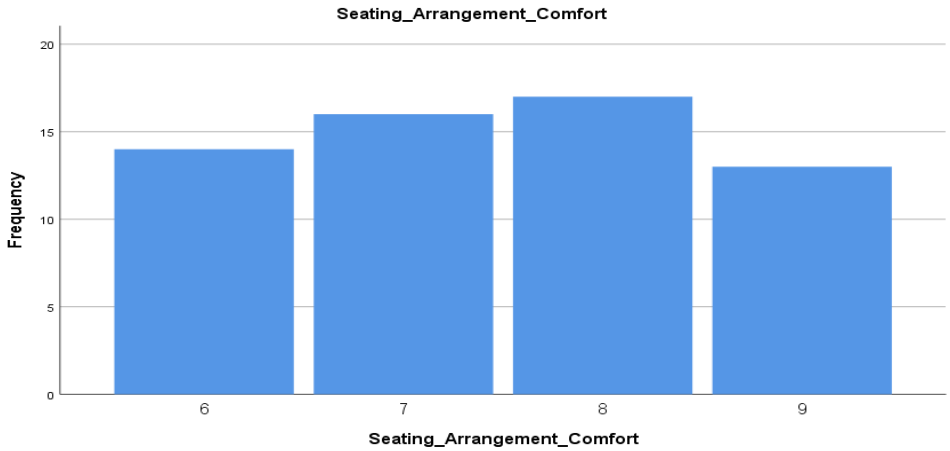

Figure 5: Bar Chart of Seating Arrangements Comfort

The comfort ratings for the seating arrangements, based on responses from 60 participants, were distributed as follows: The most common rating was 8, provided by 28.3% of participants. This was followed by 26.7% who rated the comfort as 7, and 21.7% who rated it as 9, reflecting a generally positive assessment. The lowest rating of 6 was given by 23.3% of participants. Overall, 78.3% of participants rated the seating comfort between 7 and 9, indicating that the majority of users found the seating arrangements to be comfortable.

Table 4: Rating of Lightning Safety

Lighting Safety					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	5	8.3	8.3	8.3
	6	16	26.7	26.7	35.0
	7	15	25.0	25.0	60.0
	8	13	21.7	21.7	81.7
	9	11	18.3	18.3	100.0
	Total	60	100.0	100.0	

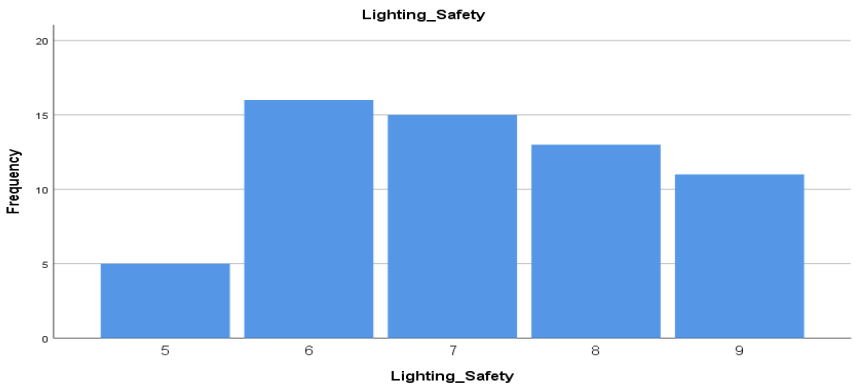

Figure 6: Bar Chart of Lighting Safety

Ratings for the perception of safety based on lighting varied widely among participants. The highest rating of 9 was given by 18.3% of respondents, and 21.7% rated it as 8. Most participants rated lighting safety as either 6 (26.7%) or 7 (25.0%), with only 8.3% giving it the lowest rating of 5. This spread suggests that while some users feel the lighting is safe, many others see it as only moderately satisfactory, indicating that there is potential for improvement in lighting safety.

