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Original Article

Integrating Cycling with MRT Jakarta for First-Mile and Last-Mile Accessibility: A Stated Preference Approach

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Abstract

Urban mobility in Greater Jakarta is characterized by high commuter volumes between suburban and urban core areas, with daily MRT Jakarta ridership averaging 124,397 passengers in 2025, yet first-mile and last-mile station accessibility remains a persistent challenge. This study evaluates the potential for improving MRT Jakarta accessibility through bicycle integration as first-mile and last-mile modes, and estimates acceptable pricing for public bike-sharing and private bicycle parking. A Stated Preference (SP) approach was employed with 385 respondents within a 3 km radius of Lebak Bulus MRT Station, where the existing access mode was disaggregated into seven categories and compared against private bicycle and bike-sharing alternatives, generating twenty-one utility equations estimated through logistic regression. Each alternative's systematic utility was specified as a function of cost, distance, and travel time, with resulting coefficients translated into a generalized cost function and a mode choice probability and sensitivity analysis. Results indicate strong mode-shift potential across all seven existing-mode groups, with the probability of retaining the existing access mode falling to roughly 2-4% while the combined shift probability to cycling exceeds 95% under improved conditions. Cost exerts a consistently negative and statistically significant effect on cycling choice, confirming that higher fares reduce adoption likelihood, while distance and travel time generally lower utility as expected. Private bicycles show higher selection probability than bike-sharing, though the latter remains a viable complementary alternative. Overall, cycling integration with MRT Jakarta holds strong potential to enhance accessibility, driven by affordable pricing and supportive infrastructure.

Keywords: Active Mobility, MRT Jakarta, Stated Preference.

1. Introduction

Urban mobility in Jakarta is characterized by very high travel intensity driven by the interaction between residential areas in the suburbs and activity centers in the urban core. As the capital city of Indonesia and the center of economic activities, Jakarta attracts a large number of daily commuters from surrounding regions such as Bogor, Depok, Tangerang, and Bekasi (Greater Jakarta). This condition results in high travel demand within the metropolitan area, which places significant pressure on the urban transportation system, particularly during peak hours. The imbalance between travel demand and road capacity has led to congestion, long travel times, and high dependence on private vehicles, indicating the need for a more efficient and sustainable transportation system. The commuting volumes summarised in Figure 1 make this argument concrete. The sheer scale of daily core-bound movement means that even a high-capacity MRT can only relieve congestion if commuters can reach its stations efficiently. This perspective reframes the first and last mile, rather than line-haul capacity, as the primary constraint addressed by this study.

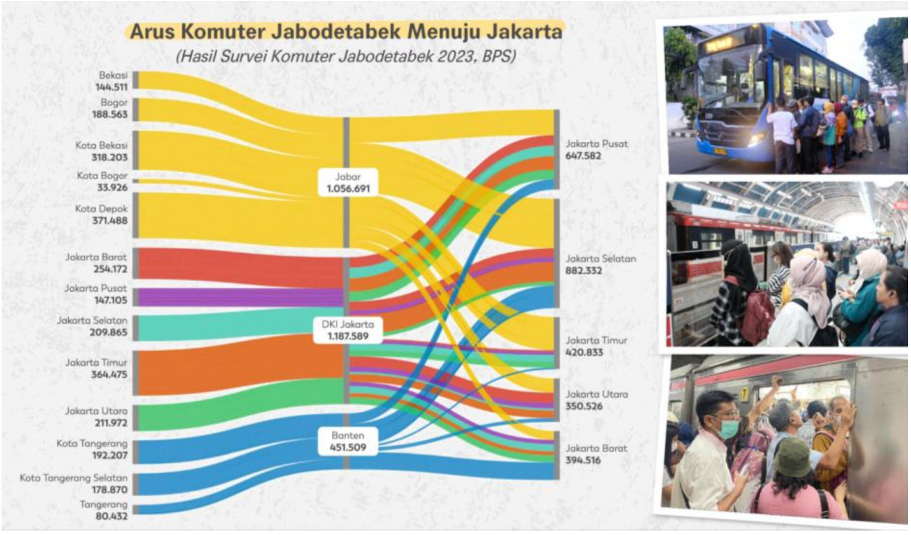

Figure 1. Mobility Condition of Greater Jakarta
Source: Central Bureau of Statistics, 2023

To address these challenges, the Government of DKI Jakarta has developed mass rapid transit systems as the backbone of urban transportation. One of the main systems currently in operation is the Jakarta Mass Rapid Transit (MRT), which serves the Lebak Bulus - Bundaran HI corridor and connects major residential, commercial, and business districts. The MRT system is designed to provide fast, reliable, and high-capacity public transport that can reduce dependence on private vehicles and support the transition toward sustainable mobility. The MRT corridor plays a strategic role in connecting activity centers in South Jakarta and Central Jakarta, making it an important component of the metropolitan transport network.

Figure 2. MRT Jakarta's Corridor
Source: PT MRT Jakarta, 2026

Table 1. Average Passenger of MRT Jakarta in 2025

Month (2025)	Monthly Passenger (in million)	Average Daily Passenger
January	3.53	113,871
February	3.47	123,929
March	3.19	102,903
April	3.25	108,333
May	3.63	117,097

Month (2025)	Monthly Passenger (in million)	Average Daily Passenger
June	3.6	120,000
July	4.35	140,323
August	3.98	128,387
September	3.91	130,333
October	4.39	141,613
November	4.06	135,333
December	4.05	130,645
Average Daily Passenger 2025		124,397

Source: PT MRT Jakarta, 2026

The significance of MRT in the Jakarta transport system is reflected in the number of passengers served throughout 2025. Monthly ridership ranges between 3.19 million and 4.39 million passengers, with the highest number recorded in October at 4.39 million passengers. The average daily ridership during 2025 reached approximately 124,397 passengers per day, indicating that MRT has become one of the important public transport modes in Jakarta. Although the number of users continues to increase, many passengers still experience difficulty accessing MRT stations, especially those living beyond walking distance from the station. Limited accessibility to stations reduces the potential service coverage of MRT and encourages the continued use of private vehicles for first-mile and last-mile travel.

Figure 3. Green Transportation Hierarchy
Source: Jakarta Transportation Council, 2019

In accordance with the sustainable mobility policy adopted by the Government of DKI Jakarta, the development of urban transportation follows the green transport hierarchy, which prioritizes pedestrians, cycling, and public transport over private motorized vehicles. This hierarchy emphasizes that active transport modes should become the primary access mode to mass transit systems, particularly for short-distance travel. Improving accessibility to transit stations through non-motorized transport is considered an important strategy to increase public transport usage while reducing congestion and emissions in urban areas. Therefore, the integration between active transport modes and mass transit systems becomes a key element in achieving sustainable urban mobility.

