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Analysis of Metro Users' Perception Towards Attributes Related to Bicycle–Metro Integration: RIDIT and TOPSIS Model Approach

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Abstract: This study investigates the viability of incorporating bicycles into the Dhaka Metro system, a groundbreaking urban transit project for Bangladesh. As Dhaka's inaugural metro rail network, the system signifies a substantial advancement in addressing urban congestion and enhancing transportation alternatives in one of the world's most densely populated cities. The current design of the metro fails to accommodate bicycles, hindering efficient first- and last-mile connectivity. The investigation utilized data from 382 fully completed questionnaires, obtained through purposive sampling, about metro–cycle integration in Dhaka. The research employed RIDIT and TOPSIS analyses to rank the characteristics deemed most essential for bicycle–metro integration according to user opinions. Research indicates that secure bicycle parking, multi-modal ticketing, route comfort, and safety measures are the foremost objectives for commuters. The high emphasis on secure parking indicates the need for safe and accessible storage options that would make cycling a viable mode for reaching metro stations. A multi-modal ticketing system further enhances convenience, providing seamless transitions between transit modes. Journey comfort and the need to mitigate risks posed by motorized vehicles underscore the importance of safe and user-friendly commuting environments. While features like road and station design were ranked lower in priority, the study emphasizes that a well-integrated bicycle infrastructure is essential to ensure the metro system's success. With these improvements, Dhaka's metro system can meet the growing demands for sustainable and inclusive urban mobility, setting a precedent for future infrastructure projects in Bangladesh.

Keywords: metro rail; bicycle; integration; RIDIT; TOPSIS

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1. Introduction

Urban transport systems are the lifeblood of cities, facilitating mobility, enhancing connectivity, and driving economic growth [1]. With rapid urbanization, particularly in developing countries, cities worldwide are experiencing increasing transportation demands, congestion, and environmental challenges. In response, metro rail systems have emerged as an integral component of urban transit strategies, offering high-capacity, reliable, and environmentally sustainable solutions to address these challenges [2,3].

Metro rail systems are often regarded as the backbone of urban transportation networks due to their ability to move large volumes of passengers efficiently. By offering dedicated tracks and avoiding road traffic, metro systems ensure faster, more reliable commutes, which is crucial for densely populated cities [4,5]. Globally, cities like Tokyo, London, and New York rely heavily on their metro networks to maintain the daily mobility of millions. These systems not only ease traffic congestion but also contribute to reducing greenhouse gas emissions by offering a viable alternative to private vehicles [6]. In addition to being a practical solution for urban mobility, metro systems are increasingly recognized for their role in promoting sustainable development. By integrating with non-motorized and other public transport modes, metro systems enhance the accessibility and inclusivity of urban transit networks. This integration fosters multi-modal travel, reduces dependency on motorized vehicles, and supports the transition to greener cities [7,8].

Internationally, cities such as Amsterdam, Copenhagen, and Tokyo have set benchmarks for bicycle–transit integration by fostering secure bicycle parking, bike-sharing systems, and dedicated cycling lanes. These measures have enhanced urban mobility, reduced dependency on motorized vehicles, and promoted eco-friendly commuting practices. Such practices highlight the potential of integrating bicycles with metro systems, particularly in addressing accessibility gaps for commuters residing beyond walking distance from transit nodes [9].

In contrast, developing countries like Bangladesh face unique challenges in implementing similar integration due to infrastructural deficits, socioeconomic disparities, and an underdeveloped cycling culture. Dhaka, one of the world's most densely populated megacities with over 24 million residents, is grappling with chronic traffic congestion, limited public transport options, and environmental pollution [10]. The recent introduction of the Dhaka Metro system represents a transformative step toward mitigating these challenges. However, its success heavily depends on its ability to connect effectively with NMT modes like bicycles, which are cost-effective and environmentally sustainable options for a large segment of the population [11].

Without a clear understanding of commuter perceptions and preferences, policymakers and the authorities face difficulties in designing effective strategies to promote bicycle–metro integration. This integration is critical for enhancing the metro rail system's utility, reducing dependency on motorized vehicles, and fostering sustainable urban mobility. As Dhaka's metro rail system is in its early stages, there is an urgent need to explore the feasibility of incorporating bicycles into the transit network, particularly from the perspective of the end users. This study addresses the critical gap in research by investigating metro users' perceptions of bicycle–metro integration in Dhaka. By identifying and prioritizing the key attributes that influence commuter behavior, this research aims to provide actionable insights to develop a more inclusive, efficient, and sustainable urban transportation system. This paper begins by exploring the relevant literature to establish the context and identify critical factors influencing metro–cycle integration. It then details the study area, data collection process, and analytical approach employed to examine commuter preferences. The findings are discussed in light of their implications for improving bicycle–metro integration, followed by a conclusion that highlights the key insights, limitations, and directions for future research.

2. Research Gaps and Novelty

Despite the growing recognition of bicycle–metro integration as a sustainable solution for enhancing urban mobility, significant research gaps remain, particularly in the context of developing countries like Bangladesh. Much of the existing literature focuses on metro–cycle integration in developed cities, such as Copenhagen, Amsterdam, and Tokyo, where cycling culture and infrastructure are well-established. These studies often highlight factors like secure parking, dedicated cycling lanes, and multi-modal ticketing. However, the unique socioeconomic, cultural, and infrastructural challenges of integrating bicycles with metro systems in densely populated and resource-constrained cities like Dhaka remain underexplored. Additionally, while global research emphasizes commuter preferences, few studies delve into how these preferences vary by socioeconomic characteristics in rapidly urbanizing cities.

The novelty of this study lies in its contextual focus on Dhaka, a city where the metro rail system is at a nascent stage and cycling infrastructure is underdeveloped. This study bridges the research gap by prioritizing the attributes critical to metro–cycle integration from the perspective of metro users in Dhaka, employing a combination of RIDIT and TOPSIS analyses. These methodologies provide a comprehensive framework for ranking user preferences and addressing first- and last-mile connectivity issues.

3. Literature Review

In order to meet the increasing difficulties of urban mobility, especially with regard to first- and last-mile connectivity, bicycle integration with metro systems is an essential answer. Numerous studies globally have examined various aspects affecting commuters' preferences and the effective implementation of bicycle–metro integration.

3.1. Global Experiences of Bicycle–Metro Integration

Bicycles have been effectively incorporated into metro systems in many cities globally to improve urban mobility. Research by Rietveld (2000) underscores the advantages of bicycles as a means of access for metro users. Rietveld discovered that 35% of commuters utilized bicycles to access metro stations, especially near the origin of their trips [12]. Nevertheless, insufficient parking availability and the potential for theft significantly dissuaded numerous commuters. Pucher and Buehler (2009) examined the effectiveness of bicycle–transit integration in European cities such as Amsterdam and Copenhagen, highlighting the necessity for dedicated bike lanes, secure parking facilities, and bicycle-friendly infrastructure within metro stations [13].

The circumstances in countries that are developing are more intricate. Pucher et al. (2011) identified that in cities such as Delhi and Beijing, swift urbanization and the prevalence of motorized transportation have posed considerable obstacles to bicycle utilization [14]. Inadequate infrastructure, congested traffic, and safety issues hinder commuters from using bicycles as a dependable means for first- and last-mile connectivity. Bicycles, however, provide a cost-effective and environmentally responsible substitute that, with the right infrastructure, may significantly reduce traffic and pollution.

3.2. Factors Influencing Bicycle–Metro Integration

Multiple factors affect passengers' choices to utilize bicycles for accessing metro systems. These elements can be classified into infrastructure-related, socioeconomic, and environmental categories.