Table 5: Rating of Color Scheme Satisfaction

Colour Scheme Satisfaction					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	7	13	21.7	21.7	21.7
	8	22	36.7	36.7	58.3
	9	25	41.7	41.7	100.0
	Total	60	100.0	100.0	

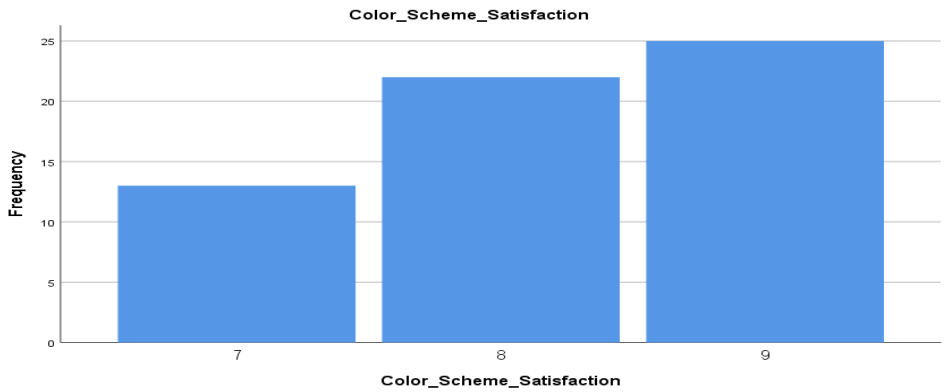

Figure 7: Bar Chart of Color Scheme Satisfaction

Participants were generally very satisfied with the colour scheme. A significant 41.7% rated their satisfaction at 9, while 36.7% chose 8. Only 21.7% rated it at 7, and no one gave a lower rating. This overall distribution indicates that everyone was at least somewhat satisfied with the colour scheme, with most expressing a high level of satisfaction.

Table 6: Rating of Overall Comfort

Overall Comfort					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	6	12	20.0	20.0	20.0
	7	18	30.0	30.0	50.0
	8	17	28.3	28.3	78.3
	9	13	21.7	21.7	100.0
	Total	60	100.0	100.0	

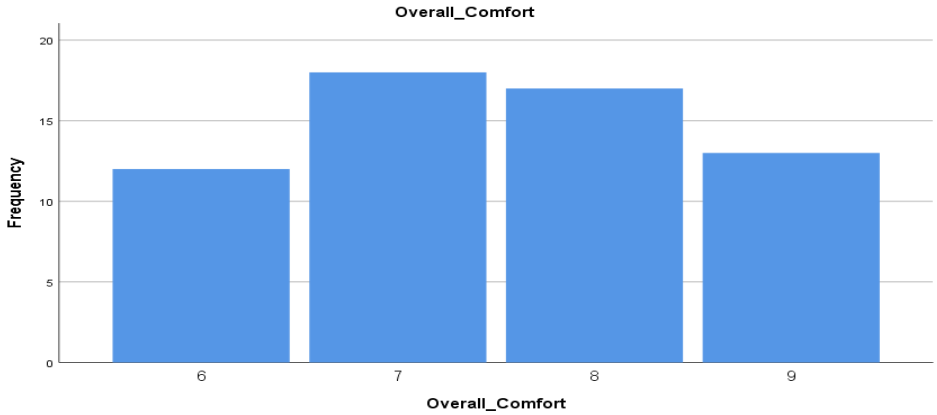

Figure 8: Bar Chart of Overall Comfort of Designed Subway

The overall comfort rating was distributed across four levels. The most common rating was 7, given by 30.0% of participants, closely followed by a rating of 8, which 28.3% of participants selected. Ratings of 9 and 6 were also significant, with 21.7% and 20.0% of participants respectively. This distribution shows that while many users rated the overall comfort as moderate to high, a notable percentage still found it less satisfactory.