One potential approach to improve first-mile and last-mile connectivity is the implementation of a Public Bicycle Sharing System (PBSS) integrated with MRT stations. Bicycle sharing can function as a feeder mode that allows users to travel short distances between their origin or destination and the nearest transit station. Compared to motorized feeder modes, PBSS offers advantages in terms of environmental sustainability, operational flexibility, and efficiency in dense urban environments. However, the success of PBSS integration depends on several factors, including service coverage, station accessibility, user preferences, and acceptable rental cost.

Although MRT Jakarta ridership continues to grow, first-mile and last-mile connectivity remains underexplored in the Jakarta context, and the integration of a Public Bicycle Sharing System with the MRT has not been systematically evaluated using behavioural choice models. Existing studies tend to treat the existing access mode as a single undifferentiated category, even though the population accessing the station in fact relies on a diverse set of modes (motorcycle, car, ride-hailing, public transport, and bicycle) whose users may respond very differently to a cycling alternative. This study addresses that gap by disaggregating the existing access mode into seven categories and explicitly modelling, for each of them, the choice between retaining the existing mode and shifting to a private bicycle or bike-sharing. Specifically, the objectives of this study are: (1) to estimate the utility and choice probability of cycling as a first-mile and last-mile access mode to MRT Jakarta relative to seven existing access modes; (2) to derive the generalized cost of each alternative from the estimated utility coefficients; and (3) to determine, through a sensitivity analysis, the pricing thresholds at which cycling remains competitive as a feeder mode.

2. Literature Review

2.1. Concept of Urban Mobility and Metropolitan System

Urban mobility is a phenomenon that extends beyond the physical movement of individuals from one location to another; it reflects the complex interactions between urban spatial structure, transport policies, socio-economic conditions, and mobility culture. From a conceptual perspective, mobility is shaped by political decisions and urban planning processes that determine regulations, infrastructure development, and the direction of transport system evolution. Therefore, mobility should not be viewed merely as a function of transport availability, but rather as an outcome of a broader system influenced by governance, spatial planning, and social dynamics.

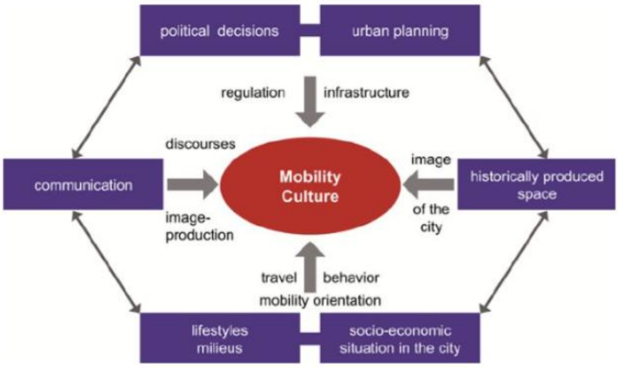

Figure 4. Mobility Culture
Source: Deffner et al. (2006)

Figure 4 illustrates that mobility culture is formed through the dynamic interplay between regulations and infrastructure, public communication, city image, socio-economic conditions, and lifestyle. Applying this framework to Jakarta helps explain the city's entrenched reliance on private vehicles: decades of road-oriented infrastructure investment, the symbolic association of motorcycle and car ownership with social status (city image), and the historical absence of safe, continuous cycling facilities have jointly produced a mobility culture in which private modes are the default for short access trips. This is directly reflected in the survey, where the existing access mode to the station is dominated by motorcycles and cars rather than active or public modes. Seen through this lens, the seven existing mode groups analyzed in this study are not merely technical categories but expressions of the prevailing mobility culture. Shifting them toward cycling requires changes in the regulatory and infrastructural cues that currently reinforce private vehicle use, including the provision of safe bicycle lanes, secure parking facilities, and supportive pricing policies.

In metropolitan systems, mobility assumes a broader dimension due to the functional interdependence between the urban core and its surrounding areas. Metropolitan areas are typically characterized by a concentration of economic activities and offices in the city center, while residential areas are distributed across suburban or peripheral zones. This spatial structure generates intensive and repetitive commuting patterns, creating a strong demand for integrated and high-capacity transport systems. Mobility in metropolitan regions occurs not only within the city (intracity), but also across administrative boundaries within the urban agglomeration (intercity).

The imbalance between residential locations and major activity centers often places significant pressure on transportation networks. In the absence of well-integrated public transport systems, reliance on private vehicles tends to increase, leading to congestion, environmental degradation, and inefficient use of urban space. Therefore, strengthening intermodal integration and improving accessibility are critical strategies in managing metropolitan mobility. In the context of this study, the concepts of urban mobility and metropolitan systems provide a foundation for understanding that the development of public bicycle systems should not be treated as a standalone intervention. Instead, it must be integrated within the broader urban mobility system. The integration of public bicycles with MRT services in office-dominated areas represents an effort to reshape mobility culture towards more sustainable patterns, enhance accessibility, and reduce dependence on private motorized transport within complex metropolitan environments.

2.2. Transport Integration and Multimodality

The demand for public transportation is dynamic and influenced by technological, spatial, social, and demographic factors. Rapid urban growth and increasing commuter mobility place significant pressure on transport systems, while financial, spatial, and policy constraints often limit the development of new infrastructure. Under such conditions, improving the quality of existing services and strengthening intermodal integration represent more realistic and sustainable strategies than large-scale network expansion.

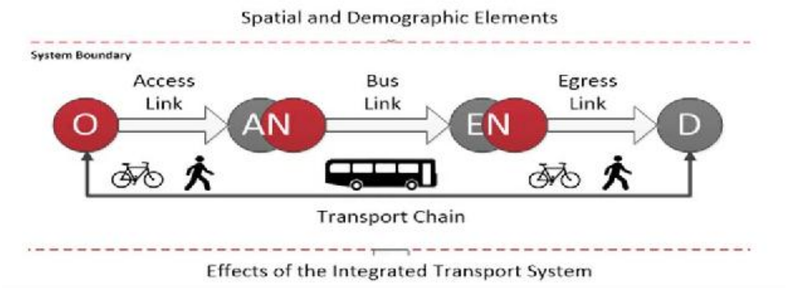

Figure 5. Integrated Transport System
Source: Brand et al. (2017)

The concept of transport integration emphasizes the importance of viewing travel as a complete transport chain, consisting of the origin, access link to the main mode, main trip, and the final connection to the destination (egress link). Figure 5 presents the journey as a continuous chain in which the access and egress links carry the same weight as the main trip, and this is precisely what justifies treating public bicycles as a feeder mode rather than an optional add-on. Because the weakest link determines the quality of the entire travel chain, a fast MRT trip is undermined when the first and last mile remain slow, costly, or dependent on private vehicles. The diagram therefore identifies the cycling alternative as a solution for the access and egress segments within the station catchment area of 3 km or less, which is the focus of the present study. Framed this way, the diagram is not merely illustrative but provides the structural rationale for modelling cycling as a substitute for the existing access mode in the seven groups examined here.

