The Potential of Cycling Superhighway on Promoting the Use of Cycling as Main Mode and FMLM: the Case of Jakarta

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Abstract: Cycling as non-motorized transport vehicles can be utilized to overcome the weakness of the First-Mile Last-Mile (FMLM) in a transit network. This research aims to examine the potential development of cycle infrastructure scenarios in one of the main corridors in Jakarta, Indonesia, by associating user perception and attitudes regarding cycling with a Hybrid Choice Model (HCM). The results show factors that would affect the choice of cycling use, namely cycling motivation, cycle facility, and cycling capability. Between the two scenarios offered, this study found that cycling as the main mode is more preferable than bike-and-ride when a cycling superhighway is provided. Among the cycling superhighway features (intersection priority, dedicated lane, and bike lane width), only dedicated lane is found significant for respondents to choose cycling as their main mode. While in terms of the perception factor, motivation to cycle affects positively to use cycling as the main mode.

Keywords: Bicycle Mode Choice; FMLM Integration; Latent Variable; ICLV; HCM

1. INTRODUCTION

Bicycle as a non-motorized mode plays a significant role in reducing many adverse effects such as greenhouse gases emissions, pollution, congestion, and fossil fuels requirement (Acharjee & Sarkar, 2021). The added value of this mode is that various groups of society can affordably have access to it. From supply perspective, several studies have shown that bicycle service, either bike-sharing or bike-and-ride, is potentially more capable of expanding the scope of the mass public transportation system than walking (Cheng & Lin, 2018; Eren & Uz, 2020 and Fields, 2012). Such infrastructure would fill in the gap of first and last mile segments (as the weakest part of public transport journey) , thus, encourage transport equity so various people groups can access multiple places with a broader range (Irawan et al., 2017; Krygsman et al., 2004; Tay, 2012; Zuo et al., 2020). Bike-sharing and bike-and-ride service require good, and, as much as possible, segregated bicycle path to allow safe and comfortable ride (Dirgahayani et al., 2017; Hussin et al., 2021). Previous research (Manafe., 2021; Wu et al., 2021) also found that the quality of bicycle connectivity to public transportation is able to increase the coverage level of transit services.

Since safety and connectivity are essential, cycle superhighway concept is being introduced by several cities in the world (London, Copenhagen, the Arnhem-Nijmegen corridor

(Netherlands), and Patna (India) (Agarwal et al., 2020; Hallberg et al., 2021). It is a lane or more that is devoted to bicycle, which is separated from pedestrian and motorized vehicles to improve safety and cycling comfort. In addition to that, the network of cycle superhighway includes priority measures at crossroads or intersections. Hence, speed and continuity are guaranteed from any origin-destination. Cycle superhighways are also suitable for encouraging electric bicycle users and high-speed road cyclists. However, this concept is different from the concept of cycling as a First Mile and Last Mile (FMLM) mode, like the bike-sharing or bike-and-ride mentioned earlier. However, those two can be mutually complementary. These two types of bicycle infrastructure network scenarios can be an option for cities in Indonesia.

Furthermore, promoting bicycle also needs more attention on safety, comfort, accessibility, convenience, and consumer surplus of cyclist (Hussin et al., 2021). Since the bicycle is human-powered mode, personal preference (such as perception and attitude about street condition, weather, views, or bicycle facilities) often become determinant factor whether users will ride by bike or other modes (Cykelsekretariatet, 2011; Xing et al., 2018). Recent studies show that the involvement of latent variables (perception, attitudes, norms) in developing new transport infrastructure can matches the user needs (Agarwal et al., 2020; Blitz, 2021; Liu et al., 2019). Vallejo-Borda et al., (2020) and (Acharjee & Sarkar, 2021) also explained that attitudes and perception of perceived quality from different services of cycling infrastructure can explain more about cycling behavior in Agartala City (India) and Global South Country, then it can be used as accurate tool of cycling infrastructure improvement. Pervious study already accommodated safety, comfort, and accessibility criteria to improve recent bicycle infrastructure in Indonesia (Dirgahayani et al., 2017; Manafe., 2021). However, in terms of introducing bicycle superhighway as new facilities and promoting cycling as FMLM choices will needs more analysis not only about the infrastructure quality but also corresponding the personal preference to provide the adequate bicycle infrastructure by meeting the user needs. Expectedly, adding more perception variables can explore more about the unobservable factors that influence cycling preferences.

This study aims to examine the potential development of a bicycle infrastructure network in response to increasingly massive use of cycling in Indonesian cities from the perspective of potential cyclists. It will be obtained by developing the alternative scenarios for the bicycle infrastructure network, comprising of: (i) integration between cycling and public transport; and (ii) cycling as the main mode supported by cycling superhighways). The study further analysed the effect of latent variables on cyclists, bicycle travel behaviour, and conditions physical route of travel by bicycle to the choice of commuting mode.