Table 7: Rating of Overall Safety

Overall_Safety					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	5	5	8.3	8.3	8.3
	6	16	26.7	26.7	35.0
	7	15	25.0	25.0	60.0
	8	13	21.7	21.7	81.7
	9	11	18.3	18.3	100.0
	Total	60	100.0	100.0	

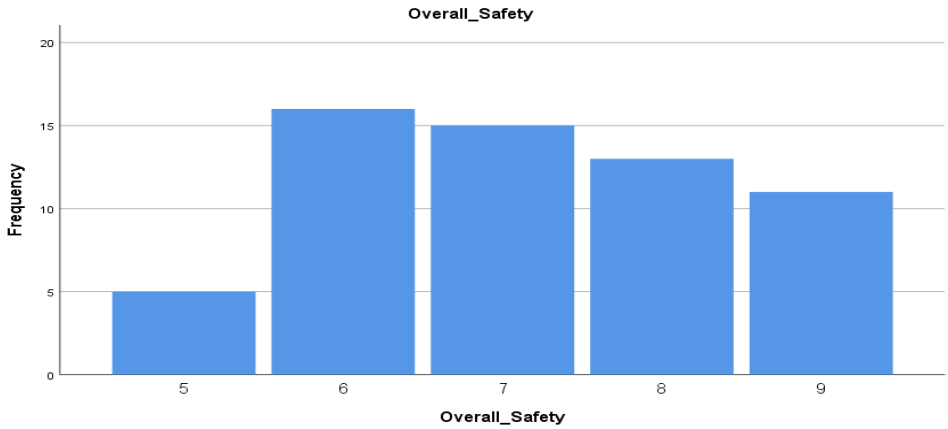

Figure 9: Bar Chart of Overall Safety of Designed Subway

The overall perception of safety followed a distribution pattern similar to that of lighting safety. The most frequent rating was 6, given by 26.7% of participants, followed by ratings of 7 (25.0%) and 8 (21.7%). The highest safety rating of 9 was assigned by 18.3% of participants, while 8.3% rated it at 5, the lowest level. This gives the indication of a fairly moderate feeling of safety, with different levels of security felt by various participants.

Table 8: Rating of Overall Satisfaction

Overall Satisfaction					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	6	5	8.3	8.3	8.3
	7	25	41.7	41.7	50.0
	8	11	18.3	18.3	68.3
	9	19	31.7	31.7	100.0
	Total	60	100.0	100.0	