Within the framework of multimodality, public bicycles play a crucial role as feeder modes that enhance accessibility to mass transit nodes. The integration of bicycles with MRT systems can expand service coverage without the need for additional corridors. Previous studies indicate that improvements in main transport services, such as increased frequency and speed, can also encourage the use of access modes like cycling at both the origin and destination ends. This demonstrates a reciprocal relationship between the quality of the main mode and the attractiveness of access modes.

A comprehensive integration approach requires evaluating the characteristics of transit services, access modes, and their interactions within a regional system. Transport planning that focuses solely on improving speed or reducing travel distance between stops, without considering first- and last-mile connectivity, may result in suboptimal system performance. Therefore, physical, operational, and fare integration must be addressed simultaneously to enhance the overall attractiveness of public transport.

In the context of this study, the integration of public bicycles with MRT is understood as a strategy to strengthen the travel chain in office-dominated areas with high mobility intensity. By improving access and egress stages through the provision of integrated bicycle services, MRT systems can reach a wider service area and improve overall travel convenience. This approach not only enhances system efficiency but also supports the transition toward more sustainable mobility within metropolitan systems.

2.3. Stated Preference

The Stated Preference (SP) method is an experimental approach in choice analysis used to identify individual preferences toward service attributes through hypothetical scenarios. Unlike Revealed Preference (RP), which is based on actual observed behavior, SP allows researchers to evaluate responses to alternatives that are not yet available or implemented in real conditions. In transportation studies, this method is widely applied to analyze sensitivity toward variables such as travel cost, travel time, service quality, and intermodal integration.

The implementation of SP follows a structured experimental procedure to ensure reliable parameter estimation. This process includes selecting relevant attributes and their levels, formulating the utility model based on theoretical assumptions, constructing experimental design scenarios, and conducting preliminary simulations before actual data collection. These steps are essential to ensure that the combinations of attributes presented to respondents are both statistically valid and realistic, thereby producing meaningful results.

The experimental design in SP aims to generate combinations of attributes and levels that can capture variations in respondent preferences while maintaining simplicity and realism. To avoid excessive complexity, studies typically apply fractional factorial or efficient design approaches instead of full factorial design. In this research, the design is developed by considering the relevance of attributes to public bicycle systems, realistic attribute levels based on existing conditions, and the need to balance the number of scenarios to prevent respondent fatigue.

Furthermore, the analysis of SP data is grounded in Random Utility Theory, where individuals are assumed to choose the alternative that provides the highest utility. The utility consists of observable components related to service attributes and unobservable random components. Models such as the logit model are commonly used to estimate the probability of choosing each alternative, allowing researchers to quantify the influence of attributes and derive indicators such as willingness to pay. This approach provides a strong analytical foundation for understanding travel behavior and supporting policy decisions in transport system development.

2.4. Stated Preference

Mode choice behavior represents the decision-making process of individuals in selecting transportation alternatives based on travel attributes and personal characteristics. This behavior is commonly explained using Random Utility Theory (RUT), which assumes that each individual chooses the alternative that provides the highest utility. In a multimodal transport system, such as the integration of Public Bicycle Sharing Systems (PBSS) with public transport, mode choice is influenced by attributes including travel cost, travel time, accessibility, and service quality.

According to RUT, the utility of an alternative is composed of two components, namely a deterministic component and a random component, which can be expressed as:

$$U_{ni} = V_{ni} + \varepsilon_{ni}$$

where U_{ni} is the total utility of alternative $i$for individual n, V_{ni}represents the observable (systematic) component of utility, and $\varepsilon_{ni}$is the random term capturing unobserved factors. The deterministic component is typically modeled as a linear function of attributes such as cost, travel time, and infrastructure quality. Improvements in these attributes, particularly infrastructure and accessibility, tend to increase the utility of cycling alternatives in urban transport systems.

To estimate the probability of choosing a specific mode, discrete choice models are applied. One of the most commonly used formulations is the logit model, where the probability of selecting alternative $i$is defined as:

$$P_{ni} = \frac{e^{V_{ni}}}{\sum_j e^{V_{nj}}}$$

This formulation indicates that the probability of choosing an alternative depends on its relative utility compared to other available options. The exponential form ensures that the probability is always positive and bounded between 0 and 1, while also capturing the sensitivity of users to changes in travel attributes.

In practical applications, the deterministic utility function $V_{ni}$is expressed as a combination of relevant attributes, such as:

$$V_{ni} = \beta_1 \cdot Cost + \beta_2 \cdot Time + \beta_3 \cdot Accessibility + \beta_4 \cdot Infrastructure$$

where βrepresents the estimated parameters reflecting user sensitivity to each attribute. These parameters allow researchers to quantify how changes in cost, travel time, and infrastructure influence mode choice decisions. In the context of PBSS, attributes such as cycling infrastructure, access distance to stations, and service integration are key determinants of bicycle usage, highlighting the importance of integrated and user-oriented transport planning.

2.5. Willingness to Pay

Willingness to Pay (WTP) is an economic measure used to estimate the monetary value that individuals are willing to pay for improvements in service attributes. In transportation studies, WTP is commonly applied to evaluate the economic value of reduced travel time, improved comfort, enhanced safety, and better integration between transport modes. It provides a practical interpretation of user preferences by translating model results into monetary terms that are easier for policy-makers to understand.

Within the framework of Random Utility Theory, WTP is derived from the estimated utility function obtained through discrete choice models. The systematic utility of an alternative can be expressed as:

$$V_{ni} = \beta_{cost} \cdot Cost_{ni} + \beta_k \cdot X_{kni}$$

where V_{ni} is the deterministic utility of alternative i for individual n, β_{cost} represents the coefficient of travel cost, $Cost_{ni}$ is the monetary cost, β_k is the coefficient of a non-cost attribute, and X_{kni} represents the value of that attribute.

Based on this formulation, the WTP for a specific attribute can be calculated as the ratio between the attribute coefficient and the cost coefficient:

$$WTP_k = -\frac{\beta_k}{\beta_{cost}}$$

The negative sign is used because the cost coefficient is typically negative. This formulation indicates the amount of additional cost that individuals are willing to pay for a one-unit improvement in a given attribute.

In the context of urban transportation and PBSS integration, WTP provides valuable insights into user preferences, such as how much users value improvements in cycling infrastructure, accessibility, or system integration. Therefore, WTP serves as a key tool in evaluating transport policies, as it enables decision-makers to prioritize investments based on the economic value perceived by users.