- Factors Pertaining to Infrastructure: Research by Parkin et al. (2008) indicates that the presence of bicycle lanes, secure parking facilities, and well-structured access routes to metro stations are essential for promoting bicycle utilization. In the absence of these, commuters are less inclined to regard cycling as a feasible alternative. The research highlighted the necessity of incorporating bicycle infrastructure with metro stations, encompassing the provision of bike-sharing systems and bike racks within trains or at stops [15].
- Safety and Security: Safety is a crucial factor for passengers. Research conducted by Heinen and Bohte (2014) and Zhao and Li (2018) highlighted that apprehensions over traffic safety and the security of bicycles at stations significantly influence commuters' decisions to pedal. The investigations revealed that in the absence of secure parking

and safe cycling routes, several commuters favor alternative forms of transportation, despite cycling being more cost-effective or environmentally sustainable [16,17].

- Socioeconomic Variables: Socioeconomic factors, including income, age, gender, and car ownership, substantially affect commuters' choices for bicycle–metro integration. Parkin et al. (2008) discovered that younger commuters and people with lesser salaries are more inclined to cycle, whereas older and wealthier individuals typically depend on vehicle transportation [15]. Zhao and Li (2018) discovered that higher-income demographics in Beijing had a lower propensity to utilize bicycles for accessing metro stations, attributing this behavior to apprehensions regarding comfort and safety [17].
- Environmental and Geographical Factors: Meteorological conditions, topography, and the distance from residence to the metro station are other critical considerations. Pucher et al. (2009) identified that severe weather conditions, including heat and monsoon rains, significantly impede bicycle usage in Indian towns [13]. Moreover, undulating landscapes or considerable distances to metro stations may dissuade commuters from selecting bicycles.

The figure is a co-authorship network visualization map created using VOSviewer. It maps the relationships and clustering among authors referenced in this study. The co-authorship network map in Figure 1 visually illustrates the collaborations and thematic clusters among the authors cited in this research. Each node represents an author, while the size of the node indicates the frequency of their citations. Clusters are color-coded, signifying different thematic groups or closely related topics within the literature.

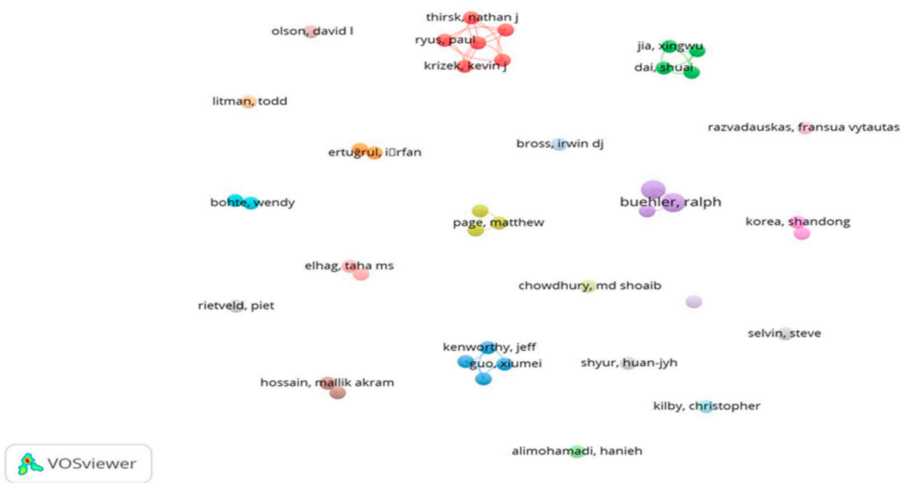


Figure 1. Literature framework.

The central red cluster consists of authors such as Thirsk, Nathan J., Ryus, Paul, and Krizek, Kevin J., who have contributed significantly to the literature on pedestrian and bicycle network integration. Their works focus on international practices for creating safe and connected infrastructure for non-motorized transportation, aligning closely with the themes of bicycle–metro integration. Buehler, Ralph is highlighted in a distinct purple cluster, emphasizing his contributions to research on bicycle infrastructure and integration with public transport systems in North America and Europe [12,13,17].

Authors like Litman, Todd, and Olson, represented in orange and pink clusters, respectively, focus on evaluating transportation accessibility and using multi-criteria decision-making (TOPSIS), providing foundational methodologies for analyzing infrastructure priorities, which are applied in this study. Heinen, E. and Bohte, Wendy (in the blue cluster) emphasize research on traffic safety and factors affecting commuter mode choices, which are crucial for understanding safety concerns in bicycle–metro integration. Razvadauskas, Vytautas, South, and Korea, in the green cluster, address socioeconomic aspects and urban planning issues in densely populated cities, including challenges related to transportation systems in megacities like Dhaka. Authors like Ertuğrul, İrfan and Elhag, Taha MS (in the teal cluster) contribute to methodological advancements, specifically in the application of fuzzy TOPSIS and analytic hierarchy processes, which are relevant for the multi-criteria evaluation methods used in this study. The network map thus reveals interconnected research areas, highlighting both foundational studies on non-motorized transport and the methodologies applied in multi-criteria decision-making [16,18–22].

The methodologies employed in studies on metro–cycle integration often blend quantitative and qualitative approaches to evaluate commuter preferences and prioritize infrastructure improvements. Rietveld (2000) conducted a statistical analysis of commuter behavior in the Netherlands, emphasizing the role of secure parking and bike-sharing systems near metro stations. The study utilized survey data to assess the frequency and determinants of bicycle usage for station access. Parkin et al. (2008) employed regression models to analyze the influence of socioeconomic and infrastructural factors on bicycle mode share, using census data as a primary source. Similarly, Pucher and Buehler (2009) relied on comparative case studies to examine best practices in European cities, integrating qualitative insights with quantitative metrics such as modal share and safety records [12–14].

In developing countries, studies by Zhao and Li (2018) used structured interviews and Likert-scale surveys to understand barriers to cycling in urban environments, with a focus on infrastructure deficits and safety concerns. These studies often combine descriptive statistics with hypothesis testing, such as chi-square tests, to explore differences in commuter preferences across demographic groups. Advanced methodologies like RIDIT analysis, first introduced by Bross (1958), have been applied to rank commuter priorities based on survey responses. This method standardizes attribute scores, enabling researchers to identify significant disparities in perception [16,23].

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method is another prevalent approach, employed by Wang and Elhag (2006) to rank attributes of transit systems by calculating their closeness to an ideal solution. TOPSIS evaluates multiple criteria, such as safety, accessibility, and parking facilities, using weighted scores derived from commuter surveys. Multi-criteria decision-making frameworks like fuzzy analytic hierarchy processes (AHPs) have also been adopted for evaluating transport integration strategies in studies such as Ertuğrul and Karakaşoğlu (2009) [24,25].

Survey-based methodologies remain a cornerstone for capturing commuter perspectives. Many studies employ mixed-method designs, combining quantitative surveys with qualitative interviews to provide a holistic understanding of user needs. These approaches are often complemented by secondary data analysis, such as using census or transport authority data, to contextualize findings within broader urban mobility patterns. The integration of statistical tools and decision-making frameworks across these studies underscores the importance of a multi-faceted approach to understanding and improving metro–cycle integration globally.

4. Methodology

This study utilizes a systematic methodology to assess commuters' perceptions of the integration of bicycles with the Dhaka Metro system. The research aims to identify critical elements affecting metro users' behavior, gather and analyze their perceptions, and examine potential variability in responses among socioeconomic categories. The total method comprises three essential steps: attribute identification, questionnaire design, and data collecting and analysis.