This paper is organized into six sections. Section two provides a review of the conceptual framework about bicycle usage as FMLM mode, superhighway bicycle and determinant factors of bicycle choice. While section three describes about bicycle case study in Jakarta, Indonesia. Section four gives detail about data collection and model specification. Section five present the modelling result. Last, section five contains conclusions and recommendations.

2. CONCEPTUAL FRAMEWORK OF CYCLING AS A TRANSPORT MODE

One solution to improve transit service coverage is by providing accessibility to a transit point, from the transit point to the endpoint of the journey, called access and egress trip or the FMLM. As a feeder in the transport network, FMLM is the most challenging and the weakest part of the transport network (Hussin et al., 2021; Irawan et al., 2017; Krygsman et al., 2004).

Integrating public transport stops with public bicycle facility become the most favorable determinant to increase the public bikes popularity either as substitute or complement mode for different groups in FMLM trip (Irawan et al., 2017; Ji et al., 2017; Podgórniak-Krzykacz & Trippner-Hrabi, 2021; van Marsbergen et al., 2022; Zuo et al., 2020).

In transit planning, the appropriate mileage for the first and last-mile trips is about 0.25 miles on foot and 3 miles on a bicycle. Using a bicycle as an active transportation mode can make the access distance longer with shorter travel time compared to walking (Zuo et al., 2020). By reducing the distance travelled on this first-and-last-mile, various groups of people can access multiple places with greater coverage accessibility. Since the FMLM is related to the degree of multimodality, the policy maker should consider more about shifting through multimodal mobility because it can lead to more sustainable behaviour (Faber et al., 2022) In Mexico-city, the intention of bicycle is increasing because some road users can get freedom and independence through commuting with bicycle so it makes the trip become more relaxing and comfortable (Cepeda Zorrilla et al., 2019).

Safety and security factors often become a problem in cycling. No dedicated cycling path separate from the motorized vehicles lane, making cycling activities too risky. Therefore, bicycle-friendly transport components are needed in long-term urban planning. Integrating bicycles and public transportation can be a win-win solution for transportation service providers and community groups (Ji et al., 2017).

Bicycle superhighways, also known as “fast cycle routes,” is an emerging concept in urban planning that describes long-distance, with serious safety concern and high-quality bicycle lanes with the purpose of providing safer, faster, direct, and comfortable routes for all types of bicycle riders (Agarwal et al., 2020; Hallberg et al., 2021; Liu et al., 2019). (Agarwal et al., 2020; Law et al., 2014) also mentioned that this new infrastructure increased bicycle shares and the significance of bicycle usage mainly on direct, continuous routes and on routes with a better cycling landscape. Most cycling superhighways in many cities (Agarwal et al., 2020; Hallberg et al., 2021; Liu et al., 2019) apply separated lanes to avoid motorized traffic, making cycling more comfortable as well. As a result, it is expectedly able to encourage people to shift from motorized modes to cycling.

The primary criteria for cycling superhighway are as follow (Cycling Embassy of Denmark, 2019):

- Accessibility: should provide a high connection among all urban areas to make easier access between home, workplace, educational institutions, and public transport for the commuters.
- Passability/directness: should be the direct and fastest cycle path with few obstacles and stops.
- Comfort: offers an excellent experience for cyclists because of its comfortable route, good paving, and extra services.
- Safety and security: should ensure high quality of design, safety, and security so the risk of bicycle accidents and criminality can be decreased.
- Identity and recognizability: be easily recognized from other transport infrastructure.

Although much evidence shows the effectiveness of cycling superhighways in increasing cycling share, this new infrastructure often encounters several problems when it is newly introduced such as traffic jams in some areas due to the narrow area, land limitation to building dedicated cycle lanes that will rise the construction costs and weak law enforcement for motorized vehicle to pass the lanes (Agarwal et al., 2020). In the other hand, the cycle experience is one key element in designing a success superhighway bicycle because it describes how you interact with your surroundings while cycling. As innovation in transportation infrastructure, bicycle superhighways require high-quality infrastructure to make journeys more pleasant for cyclists (Liu et al., 2019). The experience is related to personal preferences, hence the involvement of laten variable into bicycle planning process is very necessary to complement the procurement process of bicycle infrastructure.

Different people with different demographics conditions can show vary preferences when using bicycles. (Zhao & Li, 2017) investigated that young people is less likely to use bicycle rather than bus in Beijing. In contrast, (Böcker et al., 2020; Ji et al., 2017) revealed that women and older people is less likely to cycling to access rail transit in Nanjing China and Oslo Norway. Difference occupancy, income and educational level also effect the choice of bicycle either as personal bike or public bike/bike sharing (Ji et al., 2017; Zhao & Li, 2017). Trip characteristic such as trip distance, trip frequency, trip purpose become other determinant factors of choosing bicycle as transport mode (Ghekiere et al., 2014; Hussin et al., 2021; Irawan, 2022; La Paix et al., 2021) Furthermore, environmental condition either around cyclist houses, along the bike lane or surround public transport points, such as population density, land use, facilities, can affect people choice of bicycle (Böcker et al., 2020; Chen et al., 2022)