2.6. Previous Research

Previous studies on urban mobility increasingly emphasize the integration of active transport modes, such as cycling, within multimodal transport systems. Cycling, both in the form of private bicycles and public bike sharing, is widely recognized as an effective solution to address first mile and last mile connectivity issues. Dill and Rose (2012) highlight that cycling plays an important role in bridging access to public transport systems, while Midgley (2011) explains that bicycle sharing systems have evolved into an integral component of sustainable urban mobility. In this context, cycling is not only an alternative mode but also a complementary element that enhances the overall performance of public transport systems.

Several studies have identified a strong relationship between cycling and public transport usage. Radzimski and Dzięcielski (2021) find a positive correlation between public transport frequency and bicycle sharing trips, particularly for short to medium distance travel. Similarly, Ma et al. (2015) demonstrate that cycling systems can influence modal shift from private vehicles and conventional public transport. These findings indicate that improvements in public transport services, such as frequency and reliability, can increase the use of bicycles as feeder modes, reflecting a complementary relationship between cycling and mass transit.

From a spatial and environmental perspective, cycling demand is strongly influenced by land use characteristics and infrastructure conditions. Tran et al. (2015) show that built environment factors, including land use density and proximity to transit, significantly affect bicycle usage. Sun et al. (2017) further highlight that safety, accessibility, and environmental conditions play an important role in shaping cycling behavior. In addition, Kabak et al. (2018) demonstrate that spatial analysis using GIS can effectively identify optimal locations for bicycle stations and improve service coverage. Behavioral studies by Te Pai and Ying Pai (2015) also indicate that station location and perceived service quality are key determinants of user preference.

Despite the extensive literature, several research gaps remain. Most studies are conducted in developed countries with established cycling infrastructure, which limits their applicability to developing metropolitan contexts. Frade and Ribeiro (2014) emphasize that demand estimation for bicycle systems should consider local characteristics, yet context specific studies remain limited. In addition, many studies focus either on spatial analysis or behavioral modeling separately, with limited integration between the two approaches. Economic evaluation, such as willingness to pay, is also rarely incorporated into the analysis. Therefore, further research is needed to integrate spatial accessibility, user preferences, and economic valuation in a unified framework, particularly in the context of metropolitan areas with emerging mass transit systems such as MRT Jakarta

Building on these gaps, the novelty of this study lies in three aspects. First, it is among the first to apply stated-preference choice modelling to the integration of a Public Bicycle Sharing System with the MRT in Jakarta, combining spatial accessibility within a ≤3 km catchment, behavioural preferences, and economic valuation in a single framework. Second, rather than treating the existing access mode as one aggregate alternative, the study disaggregates it into seven distinct existing modes and estimates a separate utility equation for each mode-by-alternative combination, producing twenty-one utility models that reveal how the propensity to shift to cycling differs across user groups. Third, the study translates the estimated utility coefficients into a generalized cost function expressed in monetary units, providing one of the first quantified cost thresholds for cycling adoption as an MRT feeder mode in a developing-country megacity. Together, these contributions extend the largely developed-country and spatially focused literature toward a behaviourally and economically grounded analysis tailored to Jakarta's context.

3. Methods

3.1. MRT Jakarta Ridership

The secondary data on MRT Jakarta ridership used in this study were obtained from a compiled origin-destination (OD) matrix, representing passenger movement patterns between stations. This dataset reflects the distribution of trip origins and destinations along the MRT Jakarta corridor, from Lebak Bulus to Bundaran HI, and provides an overview of daily passenger flows within the system. Based on the data, the total number of passenger movements is recorded at 18,420 trips per day, consisting of 8,446 origin trips and 9,974 destination trips. The difference between origin and destination totals indicates variations in travel activity distribution across stations, which are generally influenced by surrounding land use characteristics such as residential, office, and commercial areas.

Assuming round-trip travel behavior, the effective number of MRT users is estimated at approximately 9,210 individuals per day, calculated by dividing the total origin-destination movements. This figure represents the number of unique users utilizing the MRT system within a single operational day. Furthermore, the aggregated data indicate that certain stations, such as Dukuh Atas and Bundaran HI, experience higher passenger volumes due to their roles as major activity centers within the urban network. This secondary dataset also serves as the basis for determining the sample size of the study. Using the Slovin formula with a 5% margin of error, the minimum required sample size is approximately 384 respondents. In this study, a total of 385 respondents were collected, thereby satisfying the requirement for statistical adequacy in further analysis. Overall, the MRT ridership data provide an initial understanding of travel intensity, spatial distribution of trips, and the potential for further modal integration, particularly in supporting first-mile and last-mile connectivity through cycling.

3.2. Primary Data

Primary data in this study were collected through a questionnaire survey involving 385 respondents located within an approximate radius of ±3 km from Lebak Bulus MRT Station. Respondents were selected through a screening process to ensure that only individuals who live or conduct activities within this service area were included in the analysis. This approach was intended to ensure direct relevance to first-mile and last-mile accessibility toward the MRT system.

The collected data include both demographic characteristics, such as gender, age, occupation, and income level, and travel characteristics, including trip purpose, MRT usage frequency, access mode to the station, travel distance, travel time, and travel cost. These variables are essential for understanding travel behavior patterns and the level of dependency on different modes when accessing MRT stations.

The results indicate that most respondents are located within a distance of less than 3 km from the MRT station, with travel times ranging from less than 10 minutes to more than 30 minutes depending on the mode used. In practice, access to the station is still dominated by private vehicles and ride-hailing services, while cycling and walking remain less preferred options. This finding highlights a gap between the short travel distance and the actual mode choice behavior of users.

Table 1. Stated Preference Scenarios

Scenario	Mode	Cost	Bicycle Infrastructure	Distance (km)
1	Bike-sharing	Rp8,000/hour	Not available	3
	Private bicycle	Rp5,000/day (parking)	Not available	3
	Existing mode	Current condition	Not available	3
2	Bike-sharing	Rp8,000/hour	Partially available	2
	Private bicycle	Rp5,000/day	Partially available	2
	Existing mode	Current condition	Partially available	2
3	Bike-sharing	Rp8,000/hour	Fully available	1
	Private bicycle	Rp5,000/day	Fully available	1
	Existing mode	Current condition	Fully available	1
4	Bike-sharing	Rp5,000/hour	Partially available	3
	Private bicycle	Rp2,000/day	Partially available	3

Scenario	Mode	Cost	Bicycle Infrastructure	Distance (km)
5	Existing mode	Current condition	Partially available	3
	Bike-sharing	Rp5,000/hour	Fully available	2
	Private bicycle	Rp2,000/day	Fully available	2
	Existing mode	Current condition	Fully available	2
6	Bike-sharing	Rp5,000/hour	Not available	1
	Private bicycle	Rp2,000/day	Not available	1
	Existing mode	Current condition	Not available	1
7	Bike-sharing	Rp2,000/hour	Fully available	3
	Private bicycle	Free	Fully available	3
	Existing mode	Current condition	Fully available	3
8	Bike-sharing	Rp2,000/hour	Not available	2
	Private bicycle	Free	Not available	2
	Existing mode	Current condition	Not available	2
9	Bike-sharing	Rp2,000/hour	Partially available	1
	Private bicycle	Free	Partially available	1
	Existing mode	Current condition	Partially available	1