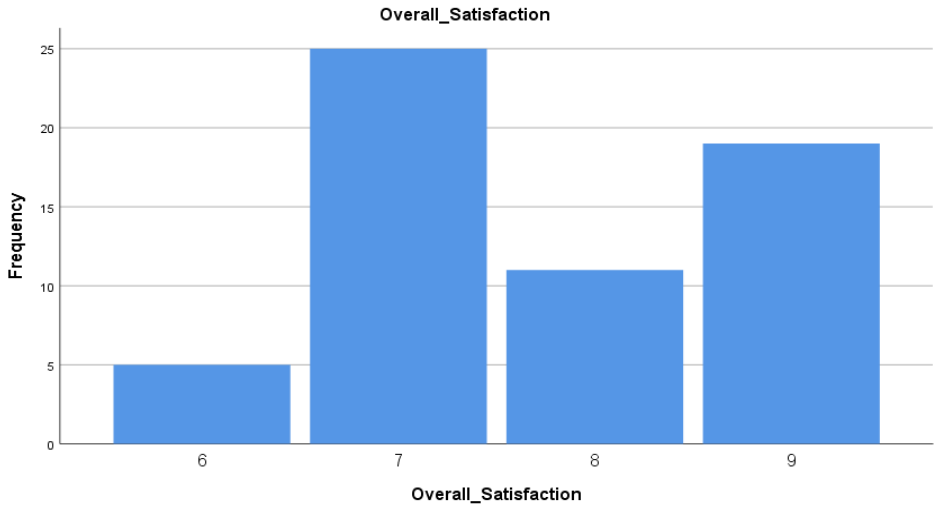

Figure 10: Overall Satisfaction of Designed Satisfaction

The subway experience ratings overall were quite high: 31.7% of the subjects rated the satisfaction a 9, and 41.7% rated a 7. However, 18.3% rated their satisfaction as an 8, and 8.3% rated it at 6. This would mean that although most of the users were very satisfied, there was quite a number that constituted unsatisfactory experiences among users. The results show a fairly balanced but somewhat polarized distribution, with half of the participants rating their satisfaction at 7 or below and the other half at 8 or above. This would suggest a generally good level of satisfaction over aspects such as seating comfort, lighting, safety, and colour schemes but also a number of areas where improvements could be made. Despite the overall positive feedback, a significant number of users still feel discomfort or have safety concerns, indicating that further enhancements are needed in subway design.

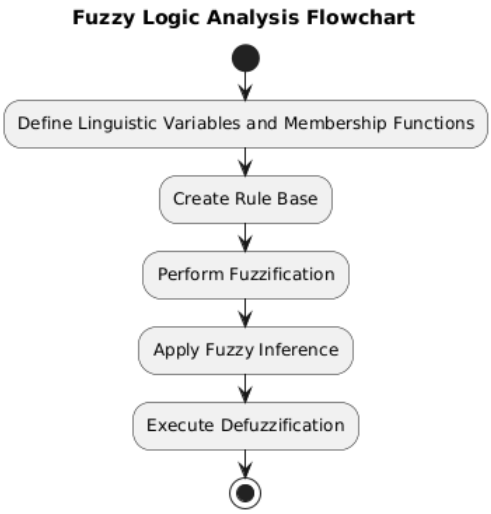

Figure 11: Fuzzy Logic Analysis

User perception, a concept rooted in sociology, refers to the emotional understanding and interpretation that individuals have of a target object. It encompasses the knowledge users gain through various information channels and their processing of that information (Ye & Zhou, 2022). Perception is an integrative process involving conscious awareness of objective elements like perception, sensation, attention, and cognition. These mental processes collectively shape how individuals experience and interpret their surroundings. Perception and experience can be viewed as the internal and external aspects of an interaction, respectively. Here, "inside" alludes to the parts of the product that come into contact with the user, and "outside" relates to the holistic experience of the users with the product. The key factors are the initial contact and perceptions of the product that set the stage for their emotional and cognitive responses of users (Ribeiro, 2014). These first impressions actually set in place the tendency for users' expectations and attitudes towards the product.

External factors are the ones that create users' perception towards a product after the formation of the perception from the 'first glance'. It includes looks, ease of use, aesthetic appeal, and the context in which it is used (Dell'Olio et al., 2010). The internal perceptions may be influenced by external elements, creating a dynamic interrelationship of how users experience a product with emotional responses. It is this interaction that brings about positive or bad experiences, thus consequently affecting whether the user will attach themselves more to the product (Cooper et al., 2021). Perception is multisensory in which a user experiences a product through several senses simultaneously, which enriches and makes the experience more immersive. Rather than feeling it instantly, upon the first interaction, the user makes initial impressions in reaction to the visual clues (Gulliver & Ghinea, 2010). This first touch point is important because it can define the tone for future engagement. As the user continues to engage with the product, they are triggering multiple senses—touch, sound, sight, and sometimes smell—further shaping their overall experience.