The bicycle as a human-powered vehicle should be developed as the environmentally friendly transport choice for many more citizens in their daily lives (Cykelsekretariatet, 2011). In addition, the motivation for cycling is varied among people, some people do cycling as a hobby or recreational activity, but others use the bicycle as the primary mode to commute daily from home to the workplace (utilitarian activity) (Liu et al., 2019). Hence the implementation of cycling behavior can be regarded as a process of individual decisions involving attitudes, intentions, and actions (Bamberg, 2012). Recent studies try to add unobservable variable or called latent variable, which involve psychological perspective, into bicycle mode choice analysis. A latent variable is a random variable that is hard to be observed directly because it usually relates to individual cognition and feels or experiential aspects (such as enjoyability, convenience, safety, and attractiveness) that shape people's behavior through the choice process. (Bierlaire, 2016; Xing et al., 2018). Structural equations model could increase the accuracy in predicting the choice behavior by corresponding attitudes and perceptions as latent constructs in choice models. Involving latent psychological factors can capture individual behavior that cannot be inferred from stated or revealed preferences and objective variables such as time and cost. (Ben-Akiva, WALKER, et al., 2002; Munoz et al. in Dzisi & Lugada, 2021). The conceptual framework of this study can be seen in Fig. 1.

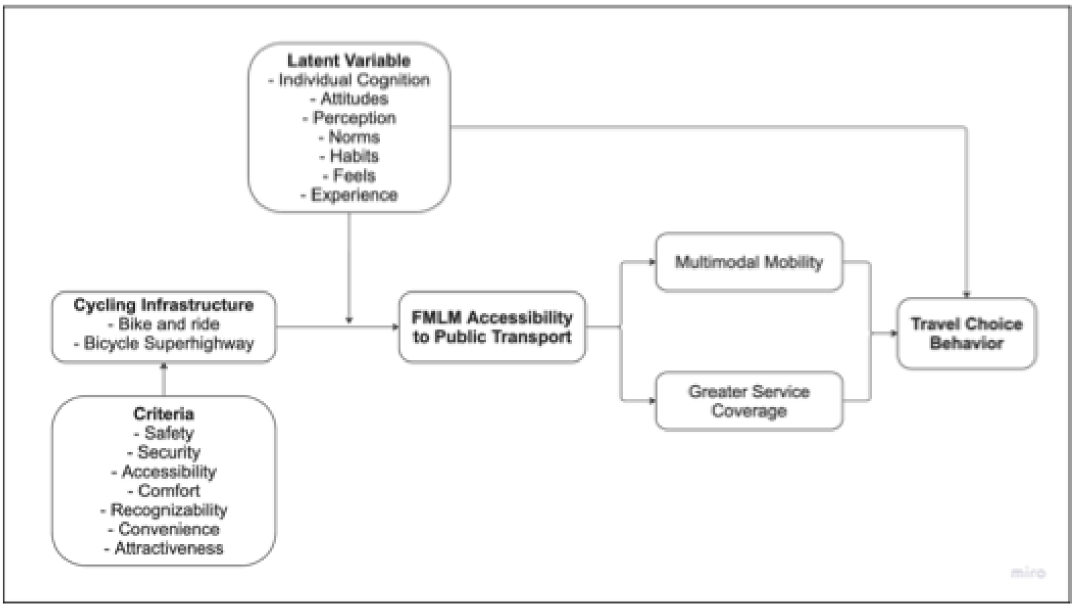

Figure 1. Conceptual Framework of the Influence of Cycling Infrastructure and Latent Variables on Travel Choice Behaviour

3. CASE STUDY

Jakarta, as the capital city of Indonesia, has become home to ten million people. With the high attraction of many activities, 1,255,771 commuters come to Jakarta from surrounding cities (Bogor, Depok, Tangerang, Bekasi) for work (83%) and school (17%). Meanwhile, 250,575 people commute outside Jakarta primarily for work (76%), school (23%), and courses (1%) (BPS, 2020). Sunitiyoso et al., (2022) surveyed 5,064 mass transport users in Greater Jakarta about commuter mode choices during the pandemic. For the first-mile journey, most commuters use private motorcycles (31.24%) as transport mode choice, followed by two-wheeled ride-hailing vehicles (24.54%), walking (22.58%), and microbuses (17.40%). For main mass transport, the respondent chooses the commuter line with the proportion of 55%, and the rest is BRT (40.47%). Then, the last mile journey is dominated by walking (51%), two-wheeled ride-hailing vehicles (32.2%), and microbuses (11.6%).