In addition, a Stated Preference approach was applied using nine scenarios that compare three alternatives, namely bike-sharing, private bicycles, and existing modes. Each scenario varies in terms of distance (1-3 km), availability of bicycle infrastructure (none, partial, full), and cost (rental and parking fees). This approach allows the analysis of user preferences under hypothetical conditions and captures sensitivity to changes in service attributes. The results show that the preference for cycling increases as infrastructure improves and costs decrease. Under conditions without bicycle lanes, respondents tend to retain their existing modes. However, when bicycle infrastructure is partially or fully available and costs are reduced or free, a noticeable shift toward cycling is observed, both for private bicycles and bike-sharing. This indicates that infrastructure and cost are the primary determinants in mode choice decisions.

Furthermore, general preference results suggest that respondents are willing to consider cycling as a first-mile and last-mile option when supported by adequate conditions. Key factors influencing this decision include safety, availability of bicycle lanes, travel distance, and ease of access. These findings emphasize that transport system performance is not only determined by the availability of modes but also by the quality of the travel environment. Overall, the primary data analysis reveals a significant potential for the development of cycling as a feeder mode to MRT Jakarta, particularly within a radius of ≤3 km. However, realizing this potential depends on improvements in infrastructure quality, system integration, and supportive policies that promote active transport usage.

Each scenario represents a different combination of travel conditions, including bicycle infrastructure availability, travel distance, and travel cost, allowing for the analysis of changes in respondents' preferences under varying situations. Therefore, this recapitulation table not only presents the distribution of mode choices but also serves as the basis for identifying mode shift patterns across scenarios. The results from this table are further used for subsequent analysis, particularly in estimating mode choice probabilities and evaluating the influence of travel attributes on respondents' decisions.

Table 2. Recapitulation of Stated Preference Results

Scenario	Existing Mode	Private Bicycle	Bike-sharing	Total
1	218	113	54	385
2	113	178	94	385
3	68	203	114	385
4	36	220	129	385
5	23	230	132	385
6	12	237	136	385
7	5	242	138	385
8	3	244	138	385
9	2	245	138	385

Based on table 3, a significant shift in mode choice patterns can be observed as the scenario conditions improve. In Scenario 1, the existing mode remains dominant with 218 respondents, accounting for more than half of the total sample. This indicates that under initial conditions, where travel attributes do not support cycling, respondents tend to maintain their current mode of transport. However, in Scenario 2, a noticeable shift begins to occur, with the number of respondents choosing private bicycles increasing significantly to 178, surpassing the existing mode. This trend continues in subsequent scenarios, where private bicycles become the most dominant mode. This pattern suggests that improvements in travel conditions strongly influence the adoption of cycling.

Similarly, the use of bike-sharing shows a consistent upward trend, increasing from 54 respondents in Scenario 1 to 138 respondents in Scenario 9. This indicates that bike-sharing has considerable potential to support modal shift, particularly for individuals who do not own a private bicycle. On the other hand, the use of existing modes declines sharply, from 218 respondents in Scenario 1 to only 2 respondents in Scenario 9. This substantial decrease suggests that when travel conditions become more supportive, such as improved bicycle infrastructure, shorter distances, and lower costs, respondents are more likely to shift away from existing modes toward cycling alternatives.

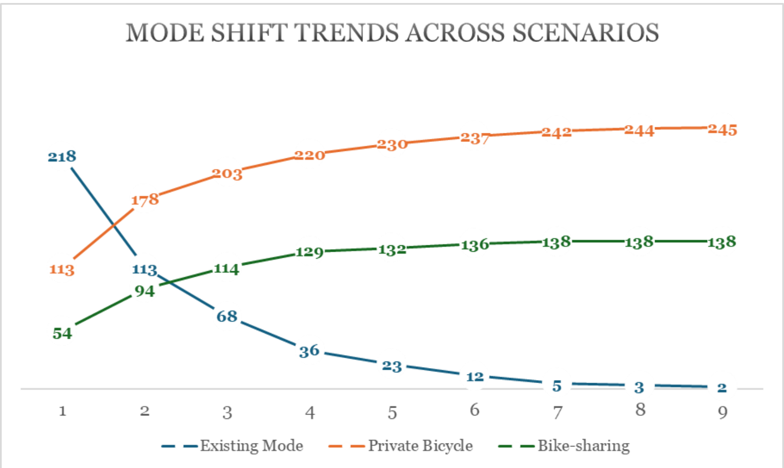

Figure 6. Mode Shift Trends Across Scenarios

The figure 6 illustrates how respondents' mode choices shift as scenario conditions change across nine incremental levels. The existing mode shows a consistent decline, falling from 218 respondents in Scenario 1 to just 2 in Scenario 9, indicating a progressive reduction in its attractiveness as travel attributes are adjusted. In contrast, private bicycle use increases substantially over the same range, rising from 113 to 245 respondents, suggesting that this mode becomes increasingly competitive under improved conditions. Bike-sharing also shows an upward trend, growing from 54 to 138 respondents, though its rate of increase is more gradual compared to private bicycle. Notably, the two alternative modes begin to diverge from Scenario 3 onward, with private bicycle consistently attracting more respondents than bike-sharing throughout all subsequent scenarios. These trends reflect a general willingness among respondents to shift away from their existing mode when presented with more favorable cost, distance, and infrastructure conditions.

4. Results and Discussion

4.1. Research Results

4.1.1. Result 1 about figures

Building upon the observed patterns of mode shift across scenarios, further analysis is conducted to quantitatively assess the influence of travel attributes on mode choice behavior. This analysis aims to explain how variations in cost and infrastructure conditions affect the likelihood of respondents selecting cycling as an access mode to MRT.

To capture these relationships, a disaggregated regression-based modelling approach is applied. The existing access mode is divided into seven categories (E1 motorcycle parked at the MRT, E2 car parked at the MRT, E3 motorcycle drop-off, E4 ride-hailing, E5 car drop-off, E6 public transport, and E7 bicycle), and for each category the choice among retaining the existing mode, shifting to a private bicycle (A1), and shifting to bike-sharing (A2) is modelled. This yields twenty-one utility equations (U1-U21), each estimated by binary logistic regression with cost, distance, and travel time as explanatory variables. Travel time for the existing modes was obtained from a distance-based estimation following the typical operating speed of each mode, consistent with routing services such as Google Maps. The systematic utility of alternative i for an individual in existing-mode group g is specified as $V_i = \alpha_i + \beta_{cost} \cdot Cost + \beta_{dist} \cdot Distance + \beta_{time} \cdot Time$, where every equation is estimated independently so that no alternative is fixed as a zero-utility base. The results provide insight into the direction and magnitude of each variable and into how the propensity to shift to cycling differs across the seven existing-mode groups.