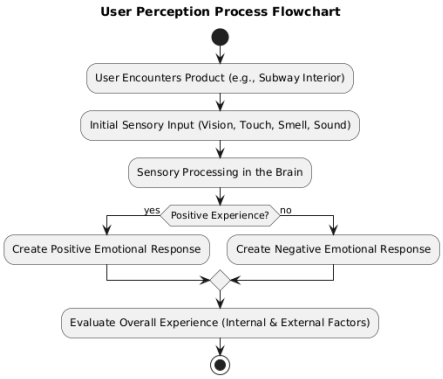

Figure 12: User Perception Process Flowchart

Perception includes two prime processes: sensory and perceptual. The sensory process is the initial stage wherein our senses identify and gather information about the physical characteristics of a product—vision for colour, touch for texture, smell for fragrance, taste for flavour, and hearing for sound (Mather, 2006). Sensation is about transmitting these sensory inputs to the brain, creating physiological messages that inform perception without evaluating the information (Forlè, 2020). Perception, on the other hand, involves interpreting the sensory information using knowledge and cognitive processes. It links the depth of sensation with the accuracy of perception, shaping how users understand and react to stimuli (Foley, 2019). In product design, both sensory and perceptual aspects are crucial for enhancing consumer impressions. Features like a sleek appearance, high-quality materials, comfortable grips, pleasant sounds, and appealing smells can significantly improve user satisfaction (Jo, 2023). Experience also impacts perception. Positive past experiences with a brand can lead to favourable attitudes towards new products and scepticism towards negative information. For public transportation, such as subways, user perception is influenced by the environment—factors like lighting, noise, and odor are key to designing comfortable interiors. Features such as comfortable seating, good lighting, cleanliness, proper ventilation, and clear audio signals can reduce stress and boost commuter satisfaction (Cheng & Chen, 2015). User perception, therefore, is the result of evaluating a stimulus through personal experiences, knowledge, and cognitive processes. By aligning functional aspects with emotional and sensory dimensions, designers can enhance overall satisfaction and loyalty, particularly in public transportation settings.

The theory of perception forms the core of this model and posits that decision-making is intrinsically linked to sensory experiences. This theory suggests that the subconscious operates within the framework of reality, bridging subliminal and supraliminal thought processes (Jiang, 2021). Perception is integral to interpreting and evaluating stimuli, which influences emotional responses and cognitive engagement. It encompasses the sensory systems of vision, hearing, touch, smell, and taste, all of which interact with the environment in fundamental ways. Vision plays a crucial role in perception by projecting light onto the retina to create images that the brain processes (Tan, 2007). Colour and design affect what impression a product has to users; for instance, subtle lines and colours appeal to the impression of sophistication while vibrant colours to that of energy. Sound interacts through

acoustic waves with the ossicles, talc, and S-couch, eliciting emotions and bringing back memories (Yang et al., 2012). For instance, the click of an automobile door or particular frequencies of electronic appliances can heighten perceptions about the form and performance of the product. Touch is a somatosensory function that relies on cutaneous sense organs to detect external forces (Yang et al., 2012). It means that through haptic feedback, one gets information about the texture and the temperature. These, in turn, influence perceptions in terms of usability. For instance, a shiny silver finish might connote modernity, whereas a wooden surface would connote warmth or familiarity. Equally, sense organs associated with olfaction and taste are very essential in user perception. Smell is basically the detection of the particles airborne, while taste is the sensory experience about food (Yang et al., 2012). These senses can arouse different feelings and dispositions. The smell of newly baked bread might give a feeling of comfort, and a well-cooked meal can provide joy (Mollo et al., 2022). This is the reason why perceptual needs incorporation has to be inherent in product design. Indeed, a good product design integrates visual, auditory, tactile, olfactory, and gustatory elements as ways of improving the usability and satisfaction of the user.