4.1. Study Area: Dhaka Mass Rapid Transit System (MRT)

Dhaka, the capital of Bangladesh, serves as the study area for this research, offering a unique context due to its rapid urbanization and ongoing transformation in public transportation infrastructure. As one of the largest and most densely populated cities in the world, Dhaka is home to over 24 million residents and faces severe challenges related to traffic congestion, pollution, and inadequate transportation systems [10,26]. With a population density of approximately 47,400 people per square kilometer, the city's transportation needs are immense and diverse, driven by its fast-growing population and expanding economic activities [11,27]. Dhaka's Mass Rapid Transit (MRT) system is a transformative initiative to address severe traffic congestion and improve mobility for its 24 million residents. The plan includes six MRT lines spanning 129.9 km. MRT Line 6, the first operational line, connects Uttara to Motijheel over 20.1 km, significantly reducing travel times. Future lines, including MRT 1 and 5, will link key areas like Hazrat Shahjalal Airport, Purbachal, and Gabtoli. Designed for efficiency, the MRT system integrates with other transport modes to ensure seamless connectivity. Expected to be completed by 2030, the MRT aims to enhance urban mobility and support Dhaka's sustainable development (Figure 2) [28,29].

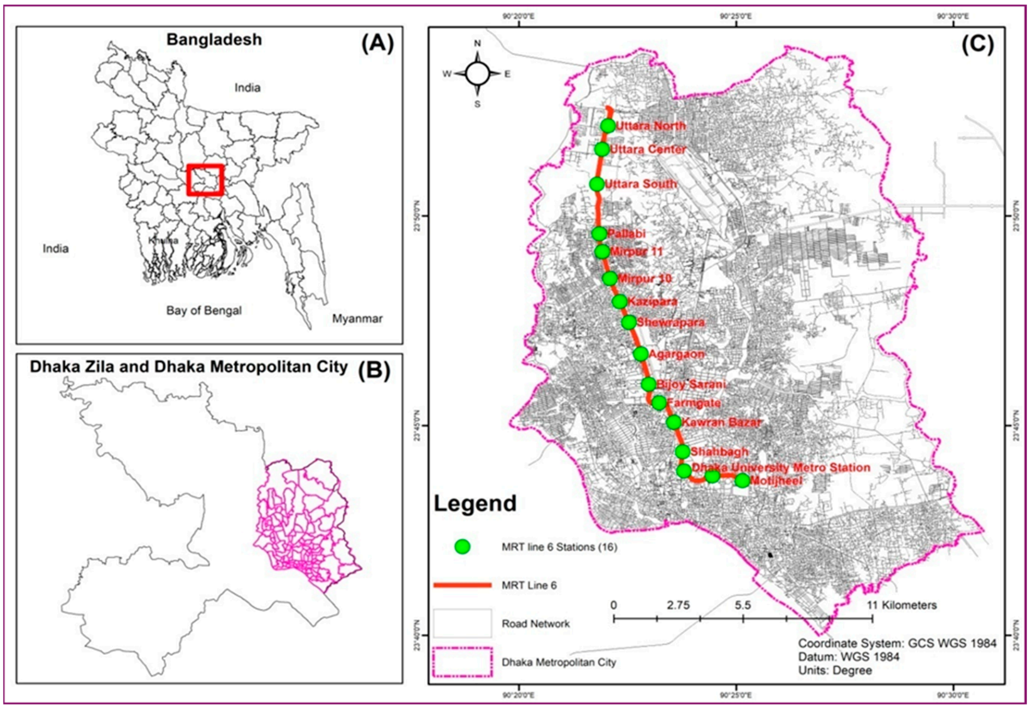


Figure 2. (**A**) Bangladesh Map, (**B**) Dhaka District Map, (**C**) Routes of MRT Line—6.

4.2. Identification of Key Attributes

The identification of key attributes for this study was guided by an extensive literature review of metro–cycle integration practices from both developed and developing urban contexts. These attributes were drawn from prior research focusing on factors that influence commuter behavior, preferences, and the feasibility of integrating bicycles with metro systems.

Globally, studies have highlighted the importance of infrastructure-related factors, such as the availability of secure bicycle parking facilities, dedicated cycling lanes, and well-designed access routes to metro stations. Research by Parkin et al. (2008) emphasized that these factors are crucial for encouraging commuters to use bicycles as a mode of access to metro systems. Similarly, the presence of well-integrated bike-sharing systems and bicycle ramps has been identified as enablers of seamless connectivity between cycling and metro commuting [14].

Safety and security also emerged as critical determinants, particularly in urban contexts where traffic congestion and theft are prevalent. Studies by Heinen and Bohte (2014) and Zhao and Li (2018) underscored the importance of safe cycling routes and secure parking to mitigate risks and encourage cycling as a reliable first- and last-mile solution. In addition to infrastructure and safety, journey-related attributes such as access time, journey comfort, and ease of connectivity were frequently cited in the literature. Multi-modal ticketing systems, which allow for seamless transitions between transport modes, have been shown to enhance commuter convenience and reduce the barriers to using multiple transport modes [15,16].

The socioeconomic and environmental contexts of commuters also informed the identification of key attributes. Factors such as income level, gender, age, and car ownership influence preferences for bicycle use, as highlighted by Parkin et al. (2008). Environmental considerations, including weather conditions and geographical terrain, further shape commuter behavior, as demonstrated in studies from cities like Delhi and Beijing [14]. For this study, these attributes were refined and contextualized to Dhaka's unique urban landscape. Local factors, such as inadequate cycling infrastructure, socioeconomic diversity, and the nascent stage of the metro rail system, were considered. Consultations with transportation experts and urban planners helped validate and adapt these attributes to ensure their relevance to Dhaka. The factors influencing commuter decisions regarding bicycle–metro integration are given below:

4.3. RIDIT Model

RIDIT analysis is a recognized methodology in Multi-Attribute Decision Making (MADM), first introduced by Bross in 1958 [30]. The designation "RIDIT" was selected for its resemblance to terminology such as "probits" and "logits". The initial three letters of RIDIT signify "Relative to an Identified Distribution", and the concluding two letters "it" represents a specific transformation type. RIDITs are fundamentally derived from the observed distribution of a response variable within a designated set of people. This approach is intimately associated with distribution-free methods grounded in ranks, as shown by the Wilcoxon test [24]. RIDIT analysis possesses two critical properties. Firstly, it assigns a rank value to each class in proportion to the relative frequency of observations within that class. Secondly, the rank value is standardized within a range of 0 to 1. This standardization property eliminates issues related to variations in the relative positions concerning the number of ranks. The RIDIT technique effectively mitigates differences in the shape of distributions [31].

Procedure

Step 1: A reference dataset must be identified. In the case of standard Likert-scale survey data, the aggregate responses may serve as a reference dataset when the population is indeterminate.

Step 2: The frequency fi for each category of replies, where $j = 1, \ldots, n$, must be computed.

Step 3: The mid-point accumulated frequency Fj for each response category must be calculated.

$$F_1 = \frac{1}{2} f_1 \Big]$$

$$F_j = \frac{1}{2} + \sum_{k=1}^{j-1} f_k \quad \text{where k} = 2,\ 3,\ 4, \ldots\ldots\ldots., \text{n}$$

Step 4: Calculate the RIDIT value Rj for each response category in the reference dataset.

$$R_j = \frac{F_j}{N} \quad \text{where j} = 1, 2, 3, 4, \ldots\ldots, \text{n}$$

In the aforementioned statement, *N* denotes the aggregate number of replies from the Likert-scale survey. The predicted value of *R* for the reference data set is, by definition, always 0.5.