To support sustainable transport development, Jakarta is committed to increase the accessibility of public transportation by improving walking and cycling conditions as Non-Motorized Transport (NMT) strategy. Jakarta Government prioritize bicycle program initiation such as providing bicycle parking space and the Dockless Bike-Sharing (DBS) program (see Fig. 1) near public transport stations (45 BRT/Transjakarta Station, 7 MRT and 15 commuter line stations). Until 2021, the DBS provide 490 cycles and 67 parking locations in central Jakarta, mainly located near Sudirman-Tahmrin street with 33 km^2 coverage area (ITDP Indonesia, 2021)

Meanwhile, regarding bicycle path, based on Governor Decree DKI Jakarta No. 128/2019, DKI Jakarta planned to develop 17 bicycle routes with 170 km and will be predicted finish by the end of 2022. However, until June 2021, bicycle route reached 63 km in length, consists of bike line along Cipinang-Pondok Kopi, Pondok Kopi-Marunda, Taman Ayodya-Mayor Office, Jl.Imam Bonjol-Jl. Diponegoro (see Fig. 2) and protected bike line along Sudirman-Thamrin street. The most extended bicycle lane is along BKT (Banjir Kanal Timur) area with 17 km. The route is already segregated from the central street, but it has not been connected yet with a mass public transit point (either bus or train station), only a small size of Transjakarta as a feeder bus that passes this route (see Fig. 3).

The other protected line, the Sudirman-Thamrin route, with 11.2 km long and 2 m wide, was introduced by Jakarta Government during the 2020 pandemic (see Fig. 4). The 11.2 km lane was separated from the rest of the street using planter boxes. The data from the local transportation agency showed that nearly 3,000 cyclists passed this route on weekdays and about 23,500 cyclists on weekends during the Pandemic period. This new segregated bike line cost Rp 30 billion, said Jakarta's Transportation Agency. (ITDP Indonesia, 2020) mentioned this protected bike line serves about 37,000 people from 14,000 subdistricts. It is also connected with 9 BRT stations, 6 MRT stations, an LRT network, commuter trains (KRL), and airport trains.

Since the increase of cyclists in the city center up to tenfold (1000%) and 340% in all Jakarta area, even during the covid-19 pandemic (the Jakarta Post,2021), Jakarta Government emphasized cycling infrastructures and facilities throughout the city. The government has started allowing passengers to bring their bikes when boarding MRT Jakarta by providing parking area and bicycle conveyor belt in MRT Dukuh Atas Station (see Fig 5.). In March 2022, the government opened people and bicycle crossing bridge in Karet-Sudirman which connected with Sudirman-Thamrin separated bike lane (see Fig 6). In addition to that, in August 2022, DKI Jakarta provided new bicycle path in recreational area such as Kota Tua revitalization area and Ragunan Zoo.

2. 	3. 	4. 
5. 	6. 	7. 

Figure 2-7. Bicycle Facilities in Jakarta

Dockless bike share and parking facility along Transjakarta BRT lines (Yanocha & Allan, 2021). The bike share was phased out in 2023.
New bike lane on pedestrian way, separated from main road, in Jatinegara Street (Faela Sufa et al., 2020)
Separated bike lane in BKT Area (author documentation, 2022)
Sudirman-Thamrin bike lane with planter box separation (Yuliani, P.A, 2021)
Conveyor belt and bicycle access in Bundaran HI MRT Station (MRT Jakarta, 2020)
6. People and bicycle crossing bridge in Karet-Sudirman (HB team, 2022)

4. METHODOLOGY

This research was be carried out using quantitative method through questionnaire survey. The scope of this study covers 20 wards along segregated bike lines Sudirman-Thamrin in Centre and South Jakarta. Detail of the data collection and data analysis methods will be described in the following subsection.

4.1 Data Collection

The data used in this paper is collected from online questionnaire survey which was distributed to 150 Jakarta citizen who lived and worked in 20 wards along the Sudirman-Thamrin bike lane and were part of a surveyor company's panel members. As mentioned, Sudirman-Thamrin corridor is one of the major roads in the city centre of Jakarta. It is equipped with a segregated bike lane which was newly introduced in Jakarta during the pandemic in 2020. This bike lane offers wide coverage service to 37.366 citizen in high density areas in central of Jakarta. It also connects with 9 BRT stations, 6 MRT stations, an LRT network, commuter trains (KRL), and airport trains (ITDP Indonesia, 2020). With wide coverage and high connectivity, the segregated Sudirman-Thamrin bike lane is expected to stimulate the development of seamless cycle infrastructure and promote the use of larger scale of cyclists in Jakarta.

The questionnaire was filled by 62 male (41%) and 88 female (59%) respondents who lived in South Jakarta (68%) and Central Jakarta (32%). Majority worked as private employee (44%) in South Jakarta (57%) and Central Jakarta (43%) with average income ranges between Rp 4.000.000,- and Rp 10.000.000,- (42%). Most respondents were youngsters with average age between 18-24 years old (34%) , followed by 24-30 years old (31%), and 30-40 years old (24%). The respondents were mostly higher education graduates, comprising of 44% bachelor and 7% postgraduates.