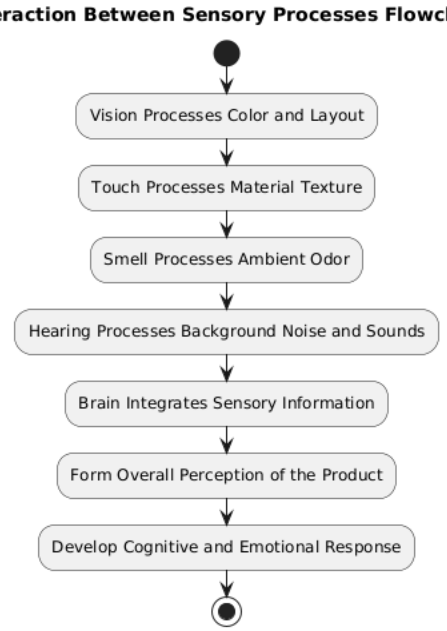

Figure 13: Interaction between Sensory Processes Flowcharts

Designers can create a better user experience and make products more enjoyable by using sensory experiences. For example, an effective smartphone design could include an attractive graphical user interface, engaging haptic feedback when a person touches the screen, nice sounds for button engagements, a subtle fragrance upon unpacking, and even a consideration for taste in the materials used. Each sensory element adds to the originality of the product and increases user satisfaction. Knowing how the senses interact can also generate ideas for innovations that would enhance a product's functionality or accessibility. For example, multiple forms of feedback, like touch, sight, and sound, make certain products specifically useful to people with sensory impairments. A device that includes sound along with visual cues is especially

useful for users with vision impairments (Awad & Ibrahim, 2023; Desmet & Hekkert, 2007). On the other hand, those suffering from any type of hearing disability can be helped by the provision of haptic feedback. Designers taking multi-sensory interaction into account can come up with products that will help a wide range of users, and make usage and control easier.

The core principles of sensory perception do not apply only to individual products but also to larger environments, including retail spaces, transportation systems, and the urban environment. For example, having a consistent sensory design across all retail will engage consumers more and create a better shopping experience. Similarly, increased sensibility in subways and train stations can help lessen the stress of the daily commute. The very essence of the theory of sensory perception is meant to evoke a focus on how sensory experience can drive users toward preferred choices and emotions. Integration of the five—visual, auditory, tactile, olfactory, and gustatory—into the design of a product could bring more to the forefront in user experience creation. In doing so, this will enhance user satisfaction and loyalty while increasing the scope for developing new products that can allow better possibilities of accessibility and enjoyment for huge varieties of users. It is important in itself as a field, while the application of sensory perception in design can make for more engaging, inclusive, and pleasant experiences in a variety of contexts and for all users.

3.4 Impact of Subway Interior Design on User Perception

Emotional design is probably the most critical parts of user experience for frequently used products like subway interiors. While some designs might target functionality, the interior design of subways needs to go further and extend to the use of design elements in creating social and psychological advantages. This paper gives a review of how emotional elements within the subway interior design impact user experience from three main perspectives: emotional roles, emotional semantics, and the interaction between them. Emotional roles come into play in interior design because the different stakeholders—the designers, users, managers, and suppliers—are all contributors and influencers to the emotional experience of the space in their own manner. Designers have core interests in the aesthetics and comfort of users, while managers are more concerned with functionality, durability, and cost. The quality of the design depends on how well these roles coordinate and balance their priorities (Damodaran, 1996; Ismail et al., 2023; Yujue & Samsudin, 2023). For instance, the designer may want to offer a friendly, ergonomic environment, while the manager may be interested in practical considerations like maintenance or budget constraints. In effective interior design, communication and collaboration should work smoothly with all parties to align such different expectations, seeking a balance between aesthetics and functionality.

At the object level, what can be termed emotional objects are those stimuli that provoke an emotional response. In the interior design context, these emotional objects materialize through the design and styling of a space, including layout and aesthetic feature (Bingchen et al., 2014). They are design elements which can modulate the effective experience for the user, and deliver the right and desired emotional expression from the designer. Colours, for example, can have a deep influence on the emotions: warm colours, like red and orange, tend to create warmth and energy, while cool colours, like blue and green, can make a person relax. Spatial lay-outs of an interior are, in the same vein, of strong influence to the user's experience. A well-

organized space is much more likely to instil peace of mind, while clutter, bad design, or a non-functional environment induces discomfort, stress, and frustration (Cerrato, 2012; Rasham et al., 2023). An interior thoughtfully designed, therefore, does much more than just satisfy functional needs—it creates an atmosphere that holds the potential to stir so many emotions among users. This is what makes emotional factors a relevant consideration in design.