Step 5: Calculate RIDITs and mean RIDITs for the comparative datasets. A comparative dataset consists of the response frequencies for each category of a Likert-type scale item. If there are m Likert-type scale items on the answer scale, there will be m corresponding comparison data sets. The RIDIT value *rij* must be computed for each category according to the subsequent formula:

$$r_{ij} = \frac{R_j * \pi_{ij}}{\pi_i} \quad \text{where I} = 1, 2, 3, 4, \ldots\ldots, \text{n}$$

πij denotes the frequency of category j for the ith scale item, while πi represents the aggregate of frequencies for scale item i over all categories, i.e.,

$$\pi_i = \sum\nolimits_{k=1}^{n} \pi_{ik}$$

The average RIDIT ρi for each Likert-scale item must be computed using the subsequent formula:

$$\rho_i = \sum\nolimits_{k=1}^{n} r_{ik}$$

Step 6: Calculate the confidence interval for ρi. When the reference data set is significantly larger than any comparative data set, the 95% confidence interval for any ρi is as follows:

$$\rho_i \pm \frac{1}{\sqrt{3\pi i}}$$

Step 7: Test the following hypothesis using the Kruskal–Wallis statistic:

$$H_0 = \forall i,\ \rho i = 0.5$$

$$H_a = \exists i,\ \rho i \neq 0.5$$

$$W = 12\sum\nolimits_{i=1}^{m} \ \pi_i(\rho_i \ - 0.5)^2$$

The following section outlines the general guidelines for interpreting the values of ρ:

Firstly, if the ρi value of a scale item statistically differs from 0.5, it suggests a significant distinction in the response patterns between the reference dataset and the comparison dataset for that specific scale item. When the confidence interval of ρi contains 0.5, it signifies that the ρi value is not significantly different from 0.5.

Secondly, a lower ρi value is given a higher rank compared to a higher ρi value. This is because a low ρi value indicates a lower likelihood of having a negative propensity.

Thirdly, when the confidence intervals of ρi overlap, the response patterns of scale items are considered statistically indistinguishable among the respondents.

Based on the prioritization results obtained from RIDIT analysis, the research conducts necessary interpretations. These interpretations are valuable in the context of bicycle–metro integration in Bangladesh. In this specific case, the study presents a pilot investigation focused on Dhaka, a metropolitan city in Bangladesh where the metro rail system is in its early stages. Positive user perceptions regarding various attributes can be beneficial for future efforts to promote bicycle integration with public transit in the Bangladeshi setting.

4.4. TOPSIS Model

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), introduced by Hwang and Yoon in 1981, is an effective approach to multi-attribute decision-making. TOPSIS identifies the optimal alternative by determining the one closest to the positive ideal solution while being farthest from the negative ideal solution [25]. The positive ideal solution represents the best possible values for each criterion, whereas the negative ideal solution consists of the worst possible values, as described by Wang and Elhag in 2006 [26]. The method calculates proximity to these two extremes using n-dimensional Euclidean distance (e.g., the square root of the sum of squared distances for each criterion in the attribute space). Additionally, different weights can be assigned to each attribute, as highlighted by Olson in 2004, to reflect their relative importance [32].

In the current study, the TOPSIS method is implemented with the following steps, following the guidance of [33]:

Step 1: Create a decision matrix (denoted as "d") for ranking purposes. The structure of this matrix can be expressed as follows: [Provide details of the matrix structure].

Top of Form

$$\begin{array}{lll} & B_1 & B_2 \ldots\ldots B_j \ldots\ldots B_n \\ \mathrm{d} = A_i & f_{i1} & \quad f_{ij} \ldots\ldots fin \\ \quad A_j & f_{j1} & \quad fij \ldots\ldots fjn \end{array}$$

Step 2: Calculate the normalized decision matrix $\boldsymbol{R}(= [\boldsymbol{r_{ij}}])$.

The normalized value $\boldsymbol{r_{ij}}$ is calculated as follows:

$$\boldsymbol{r_{ij}} = \frac{\boldsymbol{f_{ij}}}{\sqrt{\sum_{j=1}^{J} \boldsymbol{f_{ij}^2}}} \qquad \mathrm{j} = 1,\ 2,\ 3 \ldots\ldots\ldots.,\ \mathrm{J} \quad \mathrm{i} = 1,\ 2,\ 3 \ldots\ldots\ldots\ldots\ldots,\ \mathrm{n}$$

Step 3: To calculate the weighted normalized decision matrix, each element of the normalized decision matrix is multiplied by its corresponding weight. The weighted normalized value $\boldsymbol{x_{ij}}$ is calculated as follows:

$$\boldsymbol{x}_{ij} = w_{ij} * r_{ij} \qquad \mathrm{j} = 1,\ 2,\ 3 \ldots\ldots\ldots.,\ \mathrm{J} \quad \mathrm{i} = 1,\ 2,\ 3 \ldots\ldots\ldots\ldots\ldots,\ \mathrm{n}$$

where w*i* represents the weight of the *i*th attribute or criterion.

Step 4: Determine the positive ideal solution (S^+) and negative ideal solutions (S^-):

$$S^+ = \{x_1^+, x_2^+, x_3^+, x_4^+ \ldots\ldots\ldots\ldots, x_n^+\}\text{maximum values}$$

$$S^- = x_1^-, x_2^-, x_3^-, x_4^- \ldots\ldots\ldots\ldots, x_n^-\}\text{minimum values}$$

Step 5: Determine the separation measures by calculating the n-dimensional Euclidean distance. Calculate the separation of each alternative from the positive ideal solution:

$$D_j^+ = \sqrt{\sum_{i=1}^{n} \left(x_{ij} - x_i^+\right)^2} \qquad \mathrm{j} = 1,\ 2,\ 3 \ldots\ldots\ldots.,\ \mathrm{J}$$

Similarly, calculate the separation of each alternative from the negative ideal solution:

$$D_j^- = \sqrt{\sum_{i=1}^{n} \left(x_{ij} - x_i^-\right)^2} \qquad \mathrm{j} = 1,\ 2,\ 3 \ldots\ldots\ldots.,\ \mathrm{J}$$

Step 6: Calculate the relative closeness to the ideal solution and rank the performance order. The relative closeness of the alternative A_j can be expressed as follows:

$$C_j^* = \frac{D_j^-}{D_j^+ + D_j^-}$$

where C_j^* = index value lies between 0 and 1. The larger the index value means the better the performance of the alternatives.

The selection of TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and RIDIT analyses for this research is based on their suitability for addressing the study's objectives and the nature of the dataset. TOPSIS was chosen for its ability to rank attributes by measuring their proximity to an ideal solution and their distance from a worst-case scenario. This method effectively highlights the most critical attributes for bicycle–metro integration, such as secure parking and safety measures, while identifying lower-priority factors like road design and weather conditions. TOPSIS is particularly advantageous due to its capacity to handle weighted criteria, allowing attributes with varying levels of importance to be prioritized accurately. Additionally, its computational simplicity and efficiency make it ideal for the pilot nature of this study. On the other hand, RIDIT analysis complements TOPSIS by providing a distribution-based approach to assess the relative importance of attributes. It is particularly suited for analyzing Likert-scale survey data, as it ranks attributes based on response patterns relative to a reference distribution without assuming equal intervals between categories. RIDIT also emphasizes consensus, highlighting attributes with strong agreement among respondents, such as multi-modal ticketing and journey comfort. Compared to other MADM methods like AHP or Fuzzy TOPSIS, which are either more complex or less intuitive for this dataset, TOPSIS and RIDIT offer a balanced combination of objective prioritization and subjective insights. Together, these methods ensure a comprehensive analysis by leveraging TOPSIS's ability to identify optimal solutions and RIDIT's focus on response distribution and consensus, making them the most appropriate tools for prioritizing metro–cycle integration attributes in Dhaka.

4.5. Questionnaire Design and Data Collection

The data for this study were collected through face-to-face oral interviews. A travel behavior questionnaire was specifically designed to gather information on users' socioeconomic characteristics, trip-making behaviors, and individual perceptions of bicycle–metro integration attributes. The development of the questionnaire was based on an extensive review of the literature, which involved analyzing previous research on metro–bicycle integration and examining questionnaires used in various transit systems globally [12–15,34,35]. The questionnaire was comprised of two sections. The first section acquires non-parametric information on socioeconomic characteristics (age, gender, education, and occupation) and travel behavior (travel pattern, travel distance, travel time, and travel cost). The second section acquires parametric information about the importance level of user perception on bicycle–metro integration, which covers parameters such as Physical Attributes, Journey-Related Attributes, Route Characteristics, and Bicycle Infrastructure-Related Attributes (Table 1).