Regarding travel characteristic, most respondents owned motorcycles (87%) and bicycles (81%) as their private vehicles. The bicycle was dominantly used for sport activities (94%), rather than for working (47%) or recreational activities (41%). Regarding commuting activities, only 49% of respondents used bicycle as the primary mode for commuting directly from home to working space. Respondents who usually use bicycle as their primary transport mode to commute to their office directly were not on daily basis, but several times a week (41%). If not riding bicycle, they used motorcycle (31%), ride-hailing mode (34%), or private car (11%). The majority travel distance from home to office was about 2-5 km with travel time around 10-30 minutes.

The rest of the respondents used the bicycle as a feeder mode (51%) for the first mile trip, and then they continued the journey by using public transport such as the Transjakarta bus, MRT, LRT, or commuter line. Even though the average distance from the respondents' home to the public transport transit point (bus/train station) was 1-3 km (which can be accessed in 5-10 minutes), ride-hailing mode was more favourable as a feeder mode either for first mile trip (25%) or last mile trip (38%) compared to walking or cycling.

4.2 Hybrid Choice Model

This research applied the Hybrid Choice Model (HCM) conceptualism through Integrated Choice and Latent Variables (ICLV) model from (Ben-Akiva, Walker, et al., 2002) as part to analyse how is determination of latent variable into bicycle choice model. The behaviour of bicycle mode selection is hypothesized to be primarily influenced by latent variables. HCM can include unobservable factors and the causal relationships among them, which are challenging to analyse in discrete choice analysis. These unobservable factors or latent variables can improve the choice model's explanatory power. Primarily latent variables are identified through a set of attitudinal indicators because of their difficulty in observing directly by revealed choice. Compared to the SEM, HCM is more satisfactory because it can associate with various representations in the mathematical model. HCM can deal with heterogeneities by including individual preferences and varying segmentation into mixed logit models (Kim et al., 2014)

Integrated models consist of discreate choice model and latent variable model on each one or more structural equation model (SEM) and measurement equation model (MEM) (Ben-Akiva et al. 2002). The SEM model describes the causal relationship between observatory variable and latent variable into utility function in choice process. Latent variable model in SEM shows the distribution of the latent variables given the observed variables indicators conditional to reveals the difference of the individual characteristic effect into latent variable and the individual characteristic effect into observatory variable. The latent variable model equation for each latent variable can be stated is as follow:

$$f_1(X_n^* \mid X_n ; \lambda, \Sigma_\omega)$$

$$X_n^* = h(X_n; \lambda) + \omega_n \quad \text{and} \quad \omega_n \sim D(0, \Sigma_\omega) \qquad (1)$$

Meanwhile, in Choice model of SEM, to describe the Distribution of the utility can follow this equation

$$f_2(U_n \mid X_n, X_n^* ; \beta, \Sigma_\varepsilon)$$

$$U_n = V(X_n, X_n^* ; \beta) + \varepsilon_n \quad \text{and} \quad \varepsilon_n \sim D(0, \Sigma_\varepsilon) \qquad (2)$$

The MEM describes the distribution of indicators conditional on the values of the latent variable (Ben-Akiva et al. 2002). The latent variable model equation for each latent variable can be stated is as follow

$$f_3(I_n | X_n , X_n^* ; \alpha , \Sigma_\upsilon)$$

$$I_n = m(X_n, X_n^* ; \alpha) + \upsilon_n \quad \text{and} \quad \upsilon_n \sim D(0, \Sigma_\upsilon) \qquad (3)$$

Meanwhile, in Choice model of MEM to describe the Distribution of the utility can follow this equation

$$y_{in} = \begin{cases} 1, if\ U_{in} = \min_j \{U_{jn}\} \\ 0, otherwise \end{cases}$$

Integrated Model

$$P(y_n | X_n; \beta, \lambda, \Sigma_\omega, \Sigma_\eta) = \int_{X^*} P(y_n \mid X_n, X_n^*; \beta, \Sigma_\varepsilon) f_1(X^* \mid X_n ; \lambda , \Sigma_\omega) \, dx^*$$

$$f_4(y_n, I_n | X_n; \alpha, \beta, \lambda, \Sigma_\varepsilon, \Sigma_\upsilon, \Sigma_\omega) \int_{X^*} P(y_n \mid X_n, X^*; \beta, \Sigma_\varepsilon) f_3(I_n | X_n , X^*; \alpha , \Sigma_\upsilon) f_1(X^* \mid X_n ; \lambda , \Sigma_\omega) \, dx^*$$

v

X_n observed variables

X_n^* latent (unobservable) variables

I_n indicators of X_n^*

U_n vector of utilities

U_{in} utility of alternative i for individual n

y_n vector of choice indicators

y_{in} choice indicator: equal to 1 if alternative i is chosen by individual n and 0 otherwise

α, β, λ unknown parameters

$\omega, \varepsilon, \upsilon$ random disturbance terms

Σ covariance of random disturbance terms

D distribution function

4.3 Setting Variable and HCM Construct

The ICLV model incorporated both the observatory variables and the latent variables into the model. These unobservable variables and observable explanatory variables can affect individuals' preferences toward different alternatives and their decision-making process (Ben-Akiva et al. 2002). (Lizana et al., 2021; Mohammadi et al., 2021; Vij & Walker, 2016) implemented ICLV model to understand about processes behind public transport mode choice decision, including bicycle, by incorporating psychological dimension, besides socioeconomic, bicycle facilities and experience into the model.