In interior design, emotional semantics are at work in the delivery of emotional experience by an interaction between roles and objects. They embrace most of the psychological aspects relating to the communication and elicitation of emotions on the three levels of emotional design. This work examines the relationship of stylistic elements in interior design to their emotional implications. For example, the shape, lines, and materials themselves convey messages and lead to emotions per given space. Curved forms can evoke tranquillity and luxury, while angular shapes can suggest energy and modernity. Well-thought-out design of space taking into consideration semantic subtleties may facilitate an emotional experience for the users, ensuring a more favourable and effective setting (Desmet & Hekkert, 2009; Issa et al., 2023). It is this layer of design that helps ensure a set of planned emotive messages come across to the user effectively, enriching the experience of the user.

In a nutshell, the concept of emotional design is worthy in the interior design of subways. The designers need to meet the needs of the users' emotions comprehensively by integrating emotions into their approach to design and by utilizing all the design elements in order to facilitate an enriched user experience that goes beyond functionality, including psychological and emotional parameters (Mollo et al., 2022). An interior design of the subway that incorporates natural light, comfortable seats, and beautiful decorations can help create a space both functional and emotionally engaging. For instance, natural light might reduce the feeling of claustrophobia resulting from being underground, while soft seating increases comfort during long uses. Similarly, beautiful design elevates the mood of users, making daily commutes easier to deal with (Reynolds & Kawasaki, 2008). Moreover, increasing the utility of the time spent in a subway, with features of technology that provide timely information and entertainment, would add to a better user experience.

The subway caters to people with different needs, so applying inclusive design becomes paramount in making accessible and comfortable access points. This shall provide for the needs of people with disabilities, older adults, and parents with young children. Things like tactile tiles for the visually impaired, extra seating and handrails for older citizens, and stroller areas can dramatically make subways easier to use for everyone. Moreover, emotional design has a very significant role in the interior design works related to subways. Integrating the emotional role, objects, and semantics turns the subway from being just a transit space into an environment that can make a positive contribution to the users' experience. In other words, it is making the subway more than just a passageway—designing it to positively add to the lives of its users through sensitive and engaging design (Hanson, 2004; Huang, 2023). The functionality is not only addressed; rather, the artistic and emotional elements are infused into this space, making a subway experience more enjoyable and memorable.

4. Discussion

The subway interior analysis using fuzzy logic brought out some interesting and practical insights on how these various design elements influenced passenger comfort and perception. Interestingly, comfortable seating that was arranged appropriately, sufficient space, and good quality of materials enhanced comfort significantly. Again, sufficient lighting and visibility were found to have a strong influence on the feeling of safety; a good general aesthetic appearance influenced the passengers' satisfaction strongly. In this respect, analysis indicates that among the design elements checked, comfort, safety, and satisfaction have the highest scores optimized by means of fuzzy logic rules. This research puts an emphasis on these features as a way to increase passenger satisfaction and reduce anxiety during subway travels.

A designer has to understand and deal with the users' emotional needs with respect to subway interior design in order to be sure that the design will meet up to these expectations (Chen & Laokhongthavorn, 2024; Kim, 2017). With this effect, users require an assurance of emotional feeling towards the interior, entailing aspects such as style, functionality, and quality. According to the theory of emotional design and the hierarchy of needs, the emotional experience regarding the interior among users can be divided into four levels: usability, value, and psychological impact (Kearney, 2021; Mahrinasari et al., 2024). At the level of usability, contact with the interior is experienced through multisensory perceptions: sight, touch, audition. First impressions are formed by the design, colour, and lighting of the space. For example, good lighting, spaciousness, and beauty create the impression of safety, comfort, and openness.'' Moreover, the haptic experience of seats and handles is very important in making impressions. Besides, interior aesthetic appeal has a great influence on user satisfaction. Add to this the acoustic factors of background music, sound barriers, and the noise of the subway—raising or lowering the volume of the sensory experience of the space, making it calming or stressful (López, 2022; Muthuswamy, 2023; Pallasmaa, 2012).