The initial version of the questionnaire was reviewed by seven regular metro users and two experts to ensure that the items were well-structured. Substantial revisions were made based on their feedback, which was incorporated into a pilot survey. Perception data were collected using a standard five-point Likert scale (1 = Low Importance to 5 = Very High Importance). The on-site survey was conducted in January 2024 at Metro Rail Line 6 stations and onboard trains during peak and off-peak hours on weekdays and weekends in Dhaka.

Table 1. List of identified attributes relevant to bicycle–metro integration.

SI.	Factor Category	Attribute
1	Physical Attributes	Road design
2		Weather condition
3		Surface condition
4		Station design
5		Safety measures
6	Journey-Related Attributes	Access time
7		Access distance
8		Journey comfort
9		Multi-modal ticketing system
10		Visual communication
11	Route Characteristics	Traffic congestion
12		Mobility
13		Connectivity
14		Risks from motorized vehicles
15	Bicycle Infrastructure-Related Attributes	Bicycle lane
16		Bicycle security
17		Bicycle parking facility
18		Bicycle maintenance and safety
19		Bicycle ramp
20		Bicycle parking charge
21		Bicycle rental deposit

Due to the absence of a defined population of public transit users, data were collected using a convenience purposive sampling technique. For each identified attribute (Table 1), respondents were presented with five options and asked to indicate their perceived level of importance on a five-point scale: Very High Importance, High Importance, Neutral, Low Importance, or Very Low Importance. Since the study aimed to assess the attributes of cycle–metro integration, participants were required to have some prior understanding of integration concepts. Those who agreed to participate completed a pencil-and-paper questionnaire under the supervision of data collectors.

A total of 400 users participated in the survey, of which 18 responses were excluded due to incomplete data, leaving 382 valid responses for database development and analysis. One key limitation of this study is its relatively small sample size. However, as a pilot study, it provides foundational insights that will inform a more comprehensive, long-term evaluation of the feasibility of bicycle–metro integration in the Bangladeshi context.

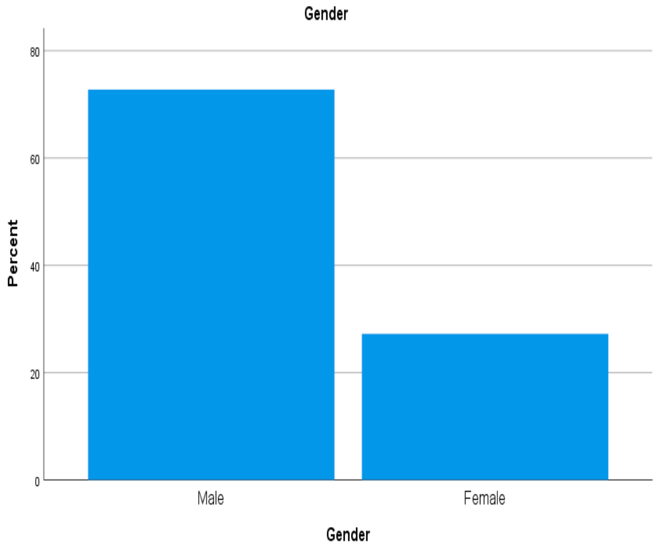
4.6. Statistical Tools

All statistical analyses for this study were conducted using a combination of MS Excel and SPSS 25.0 to ensure accuracy and efficiency in handling the dataset and performing computations. MS Excel was employed for implementing the TOPSIS and RIDIT analyses, leveraging its flexibility and ease of performing complex mathematical operations and decision-making computations. SPSS 25.0 was utilized for creating visual representations, including graphs and charts, to effectively communicate the results and provide a clear understanding of the findings. The combined use of these tools facilitated a comprehensive approach to data analysis, ensuring the methodological rigor required for prioritizing attributes and interpreting commuter perceptions in the context of bicycle–metro integration in Dhaka.

5. Data Analysis

5.1. Socioeconomic Condition of the Respondents

A total of 382 participants attended the face-to-face oral survey; the proportion of male respondents was higher compared to female respondents. There were 72.8% male and 27.2% female respondents in this study. The lower participation of women in the survey can be attributed to the socioeconomic and cultural context of Dhaka. The MRT line in this study runs through the most commercial hubs of the city, areas predominantly occupied by office workers. In Dhaka's social context, the majority of office workers in these commercial zones are male. Consequently, the user base of the metro rail and, thus, the participants in our survey are predominantly male. This reflects the broader gender disparity in workforce participation and public transport usage patterns observed in Dhaka, where men are more likely to be regular commuters in such urban transit systems. The majority of responders belong to the 21–30 age group (51.1%), signifying a youthful demography. The representation diminishes with age, indicating a possible emphasis or attraction to younger demographics. A significant percentage of respondents possess a bachelor's degree (44.5%) or above (31.4%), indicating a highly educated sample. A mere 1.8% possesses an education below the secondary school level. Students constitute the predominant occupational category (39.8%), corresponding with the younger age demographic. The main goals for trips are office (31.7%), education (19.1%), recreation (16.5%), and visiting friends and relatives (14.1%). This indicates a varied array of activities among the respondents, with a significant focus on employment, education, and social engagements. Metro passengers exhibit a 57.9% irregularity rate and a 42.1% regularity rate (Figure 3).