4.3.1 Exploratory variable

To describe about exploratory variables, the data from questionnaire survey, particularly socio-demography and travel characteristics are included into the variable list. Then, the attributes of choice set from stated preference (SP) survey also contribute to the explanatory variable. Each attribute level of stated choice is explained as follow:

1) Intersection priority: Currently in Jakarta, there is no intersection priority for cyclist, either bicycle traffic light or regulation to prioritize bicycle when crossing the street. Meanwhile for bicycle superhighway alternative, there are two levels of attributes. First, it is assumed that there will be traffic signal priority for cyclist in some intersections, and second, there is none.
2) Regarding time travel, the cyclist needs to allocate time longer for using bike sharing and bike and ride compared to bicycle superhighway services. The allocation time for using bike sharing along Sudirman-Thamrin route is approximately 50 minutes include time for accessing/walking the bike renting spot from home and after using public transport, renting the bike, riding bike to transit point (bus/train station) and to destination place after using public transport, transporting the train or bus, and walking to the destination places. In bike and ride service, the cyclist no need to allocate time for renting the bike, only additional time for parking the own bike, so the time is slightly decrease become 40 minutes. The time calculation is based on assumption that average walking speed is 3 m/s and average bicycle speed is 20 km/h. Meanwhile for bicycle superhighway alternative, the cyclist no need to rent bike or parking their bike near the station, also because they substitute riding the bus/train with cycling the bike directly from home to destination places, so travel time become much shorter, which for 5 km the trave time is only 20 minutes if they pass the intersection with bicycle prioritizing and 30 minutes if there are no intersection priorities.
3) The existing bike lane width is approximately 1.5 meter for bike sharing and bike and ride services. Besides the future bicycle superhighway width is assumed between 1.5 – 3 meters.
4) Similar to the intersection priority, bike-and-ride alternative uses the same lane with motorized vehicle (mixed traffic). On the other hand, bicycle superhighway alternative has two levels of attribute: (i) using separated lane for cycling and (ii) using the same lane with motorized vehicle.

From the set of attribute level for each choice, the bicycle superhighway choice is designed to be more dominant compared to bike and ride choice, specifically in terms of travel time and travel cost. In case of Jakarta, either bicycle superhighway, bike sharing, or bike and ride choice are provided as alternative mode for accommodating the needs of Jakarta citizen in using bicycle since there was significant number of cycling in Jakarta. On the other hand, as metropolitan city in developing country which have still high dependency on motorized vehicle especially private vehicle, bicycle is still less favourable to use as alternative mode for connecting commuting trip, the majority trip specially for commuting trip is still dominated by private car/motorcycle and ride-hailing vehicle (Sunitiyoso et al., 2022). The use of bicycle is mostly for leisure or sport activities during weekend (ITDP Indonesia, 2021). Hence, even those bicycle facilities have different level of predominancy, the bicycle facility choices can be grouped in the same level because those are newly introduced in the recent decade as innovation mode of non-motorized vehicle as sustainable transportation mode in Jakarta.

Regarding stated preference, it is a data collection technique that can overcome difficulties in collecting respondent decisions in testing policies that have not been implemented in the real world (Ortúzar & Willumsen, 2011). The stated choice is one of the most dominant experimental methods used in transportation planning. Each option presented to the respondent is stated in a 'package' consisting of a combination of several different attributes. Based on stated preference steps from (Greene & Hensher, 2010), the SP design is developed using the R program with fractional factorial design, and provides eight scenarios as shown in Table 1.

Table 1. Stated-preference scenario

Attribute	Attribute Level of Alternative Choice								
	Bike and ride	Cycle Superhighway							
Scenario	1-8	1	2	3	4	5	6	7	8
Intersection priority	No	Yes	Yes	No	Yes	No	Yes	No	No
Travel time (minute)	40	20	30	30	20	20	30	30	20
Bike lane width (meter)	1.5	1.5	3	3	3	3	1.5	1.5	1.5
Separation of bike lane	No	Yes	Yes	No	No	Yes	No	Yes	No

4.3.2 Latent variable

The latent variables are derived from superhighway criteria or indicators from (Cycling Embassy of Denmark, 2019), such as accessibility, directness/passability, comfort, attractiveness, security, and safety, recognizability, and identity. The other latent variables related to bicycle mode choice are also adopted from previous research, such as convenience, awareness of environmental aspects and health, and social control. Each variable is detailed into specific attribute and then divided into two psychological constructs: perception and attitudes. Ben-Akiva et al. (2002) stated that attitudes and perceptions of individuals are predicted to be significant factors in reflecting the behaviour.