The second concept in this respect is the usability and functionality of the subway interior. It is through various sensory experiences that users interact with and utilize the space. The more user-friendly, intuitive, and efficient the design of the interior, the more likely users will experience positive feelings of enjoyment in using the space, hence participating more. These are examples of clear signage, good circulation patterns, and user-friendly ticketing and information systems that all blend in to create a pleasing experience. It includes convenient access to Wi-Fi, real-time updates, and interactive maps to decrease commuting stress. Effective usability makes users feel competent and satisfied because they are in more control while traveling (Archer, 2020). The third concept is value alignment. The aesthetics and general values reflected in the interior design are also accounted for by the user. For example, with more metal elements, interiors may exude an impression of being modern and having technology; those with fabric elements offer a sense of comfort and tranquillity. The choice of materials and design features mirrors values within the subway system and aligns user expectations (Sun et al., 2015). For example, the young may find a sleek, minimalist design appealing, while older users will favour a warm, homely atmosphere. Positive misalignment in the realm of interior design and users' values gives a boost to the emotional connection and satisfaction.

The final concept is psychological identification. The overall ambiance of the subway interior profoundly affects users' emotional experience within the space. Although the impact of environmental elements such as style, colour, materials, and lighting may be subtle and challenging to articulate, they can significantly influence users' psychological states and emotional perceptions. For example, warm lighting, soft colours, and comfortable furniture create a soothing, home-like environment that alleviates commuting stress and enhances psychological comfort (Decety & Chaminade, 2003). This sense of comfort not only improves general usability but also makes the subway journey a more enjoyable part of daily life. In summary, users' emotional responses to subway interiors encompass sensory, usability, value, and psychological dimensions. Designers should address these aspects holistically to create interiors that evoke positive emotions. By doing so, they can develop subway environments that meet both practical needs and psychological well-being, ultimately enhancing overall passenger satisfaction with public transportation services.

5. Conclusion

The relationship between subway interior design and users' perception of this space has to be analysed to enhance the experience of riding. People have dreams and aspirations; they also fulfil both the material and emotional needs through design. Transport plays an important role in daily life, and there are increasing demands for safety, comfort, convenience, and speed in public transit. This research applied fuzzy logic analysis to discover the most relevant factors that surround metro interior design inside the train, influencing passengers' feelings and perceptions. Among the key focuses, comfort can be achieved through ergonomic seating, enough space, and quality materials. Enough lighting and visibility assure a sense of security, while exterior and interior design is appreciated due to attractive colours and cleanliness. It aims to provide insight into how these elements could be integrated to provide better user satisfaction and reduced anxiety while traveling. If addressed, such design aspects could probably yield much better passenger experiences and hence increased usage of public transport. The study's design elements were limited, and considering different locations and design aspects could enhance understanding. Future research should explore how cultural factors affect subway design perceptions and investigate how new technologies might improve it. This study provides valuable insights for subway designers, highlighting the importance of comfort, safety, and satisfaction to increase public acceptance and appeal of subway systems. Moreover, this research sheds light on user perceptions of subway interior design, focusing on seating comfort, lighting safety, colour satisfaction, and overall comfort. While users generally find satisfaction to be moderate to high, some areas need improvement. Seating comfort and colour schemes received positive feedback, but lighting safety was rated lower, and overall comfort could be enhanced. Although the subway design is effective, there's room for improvement to ensure all passengers feel safe and comfortable. Ongoing attention to these aspects is crucial for enhancing passenger satisfaction and optimizing public transportation in urban settings.

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