The estimated coefficients of all twenty-one utility equations are summarised in Table 4, and the generalized cost derived from these coefficients is presented in Table 5. The results are reported in the form of a “Variables in the Equation” table for each utility equation, summarizing the estimated constant (α) and the coefficients of cost, distance, and travel time together with their significance. Because every existing-mode group is estimated separately, the coefficients vary across the twenty-one equations rather than being shared, which allows the behavioural response of each user group to be examined individually.

Table 3. Estimation Results of the 21 Utility Models (U1-U21)

No	Existing Mode	Choice	α	βcost	Sig.	βdist	Sig.	βtime	Sig.
U1	Motorcycle Parked at MRT	Retain Existing	-1.4822	-2.83e-05	0.1978	-0.23233	0.3455	0.03761	0.64
U2	Motorcycle Parked at MRT	Private Bicycle	0.9375	-0.0001909	0	-0.17921	0.0283	0.0624	-
U3	Motorcycle Parked at MRT	Bike-sharing	-0.0143	-8.78e-05	0.0022	-0.14674	0.0873	0.0624	-
U4	Car Parked at MRT	Retain Existing	-0.9704	-2.5e-06	0.9082	0.19877	0.4735	-0.12951	0.1006
U5	Car Parked at MRT	Private Bicycle	0.8987	-0.0001281	0.0002	-0.18836	0.0274	0.0624	-
U6	Car Parked at MRT	Bike-sharing	0.1253	-0.0001263	0	-0.16923	0.0666	0.0624	-
U7	Motorcycle Drop-off	Retain Existing	-3.3094	1.88e-05	0.6328	-1.06257	0.0051	0.46644	0.0003
U8	Motorcycle Drop-off	Private Bicycle	0.9782	-0.0001519	0.0004	-0.1742	0.1069	0.0624	-
U9	Motorcycle Drop-off	Bike-sharing	-0.266	-4.96e-05	0.1823	-0.07448	0.504	0.0624	-
U10	Ride-hailing	Retain Existing	-1.645	-8.02e-05	0.0336	0.40085	0.278	-0.04507	0.7017
U11	Ride-hailing	Private Bicycle	0.956	-0.0001953	0.0003	-0.20181	0.1376	0.0624	-
U12	Ride-hailing	Bike-sharing	0.2231	-0.0001198	0.012	-0.16058	0.2582	0.0624	-
U13	Car Drop-off	Retain Existing	-4.5743	0.0001266	0.0083	-0.6052	0.1267	0.48133	0.0004
U14	Car Drop-off	Private Bicycle	1.4283	-0.000214	0.0002	-0.30017	0.0353	0.0624	-
U15	Car Drop-off	Bike-sharing	-0.2265	-0.000116	0.0292	-0.14951	0.3447	0.0624	-
U16	Public Transport	Retain Existing	-2.551	0.0001398	0.0016	-2.39302	0.0024	0.41118	0.0218
U17	Public Transport	Private Bicycle	1.0612	-0.0001954	0.0017	-0.17047	0.2759	0.0624	-
U18	Public Transport	Bike-sharing	-0.0813	-0.0001321	0.0204	-0.08538	0.613	0.0624	-
U19	Bicycle	Retain Existing	-2.7426	2.61e-05	0.564	-0.2496	0.8304	0.13769	0.5481
U20	Bicycle	Private Bicycle	1.1703	-0.0002105	0.0065	-0.25988	0.18	0.0624	-
U21	Bicycle	Bike-sharing	0.3598	-0.0001928	0.0079	-0.17984	0.3979	0.0624	-

Across the twenty-one equations, the cost coefficient for the cycling alternatives (A1 and A2) is consistently negative and, in most groups, statistically significant (Sig. < 0.05), ranging from about -0.0001 to -0.0002 per rupiah. This confirms that higher rental or parking fees reduce the probability of choosing cycling, and that the strength of this effect differs by existing-mode group for example, the cost sensitivity of private-bicycle choice is strongest among current car drop-off users (E5, βcost = -0.000214) and weakest among current public-transport users. The distance and travel-time coefficients are generally negative, indicating that longer or slower trips lower the utility of an alternative, although their significance varies because of the limited variation in the stated-preference design. Because each existing mode is modelled separately, the constants (α) also differ across equations, capturing the baseline tendency of each user group to retain or abandon its current mode.

Table 5. Generalized Cost per Existing Mode (Rp)

Existing Mode	GC Existing (Rp)	GC Private Bicycle (Rp)	GC Bike-sharing (Rp)
Motorcycle Parked at MRT	10,951	-45	-184
Car Parked at MRT	339,126	-904	1,751
Motorcycle Drop-off	47,906	-636	-7,092
Ride-hailing	2,882	232	1,429
Car Drop-off	21,941	1,306	1,124
Public Transport	3,542	-87	623
Bicycle	44,007	912	2,982

The estimated utility coefficients are then translated into a generalized cost (GC) for each alternative, expressed in monetary units by dividing the non-cost components of utility by the cost coefficient, GC = Cost + (βdist/βcost)·Distance + (βtime/βcost)·Time. The generalized cost summarises, in rupiah, the combined burden of fare, distance, and time perceived by each user group, and therefore links the behavioural estimates to the concept of perceived utility in Random Utility Theory: a lower generalized cost corresponds to a higher systematic utility and thus a higher choice probability. For every existing-mode group, the generalized cost of the cycling alternatives is substantially lower than that of retaining the existing mode, which is consistent with the high estimated probabilities of shifting to cycling.

Taken together, the twenty-one equations and the derived generalized cost provide consistent evidence that cost is the principal limiting factor for cycling adoption, while shorter access distance and travel time reinforce its attractiveness. Translating the coefficients into generalized cost also reveals the magnitude of the gap between cycling and the existing modes: the cycling alternatives remain markedly cheaper in perceived terms across all seven user groups, which explains why the combined probability of shifting to cycling exceeds 95% once fares are set at low-to-moderate levels.

4.1.2. Sensitivity Analysis

Building upon the estimated utility and probability functions, a sensitivity analysis is conducted for each existing-mode group to examine how changes in the bike-sharing tariff influence the probability of selecting each alternative. This analysis captures the behavioural response of users under varying pricing conditions and, in economic terms, traces the demand elasticity of cycling with respect to fare: the slope of the probability curve at a given price represents how responsive mode choice is to a marginal change in cost. The non-linear logistic form implies that this elasticity is not constant but varies along the price spectrum.