Perceptions as the individuals' belief of attribute level can represent the desirability of choices so that it can evaluate individual valuation of bicycle infrastructure toward specific product attributes. Meanwhile, attitudes related to the characteristic of the decision maker that show individuals' needs, values, tastes, and capabilities so it can assess the tendency to respond with some favorableness of using a bicycle (Ben-Akiva, WALKER, et al., 2002; Fishbein & Ajzen, 2010; La Paix et al., 2021). Cycling attitude can be relevant construct to explain cycling behavior which indirectly affected by bicycle familiarity, socio economic condition and bicycle infrastructure availability (Lizana et al., 2021).

Eleven perception statements are grouped into three categories (perception of bicycle facilities, transit facilities, and support facilities). Meanwhile, there are 17 attitude statements grouped into two categories (cyclist attitudes as individual motivations to do cycling and cyclists' attitudes due to external conditions of cycling) (see Table 2 in appendix.). The respondents were asked to choose the perception and attitudes degree through the Likert Scale 1-4 (1: Strongly disagree; 2: Disagree; 3: Agree; 4: Strongly agree)

This research follows the approach from (Walker, 2021) by getting the fitted latent variable through factor analysis on the indicator and then include it in the utility function. Exploratory Factor Analysis (EFA) will be applied to identify the fundamental factors on each psychometric indicator that explain the order and structure among measured variables. EFA common uses as an appropriate tools in identifying the main factor of cycling behavior which related to psychological aspect such as attitudes, perceptions, norms, or habit (Agarwal et al., 2020; Biernat et al., 2018; Cepeda Zorrilla et al., 2019; Clark et al., 2021; Faber et al., 2022; Heinen et al., 2011; Lizana et al., 2021; Watkins, 2018).

Using SPSS software, by taking eigenvalue criteria > 1, EFA result three factors which can explain more variance than a single observed variable. The total variance explained by all component is 51.32% The total variance is still quite acceptable for psychological/behavioral related studies, since mostly that research usually explain around 50% - 60% only (Watkins, 2018). Refer to Table 2 to see the result of EFA.

Table 2. Exploratory factor analysis

Code	Indicator	Load Factor		
		Factor 1 Cycling Motivation	Factor 2 Bicycle Facility	Factor 3 Cycling Capability
P9	Separated bicycle path makes cycling safer	**0.647272**	0.085560	0.135631
A11	I ride bicycle to keep my body healthy	**0.674822**	0.167971	0.189174
A4	I feel comfortable if there are cycling support facilities (rest area, changing room, bike pump)	**0.640974**	0.221580	0.103751
A6	I am happy to do cycling in attraction places (Kota Tua, Monas, Ragunan Zoo or along the river, garden, or green areas)	**0.621366**	0.056773	0.061543
A7	I feel save when cycling in separated cycle path	**0.662425**	0.186184	0.073254
P5	Parking space near PT transit point can/need to be used comfortably	0.416122	**0.759816**	0.214513
P6	Parking space near destination point can/need to be used comfortably	0.277528	**0.624628**	0.153148
P8	Terrain condition along cycle path makes cycling more attractive	0.142275	**0.620306**	0.259116
A3	I will still use bicycle if travel distance from home to school/office is relative far (> 5 km)	0.202045	0.095965	**0.661138**
A5	I feel comfortable when cycling in the morning/noon with high temperature	0.123691	0.313034	**0.569869**
A8	I am happy to do cycling in high elevation street	0.045656	0.128437	**0.852925**
A14	I feel safe to do cycling because it can avoid me from crime risk (theft/immoral actions)	0.140612	0.291480	**0.684460**

Not all indicators are considered as component factor association. Only the indicator with the strongest association to the underlying factor will be considered. In this research, indicator with load factor > 0.6 is considered as factor component association. Factor 1 is named as 'Cycling Motivation' factor because the five strong associated indicators are related to internal and external motivation such as to do cycling such as the availability of separated bike lane, attraction places and cycling support facilities along bike lane which make cycling become safer and more comfortable. Besides the internal motivation in related to keeping body health through cycling activity. In lined with that, (Ma et al., 2021) mentioned that cycling can reduce psychological distress and positively associated with life satisfaction.

As the second factor, three indictors formed the 'Bicycle Facility' factor. The indicators are related to the availability of parking space near public transport transit point or destination point and terrain condition along bike lane. In factor 3, four indicators are considered as component factor which have similarity to explain the experience of cyclist when cycling in high temperature, far distance, high elevation situation and avoiding crime risk. So, it is labeled as 'Cycling Capability' factor. As mentioned in (Berghoefer & Vollrath, 2022), the perception of safe route, cycle stress-free and without stopping are very important for keeping the mental and physical comfort of cycling which related to cycling motivation. The availability of separated bicycle path from motor and pedestrian traffic is very positive to increase cycling safety and mental comfort because it makes good cycling flow and more concentrate to find the route connection. (Clark et al., 2021) also mentioned that separated and protected bicycle facilities are more favorable for pro-bike groups in terms of perceived comfort and safety.