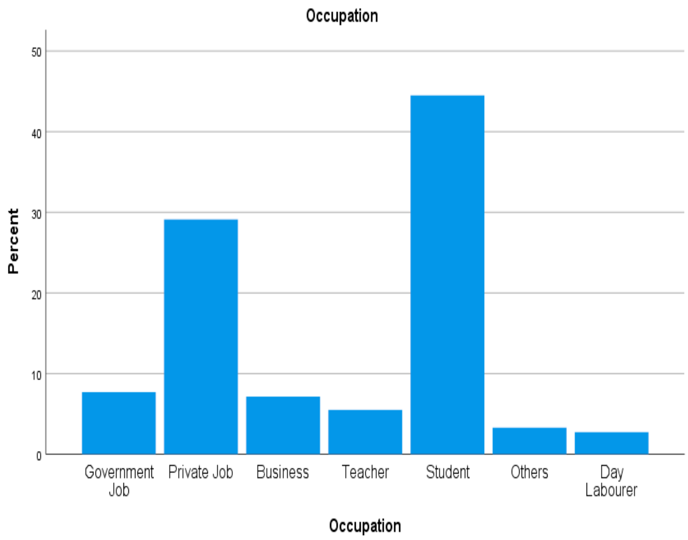


Figure 3. *Cont.*

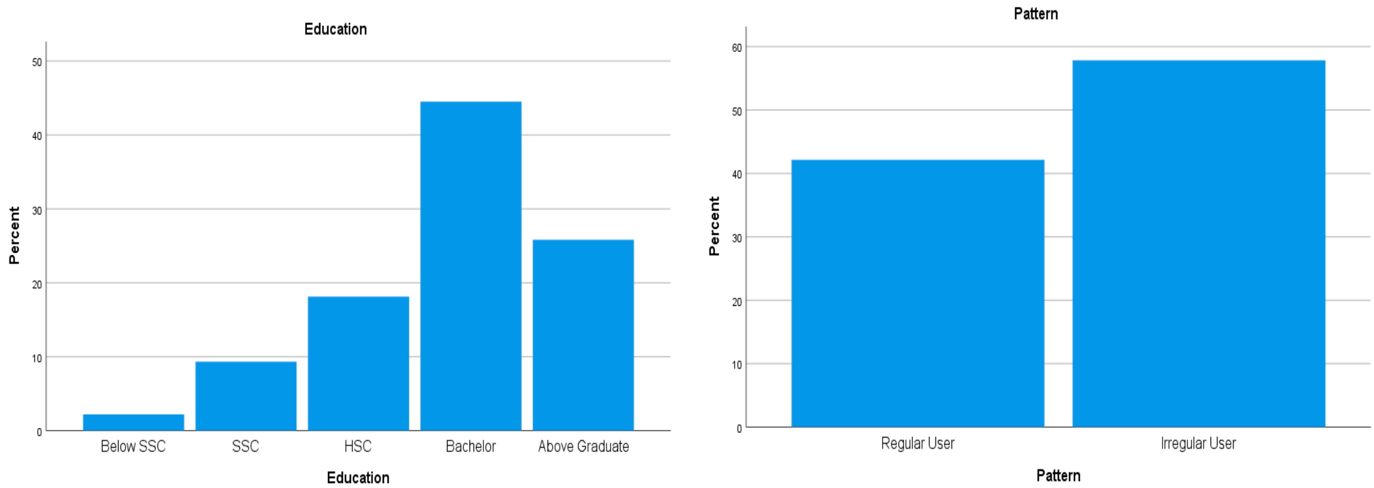


Figure 3. Socioeconomic profile of the respondents.

5.2. Heterogeneity Analysis Using Kruskal–Wallis H-Test

The Kruskal–Wallis H-test, a non-parametric method, was employed to examine variations in perceptions among socioeconomic groupings (Table 2). This test is specifically designed for ordinal data, such as Likert-scale replies, and enables the identification of significant differences in how various groups assess the value of particular traits. A *p*-value below 0.05 was deemed statistically significant, signifying evidence of heterogeneity in commuter perceptions.

Table 2. Summarized list of *p*-value for Kruskal–Wallis H-test across different socioeconomic classifications.

Attribute	Gender	Travel Pattern	Occupation	Education
Road design	0.073	0.649	0.611	0.022
Weather condition	0.745	0.337	0.423	0.133
Surface condition	0.962	0.204	0.389	0.763
Station design	0.833	0.837	0.976	0.843
Safety measures	0.719	0.313	0.709	0.864
Access time	0.929	0.526	0.298	0.206
Access distance	0.615	0.408	0.231	0.403
Journey comfort	0.043	0.582	0.331	0.141
Multi-modal ticketing system	0.416	0.306	0.523	0.059
Visual communication	0.807	0.996	0.174	0.031
Traffic congestion	0.808	0.697	0.445	0.082
Mobility	0.228	0.297	0.437	0.514
Connectivity	0.167	0.702	0.500	0.653
Risks from motorized vehicles	0.047	0.470	0.867	0.051
Bicycle lane	0.586	0.097	0.556	0.730
Bicycle security	0.537	0.625	0.898	0.397
Bicycle parking facility	0.562	0.513	0.070	0.098
Bicycle maintenance and safety	0.103	0.272	0.082	0.271
Bicycle ramp	0.051	0.582	0.714	0.440
Bicycle parking charge	0.467	0.114	0.087	0.994
Bicycle rental deposit	0.093	0.491	0.494	0.485

The investigation identified substantial disparities influenced by particular socioeconomic characteristics. Perceptions of road design significantly differed by education level (p = 0.022), indicating that individuals with varying educational backgrounds possess divergent opinions regarding the importance or effectiveness of road design. Similarly, travel comfort shows a significant difference based on gender (p = 0.043), suggesting that male and female travelers may perceive comfort levels during transit differently. The study indicated that the perceived danger linked to motorized vehicles varied by gender (p = 0.047), highlighting gender-specific differences in safety concerns during commuting. Furthermore, judgments of visual communication, such as signage and informational displays, showed considerable variance according to education level (p = 0.031), indicating that education may influence commuters' understanding or priority of visual information (Table 2).

5.3. Ranking of Factors Using RIDIT and TOPSIS Analyses

5.3.1. RIDIT Analysis

In RIDIT analysis, the ρi (RIDIT score) signifies the cumulative ranking of each attribute according to the distribution of responses from Very High to Very Low in the reference dataset. The ρi value quantifies the relative significance or priority as judged by respondents. Elevated ρi values signify increased significance attributed to an attribute, facilitating a ranking according to commuter preferences. The attributes with the highest rankings in this study correspond to the biggest ρi values, indicating their priority among respondents. The Bicycle Parking Facility has a ρi of 0.788 (Rank 1), with lower and upper bounds of 0.759 and 0.818, respectively. The elevated score indicates that most respondents prioritize secure and accessible bicycle parking facilities, deeming it a critical factor for enhancements. The limited interval between LB and UB indicates a strong consensus among responders concerning its significance (Table 3).

Table 3. RIDIT-based prioritization.

RIDIT-Based Prioritization														
RIDIT Values for Reference Data Set						RIDIT Values for Comparison Data Set								
Attribute	Very High	High	Neutral	Low	Very Low	Very High	High	Neutral	Low	Very Low	ρi	LB	UB	Rank
Road design	86	176	110	8	2	0.057	0.174	0.207	0.019	0.005	0.464	0.434	0.493	18
Weather condition	63	149	151	16	3	0.042	0.148	0.284	0.039	0.008	0.521	0.491	0.550	13
Surface condition	115	154	107	4	2	0.077	0.153	0.202	0.010	0.005	0.446	0.416	0.475	20
Station design	98	180	97	2	5	0.065	0.178	0.183	0.005	0.013	0.444	0.415	0.474	21
Safety measures	100	174	100	6	2	0.067	0.172	0.188	0.015	0.005	0.446	0.417	0.476	19
Access time	39	98	122	105	18	0.026	0.097	0.230	0.255	0.047	0.655	0.625	0.684	3
Access distance	37	125	150	65	5	0.025	0.124	0.283	0.158	0.013	0.602	0.573	0.632	8
Journey comfort	69	142	121	44	6	0.046	0.141	0.228	0.107	0.016	0.537	0.508	0.567	11
Multi-modal ticketing system	70	163	121	23	5	0.047	0.161	0.228	0.056	0.013	0.505	0.476	0.535	14
Visual communication	38	92	124	105	23	0.025	0.091	0.234	0.255	0.060	0.665	0.636	0.695	2
Traffic congestion	40	110	134	86	12	0.027	0.109	0.252	0.209	0.031	0.628	0.599	0.658	7
Mobility	78	131	102	69	2	0.052	0.130	0.192	0.168	0.005	0.547	0.517	0.576	10
Connectivity	98	163	100	19	2	0.065	0.161	0.188	0.046	0.005	0.467	0.437	0.496	17
Risks from motorized vehicles	91	146	109	33	3	0.061	0.145	0.205	0.080	0.008	0.499	0.469	0.528	16
Bicycle lane	96	139	108	34	5	0.064	0.138	0.203	0.083	0.013	0.501	0.471	0.530	15
Bicycle security	73	129	112	50	18	0.049	0.128	0.211	0.122	0.047	0.556	0.526	0.585	9

Table 3. *Cont.*

RIDIT-Based Prioritization														
RIDIT Values for Reference Data Set						RIDIT Values for Comparison Data Set								
Attribute	**Very High**	**High**	**Neutral**	**Low**	**Very Low**	**Very High**	**High**	**Neutral**	**Low**	**Very Low**	**ρi**	**LB**	**UB**	**Rank**
Bicycle parking facility	4	53	122	144	59	0.003	0.052	0.230	0.350	0.153	0.788	0.759	0.818	1
Bicycle maintenance and safety	49	99	125	93	16	0.033	0.098	0.236	0.226	0.042	0.634	0.604	0.663	6
Bicycle ramp	74	148	111	44	5	0.049	0.147	0.209	0.107	0.013	0.525	0.496	0.555	12
Bicycle parking charge	33	101	132	110	6	0.022	0.100	0.249	0.267	0.016	0.654	0.624	0.683	4
Bicycle rental deposit	39	106	132	91	14	0.026	0.105	0.249	0.221	0.036	0.637	0.608	0.667	5