The sensitivity analysis is derived directly from the twenty-one utility equations, by varying the bike-sharing tariff from Rp0 to Rp15,000 while holding the other attributes at their reference levels, and recomputing the three choice probabilities for each existing-mode group. Because the logit function is non-linear, the response of users to tariff changes is not constant but varies with the position along the price spectrum, so the elasticity of demand differs both across price levels and across user groups.

The results show that the total probability of shifting to cycling (private bicycle plus bike-sharing) remains very high and is relatively insensitive to the bike-sharing tariff, staying above 93% across all seven groups even at Rp15,000. What changes markedly is the composition of that shift: as the tariff rises, demand moves away from bike-sharing toward the private bicycle, so the bike-sharing share is the component that is genuinely tariff-elastic. The decline in the bike-sharing share is steepest in the mid-tariff interval and more gradual at the extremes, which is the expected shape of a logit response curve.

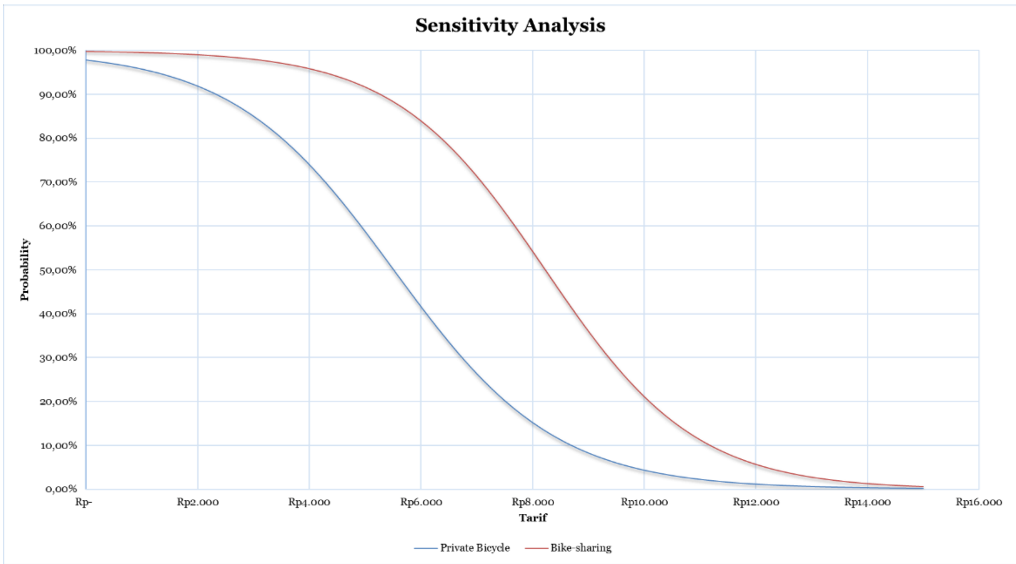

Figure 7. Sensitivity of Bike-sharing Probability to Tariff, by Existing Mode

Table 4. Bike-sharing Probability Share (%) Across Tariff Levels, by Existing Mode

Existing Mode	Rp0	Rp2k	Rp5k	Rp8k	Rp10k	Rp15k	Total shift @Rp5k
Motorcycle Parked at MRT	36.2%	32.2%	26.8%	21.9%	19.1%	13.2%	95.6%
Car Parked at MRT	36.9%	31.3%	23.7%	17.6%	14.2%	8.1%	95.8%
Motorcycle Drop-off	31.6%	29.5%	26.5%	23.7%	22.0%	18.0%	97.8%
Ride-hailing	42.1%	36.4%	28.5%	21.8%	18.0%	10.8%	95.9%
Car Drop-off	27.4%	23.0%	17.4%	13.0%	10.6%	6.2%	95.9%
Public Transport	34.9%	29.1%	21.7%	15.7%	12.5%	6.9%	96.7%
Bicycle	42.5%	33.4%	22.0%	13.6%	9.7%	3.9%	94.5%

Note: Values are the estimated probability of choosing bike-sharing at each bike-sharing tariff, holding other attributes at reference levels. The final column reports the total probability of shifting to cycling (private bicycle + bike-sharing) at a Rp5,000 tariff; this total stays above 93% for every group across the whole tariff range.

Reading the curves by existing-mode group reveals a consistent pattern. At a zero or very low bike-sharing tariff, the probability of choosing bike-sharing is at its highest for every group ranging from about 27% for current car drop-off users (E5) to roughly 42% for current ride-hailing (E4) and cycling (E7) users while the private-bicycle share takes the remainder of the shift. As the tariff increases, the bike-sharing share falls steadily and the private-bicycle share rises by almost the same amount, so the total cycling share is preserved. For example, for motorcycle-parking users (E1) the bike-sharing share declines from about 36% at Rp0 to 27% at Rp5,000 and 13% at Rp15,000, while the private-bicycle share climbs from 60% to 82% over the same range.

The tariff sensitivity of bike-sharing differs across groups. Current car-based users (E2 car parking, E5 car drop-off) are the most price-sensitive: their bike-sharing share drops below 15% once the tariff exceeds about Rp10,000, as they readily substitute toward the private bicycle. Users who already rely on flexible or low-cost modes, ride-hailing (E4), public transport (E6), and current cyclists (E7) retain a higher bike-sharing share at low tariffs but show the steepest decline through the mid-tariff range. Motorcycle drop-off users (E3) are the most tariff-tolerant, keeping a bike-sharing share above 18% even at Rp15,000. This ordering mirrors the generalized cost results, where the perceived cost advantage of bike-sharing over the existing mode is largest precisely for these groups.

A practical reading of the curves is that the policy-relevant threshold is not the point at which cycling collapses, because it does not; the demand is instead absorbed by private bicycles. Rather, the critical threshold is the point at which bike-sharing ceases to be the dominant cycling option. Across the seven groups, the bike-sharing share remains substantial (broadly 22-36%) up to about Rp5,000 per hour and falls into single digits to low double digits beyond Rp10,000. If the operational goal is to sustain a viable public bike-sharing system rather than merely to encourage cycling in general, the tariff therefore needs to be kept in the lower part of this range.

Furthermore, the non-linear shape of the curves highlights that marginal changes in cost do not produce uniform effects. Small cost increases at low levels have minimal impact, whereas similar increases within the mid-cost range can significantly reduce the probability of mode choice. This finding underscores the importance of identifying optimal pricing thresholds in transport policy design.

Overall, the sensitivity analysis confirms that the bike-sharing tariff is the critical controlling variable for the cycling mix, and that the bike-sharing share is most elastic within the mid-tariff range where its probability curve is steepest. This is consistent across the seven existing-mode groups, and the generalized cost results show the same ordering: cycling stays competitive as long as its perceived cost remains below that of the existing mode. Practically, to keep public bike-sharing a dominant rather than marginal cycling option, the acceptable pricing range is estimated at around Rp0-Rp2,000 per day for private bicycle parking and Rp2,000-Rp5,000 per hour for bike-sharing services. Within these ranges, cycling remains highly competitive as a first-mile and last-mile access mode to MRT Jakarta.