Additional features with elevated ρi ratings are Visual Communication (ρi = 0.665, Rank 2) and Access Time (ρi = 0.655, Rank 3). These results demonstrate that clear signage, excellent communication, and prompt access are greatly esteemed by commuters. Visual Communication exhibits a lower bound of 0.636 and an upper bound of 0.695, highlighting uniformity in priority among various response groups. Access Time ranges from 0.625 to 0.684, underscoring its importance to responders who prioritize reduced wait times and prompt access to transportation alternatives. Attributes such as Road Design (ρi = 0.464, Rank 18) and Station Design (ρi = 0.444, Rank 21) exhibit lower ρi values, signifying that these aspects are seen as less essential compared to others. While they enhance the overall traveling experience, they do not require immediate attention or improvements relative to higher-priority features. Attributes pertaining to bicycle facilities, including Bicycle Security (ρi = 0.556, Rank 9) and Bicycle Maintenance and Safety (ρi = 0.634, Rank 6), exhibit somewhat elevated ρi values, indicating that although they are esteemed, they are not prioritized as significantly as parking facilities or access times. This signifies a preference for a cohesive, secure, and well-maintained bicycle infrastructure capable of accommodating an increasing population of riders. The ρi values in this RIDIT-based prioritization distinctly indicate the areas where respondents identify the greatest need for enhancements, with bicycle parking, communication, and access time ranking as the most significant.

5.3.2. TOPSIS Analysis

The TOPSIS analysis provides a ranking of various attributes based on the closeness coefficient Cj*, which measures each attribute's proximity to an ideal solution. A higher Cj* indicates that an attribute closely aligns with optimal conditions preferred by respondents. This coefficient is calculated by comparing each attribute's distance from the ideal positive solution and the negative ideal solution (Table 4).

Table 4. TOPSIS-based rank.

Attribute	dj+	dj−	Cj*	Rank
Road design	0.00023	0.00089	0.79387	7
Weather condition	0.00017	0.00082	0.82973	4
Surface condition	0.00028	0.00091	0.76537	11
Station design	0.00015	0.00070	0.82639	5
Safety measures	0.00025	0.00090	0.78270	9
Access time	0.00096	0.00034	0.26050	21
Access distance	0.00021	0.00069	0.76760	10

Table 4. *Cont.*

Attribute	dj+	dj−	Cj*	Rank
Journey comfort	0.00005	0.00060	0.91839	2
Multi-modal ticketing system	0.00006	0.00068	0.92056	1
Visual communication	0.00129	0.00063	0.32861	19
Traffic congestion	0.00055	0.00026	0.32233	20
Mobility	0.00024	0.00088	0.78513	8
Connectivity	0.00023	0.00089	0.79410	6
Risks from motorized vehicles	0.00015	0.00082	0.84611	3
Bicycle lane	0.00067	0.00094	0.58230	14
Bicycle security	0.00038	0.00033	0.46887	18
Bicycle parking facility	0.00058	0.00119	0.67119	13
Bicycle maintenance and safety	0.00061	0.00058	0.48702	17
Bicycle ramp	0.00024	0.00026	0.52099	15
Bicycle parking charge	0.00015	0.00035	0.70054	12
Bicycle rental deposit	0.00042	0.00042	0.50000	16

The Cj∗ values indicate that the Multi-Modal Ticketing System is the highest-priority attribute, with a Cj∗ of 0.92056. This indicates a pronounced preference for a cohesive ticketing system that improves convenience across various kinds of transportation. Journey Comfort, with a Cj∗ of 0.91839, closely follows, highlighting the importance commuters attribute to comfort during their travels. The danger from motorized vehicles is significant, with a Cj∗ of 0.84611, underscoring the necessity of safety measures to alleviate hazards associated with motorized traffic. Moderate-priority features encompass Weather Condition (Cj∗ = 0.82973), Station Design (Cj∗ = 0.82639), and Connectivity (Cj∗ = 0.79410), signifying that these elements are esteemed, however not as crucial as the highest-ranked attributes.

Attributes of lesser priority with reduced Cj∗ values encompass Access Time (Cj∗ = 0.26050), Traffic Congestion (Cj∗ = 0.32233), and Visual Communication (Cj∗ = 0.32861), indicating a comparatively negligible effect on total commuter satisfaction. Bicycle-related attributes exhibit varied priorities: the Bicycle Lane possesses a moderate Cj∗ score of 0.58230, whereas Bicycle Security and Bicycle Maintenance and Safety are ranked lower with Cj∗ values of 0.46887 and 0.48702, respectively, indicating that secure and well-maintained bicycle facilities are appreciated but not as critically prioritized as the highest-ranking transit features. The Cj∗ values from this TOPSIS analysis underscore priority areas including multi-modal ticketing, travel comfort, and mitigation of risks associated with motorized vehicles. These data provide clarity on specific areas for transit enhancements, highlighting features that align most closely with commuter preferences.

The research on metro users' perspectives regarding bicycle–metro integration in Dhaka offers insights into the essential features for an effective integration system. The study indicates that the "Bicycle Parking Facility" is the highest priority, demonstrating a significant demand among commuters for secure and accessible bicycle storage. This corresponds with international research on bicycle–transit integration, wherein parking availability serves as a crucial facilitator for riding to metro stations. The "Multi-Modal Ticketing System" surfaced as a significant element, exhibiting a high proximity coefficient in the TOPSIS study, suggesting that a cohesive ticketing strategy across various transport modes might substantially improve convenience and user-friendliness for commuters.

The findings emphasize "Journey Comfort" and "Risks from Motorized Vehicles" as essential factors, highlighting the necessity for comfortable transportation alternatives and the imperative to reduce safety hazards linked to motorized traffic. Attributes associated with clear and accessible "Visual Communication" were highly esteemed, indicating that excellent signage and information displays could markedly enhance the passenger experience, especially in a bustling urban environment such as Dhaka.

Notably, "Road Design" and "Station Design" had lower priority ratings, indicating that although these elements influence the overall commuting experience, they are not perceived as urgent obstacles to bicycle–metro integration. Attributes associated with "Traffic Congestion" and "Access Time" exhibited the lowest proximity coefficients, signifying that commuters have a greater tolerance for these concerns relative to the provision of secure facilities and integrated ticketing choices.

6. Discussion

This study's findings correspond with international studies on bicycle–transit integration, highlighting the significance of secure bicycle parking, multi-modal ticketing, commuter comfort, and safety in encouraging bicycle usage for metro access. The emphasis on Bicycle Parking Facility as the foremost attribute corresponds with Rietveld's (2000) findings, which indicate that accessible and secure parking substantially promotes cycling to transportation stations. Research from cities such as Amsterdam and Copenhagen indicates that the efficacy of bicycle–transit integration is significantly dependent on the availability of sufficient, secure parking adjacent to metro and train stations [12]. Analogous to these cities, the findings indicate that Dhaka's achievement in bicycle–metro integration might significantly benefit from secure and accessible parking facilities, which may alleviate theft apprehensions and promote consistent riding to metro stations. The significant focus on the Multi-Modal Ticketing System underscores research from European cities, indicating that integrated ticketing systems are essential for seamless and convenient transit experiences [12,13]. In cities such as Zurich and Berlin, cohesive fare systems across public transportation modalities enhance the passenger experience and facilitate smooth transitions between modes [22].