4.2. Discussion

The findings of this study highlight the strong influence of infrastructure and cost on cycling adoption as a first-mile and last-mile access mode to MRT Jakarta. The regression results consistently show that infrastructure has a positive and significant effect, while cost has a negative effect on the probability of choosing both private bicycles and bike-sharing. This indicates that improving the quality and availability of bicycle infrastructure is a key driver in encouraging mode shift, as it directly enhances perceived safety, comfort, and convenience for users.

The sensitivity analysis further reinforces this finding by demonstrating that infrastructure not only increases the baseline probability of cycling but also stabilizes user preferences against cost increases. In scenarios where bicycle infrastructure is partially available, users are still responsive to pricing changes. However, when infrastructure improves, the decline in probability due to increasing cost becomes less pronounced. This suggests that infrastructure acts as a buffering factor that reduces the elasticity of demand with respect to cost.

In terms of pricing, the results indicate that there are clear thresholds beyond which cycling adoption declines significantly. Private bicycle users show higher sensitivity to parking costs, particularly within the mid-cost range, where small increases can lead to a substantial decrease in probability. On the other hand, bike-sharing users demonstrate relatively higher tolerance toward rental costs, especially at lower tariff levels. This difference reflects the distinct characteristics of each user group, where ownership provides flexibility for private bicycle users, while accessibility and convenience become more important for bike-sharing users.

The comparison between private bicycles and bike-sharing also reveals that bike-sharing has a slightly higher overall utility under similar conditions, particularly when supported by adequate infrastructure. This suggests that bike-sharing systems can play a strategic role in expanding access to MRT, especially for users who do not own bicycles. However, without supportive infrastructure, the potential of bike-sharing remains limited, as safety concerns and travel discomfort continue to discourage adoption.

From a broader urban mobility perspective, these results confirm that cycling should not be viewed as a standalone mode, but rather as an integral component of a multimodal transport system. The effectiveness of cycling as a feeder mode depends on the overall performance of the transport chain, including accessibility, integration, and user experience. Therefore, policies that focus solely on pricing without improving infrastructure are unlikely to achieve significant mode shift. Overall, the study demonstrates that achieving a substantial shift toward cycling requires a balanced approach that combines infrastructure investment and appropriate pricing strategies. The identified cost thresholds provide practical guidance for policy design, while the strong role of infrastructure underscores the importance of continuous investment in safe and connected bicycle networks. Together, these measures can support the development of a more sustainable and integrated urban transport system.

These findings can be connected to broader transport theory. Within Random Utility Theory, the negative cost coefficients and the generalized cost results jointly show that fare reductions raise the systematic utility of cycling and therefore its choice probability; the steep mid-range of the sensitivity curves expresses a high price elasticity of demand in that interval, a pattern well documented in the behavioural-economics literature on travel choice. The results are broadly consistent with international evidence. Radzimski and Dzięcielski (2021) and Ma et al. (2015) report that better integration and service quality increase bike-sharing use and induce modal shift from motorised modes; the present study reproduces this complementary relationship in Jakarta, where the largest shift potential is found precisely among current motorcycle- and car-based access users. Unlike those developed-country settings, however, the Jakarta context combines a young high-capacity MRT, limited dedicated cycling infrastructure, and strong private-vehicle dependence, which is why the disaggregation of the existing mode into seven groups proves informative: the propensity to adopt cycling and the cost sensitivity differ markedly between, for instance, ride-hailing users and car-parking users.

Several limitations should be acknowledged. First, the analysis relies on stated-preference data, which are subject to hypothetical bias: respondents' declared intentions in constructed scenarios may overstate their actual willingness to shift to cycling, so the high shift probabilities should be read as upper-bound potential rather than realised demand. Second, because cost, distance, and infrastructure were varied jointly in the experimental design, some attributes are correlated, which limits the precision and significance of individual distance and time coefficients; a more orthogonal design would allow these effects to be separated more cleanly. Third, the study is geographically limited to the ≤3 km catchment of a single station (Lebak Bulus), so the magnitudes reported here may not generalise directly to other MRT stations or cities with different land use and infrastructure. Finally, travel time for the existing modes was estimated from distance and typical operating speeds rather than measured directly; future work could incorporate observed travel-time data and a revealed-preference component to validate and refine the present estimates.

5. Conclusion

This study demonstrates a strong potential for cycling integration as a first-mile and last-mile access mode to MRT Jakarta, supported by both stated preference results and model estimation. Based on the recapitulation of stated preference data, a significant mode shift is observed across scenarios. The share of existing modes decreases drastically from 56.6% (218 respondents) in Scenario 1 to only 0.5% (2 respondents) in Scenario 9. In contrast, private bicycle usage increases from 29.4% (113 respondents) to 63.6% (245 respondents), while bike-sharing rises from 14.0% (54 respondents) to 35.8% (138 respondents). These results indicate a clear transition toward cycling as travel conditions improve.

The twenty-one utility equations estimated for the seven existing-mode groups confirm that cost significantly and negatively influences cycling choice, with coefficients of about -0.0001 to -0.0002 per rupiah, while shorter distance and travel time raise its utility. Estimating each existing mode separately rather than treating it as a single base alternative shows that cost sensitivity and shift propensity differ across user groups, information that an aggregate model would conceal. Translating these coefficients into a generalized cost confirms that cycling carries a substantially lower perceived cost than the existing modes for every group, and the resulting choice probabilities indicate that the combined likelihood of shifting to cycling exceeds 95% once fares are set at low-to-moderate levels.

The sensitivity analysis reveals that cycling adoption is highly dependent on pricing thresholds. For private bicycles, the probability begins to decline significantly when parking costs exceed approximately Rp5,000-Rp8,000 per day. For bike-sharing, the probability remains relatively high up to around Rp6,000-Rp7,000 per hour, but decreases sharply beyond Rp10,000 per hour. The optimal pricing range to maintain high adoption is estimated at Rp0-Rp2,000 per day for private bicycle parking and Rp2,000-Rp5,000 per hour for bike-sharing.

The contribution of this study is to provide one of the first quantified cost thresholds for cycling adoption as an MRT feeder mode in Jakarta, obtained by integrating stated-preference data, a disaggregated twenty-one-equation utility model, and a generalized cost formulation within a single framework. Compared with prior work, which is largely set in developed countries and treats the existing mode as one category, this study offers a behaviourally and economically grounded analysis tailored to a developing-country megacity. Overall, the results indicate that cost is the principal limiting factor for cycling adoption, while affordable pricing combined with supportive infrastructure can substantially increase cycling usage and support a sustainable mode shift within urban transport systems.

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