This study corroborates the findings of Heinen and Bohte (2014) and Zhao and Li (2017), which identified comfort and safety as critical determinants affecting bicycle utilization for transit access in relation to Journey Comfort and Risk from Motorized Vehicles. In urban areas such as Beijing and Delhi, where vehicular traffic poses considerable dangers, commuters frequently hesitate to utilize bicycles owing to safety apprehensions. This survey indicates a comparable mindset in Dhaka, where participants prioritize safety enhancements to mitigate exposure to motorized traffic. Establishing dedicated bike lanes or physical barriers surrounding metro stations, as demonstrated in places such as Tokyo and Copenhagen, could alleviate these issues and enhance cycling as a viable choice for first- and last-mile connectivity. The respondents of this survey underscored the necessity for clear and accessible visual information, particularly pertinent in a highly crowded urban environment such as Dhaka, where effective navigation is crucial. Pucher and Buehler (2009) observed that in places such as Vienna and Munich, clear and comprehensible transit signage bolsters commuter trust and facilitates the smooth integration of various transit modes [12,15,16].

The diminished emphasis on Road Design and Station Design in this study contrasts with findings from several Western cities, where effective road design and station aesthetics are essential for improving the cycling experience [14]. This disparity may indicate Dhaka's primary emphasis on functional, safety-centric infrastructure rather than aesthetics or trivial design aspects. In the long term, as fundamental infrastructure advances, factors such as road and station architecture may increasingly influence commuter preferences and enhance the transit experience. This study's findings underscore the necessity for Dhaka to emphasize pragmatic, safety-focused attributes and cohesive ticketing for effective bicycle–metro integration. In accordance with international best practices, secure parking, efficient ticketing, and safety infrastructure are identified as critical elements.

Globally, several cities have implemented effective metro–cycle integration strategies, providing valuable examples that Dhaka can learn from as it develops its metro rail system. Copenhagen is a global leader in sustainable urban mobility, with over 35% of its metro users accessing stations by bicycle [36]. The city's success lies in its extensive cycling infrastructure, which includes dedicated bike lanes, secure and affordable bike parking facilities, and a well-developed bike-sharing system. These measures make cycling an integral part of daily commuting, providing seamless connectivity between residential areas and metro stations. Dhaka can learn from Copenhagen by investing in similar infrastructure, such as creating secure bicycle parking spaces at metro stations and building dedicated cycling lanes, which would encourage commuters to adopt cycling for first- and last-mile connectivity.

Amsterdam, with its robust cycling culture, has effectively integrated bicycles into its public transport network [37]. The city provides secure bicycle parking at metro and train stations, along with a well-maintained network of cycling paths that enhance accessibility. Amsterdam's bike-sharing programs allow commuters to rent bicycles conveniently, further encouraging cycling as a mode of transit. Dhaka can draw inspiration from Amsterdam by introducing public bike-sharing systems and ensuring safe and affordable parking facilities at metro stations. These measures can promote cycling as a viable and sustainable transport option, particularly in densely populated urban areas where public transport systems are still developing.

Tokyo's metro system exemplifies efficient bicycle integration, featuring secure parking facilities, bicycle ramps, and multi-modal ticketing systems that simplify transit for cyclists [11]. Tokyo also emphasizes the maintenance of its cycling infrastructure, making it accessible to a wide demographic of users. Dhaka can emulate Tokyo by developing multi-modal ticketing systems that integrate bicycles with the metro network. Additionally, providing bicycle ramps and safe parking at metro stations would enhance the usability of bicycles for first- and last-mile connectivity, making the metro more accessible to diverse groups.

Singapore has successfully implemented park-and-ride schemes to integrate bicycles with its metro system [38]. The city provides designated bicycle parking areas near metro stations and promotes safe cycling through protected lanes and cycling-friendly policies. By encouraging cycling as a viable commuting option, Singapore has reduced dependency on motorized vehicles and eased traffic congestion. Dhaka can replicate Singapore's model by introducing park-and-ride facilities and ensuring the development of protected cycling paths. These measures can address safety concerns and encourage more commuters to adopt cycling as a mode of transportation for accessing metro stations.

Delhi, India provides a relevant example for Dhaka as a developing country working towards integrating bicycles with its metro system. The Delhi Metro has introduced bike-sharing programs and installed bike racks at select stations to improve first- and last-mile connectivity. These initiatives, while still evolving, demonstrate how incremental improvements can facilitate bicycle use for metro access in a densely populated urban context. Dhaka can learn from Delhi by prioritizing affordable bike-sharing programs and integrating cycling with its metro network.

By studying the successes of Copenhagen, Amsterdam, Tokyo, Singapore, and Delhi, Dhaka can adopt practical solutions tailored to its unique challenges. These include developing secure bicycle parking facilities, creating dedicated cycling lanes, introducing bike-sharing programs, implementing multi-modal ticketing systems, and addressing safety concerns through public awareness campaigns and infrastructural improvements.

7. Conclusions

This study offers an in-depth examination of metro users' perspectives regarding the integration of bicycles with the Dhaka Metro system, highlighting essential variables that could facilitate an effective bicycle–metro integration framework. The results emphasize secure bicycle parking, a multi-modal ticketing system, journey comfort, and safety as the foremost priorities for commuters. Features such as bicycle parking and ticketing integration are regarded as crucial facilitators, meeting the practical and psychological requirements of cyclists and promoting a more cohesive and accessible transit experience. The survey indicates that Dhaka commuters prioritize safety measures, comfort, and ticketing convenience, while regarding road and station design as secondary concerns. This indicates an immediate necessity for pragmatic, function-focused infrastructure that tackles existing accessibility and security issues, a requirement similarly noted in other swiftly urbanizing areas. Cities with established bicycle–metro networks, like Amsterdam and Copenhagen, have effectively combined secure parking and efficient ticketing, which Dhaka might replicate to promote increased cycling for metro access. This integration in Dhaka not only aims to alleviate traffic congestion but also provides a sustainable transportation alternative that matches with public health and environmental objectives. By establishing secure parking facilities, effective communication infrastructure, and integrated ticketing systems, Dhaka's metro system can accommodate a wider demographic, promote non-motorized transportation alternatives, and facilitate a cultural transition towards sustainable urban mobility. These findings facilitate targeted infrastructure advancements, offering planners practical insights for incorporating bicycles into the metro system. As Dhaka undergoes urbanization, emphasizing these critical components may result in substantial advantages in achieving a cleaner, more efficient, and inclusive transportation system.

8. Study Limitations

This study provides valuable insights into the integration of bicycles with the Dhaka Metro system; however, several limitations must be acknowledged. Firstly, the study is constrained by a relatively small sample size, which may limit the generalizability of the findings to the broader metro user population. Additionally, the sample exhibits an over-representation of male and well-educated riders, which reflects the socioeconomic and cultural context of Dhaka but may not fully capture the perspectives of underrepresented groups, such as women and less-educated individuals. This demographic imbalance could affect the comprehensiveness of the results and their applicability to diverse user segments.

Another limitation lies in the reliance on live polling and face-to-face oral surveys, which, while useful for gathering in-depth data, are time-intensive and require well-trained interviewers to ensure consistent data collection. Variability in interviewer approaches and participant responses could introduce biases. Furthermore, the use of purposive sampling, rather than random sampling, may result in selection bias, as it focuses on individuals more likely to have relevant knowledge or experience with metro–cycle integration.

9. Future Research Direction

Future studies should address these limitations by employing larger, more representative sample sizes to ensure inclusivity across gender, education levels, and socioeconomic groups. Implementing random sampling techniques could further enhance the robustness and reliability of the data. Additionally, digital or online surveys could be explored as an alternative to live polling to save time and reduce the dependency on interviewer training while reaching a wider audience.

Future research should also investigate longitudinal data to assess changes in commuter behavior and perceptions over time as metro and cycling infrastructure in Dhaka evolve. Comparative studies with other developing cities implementing bicycle–metro integration could provide actionable insights and foster the adaptation of best practices. By addressing these limitations and exploring these directions, future studies can contribute to a deeper understanding of bicycle–metro integration and offer more comprehensive recommendations for enhancing urban mobility in Dhaka and similar cities.

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