4.3.3 HCM construct

By referring to the results of descriptive analysis on the questionnaire survey and considering the variables which have been found to be statistically significant in previous studies, we formulated the full HCM construct of the model as illustrated in Figure 8.

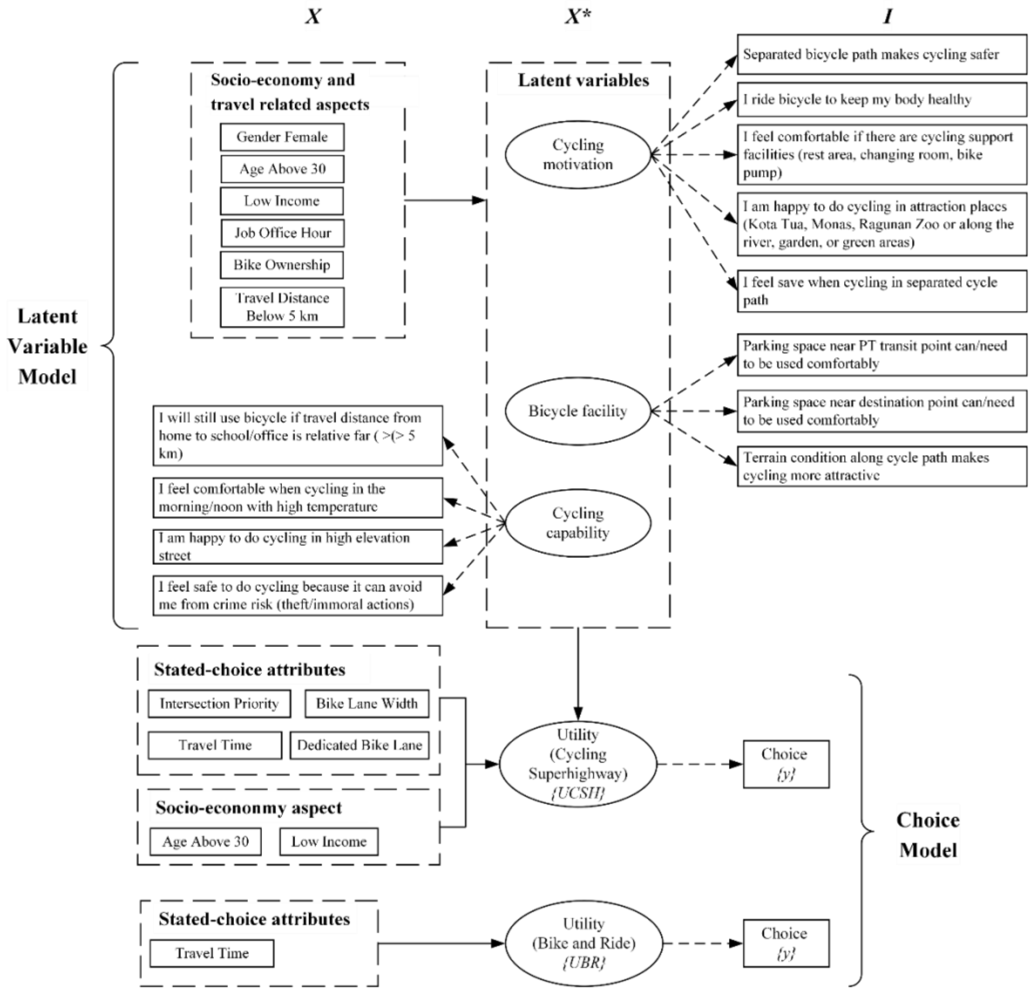

Figure 8. HCM construct: the influence of latent variables on mode choice of cycling

5. ANALYSIS

5.1 Descriptive Statistics

From the survey, most respondents strongly agreed with the perceptions statement of bicycle infrastructure (see Fig.9 and Appendix C). Bicycle facilities such as separated bicycle paths (P9–85%) and bicycle traffic lights (P3-69%) in the intersection are essential to make cycling safer and faster. The availability of bicycle wayfinding/signage (P11-61%) also becomes necessary for cyclists to find the quick route to their destination place easily. Meanwhile, only 37% of respondents feel safe when cycling on a recent bicycle route (P10). It can be interpreted that the condition of the physical bicycle route is currently not secure and needs improvement. At some points of the bike lane in Jakarta, there are still slippery, rocky, and rough street that annoys cycling trip. Besides cycling, supported facilities are also considered essential to support cycling activities. 73% of respondents considered the availability of open green spaces (P7-73%) and rest areas (P4-63%) along the cycle path can make cycling more comfortable and shadier.

Meanwhile, terrain condition in Jakarta is not so attractive for the cycling experience; only 45% of respondents think that the terrain condition along the bike lane in Jakarta is very attractive. Meanwhile, the perception of transit facilities, such as the availability of parking space (P5-47%, P6-49%) and high access to public transport transit points (P1-52%) or destination places directly (P2-53%) is not so high compared to bicycle facilities and bicycle supported facilities. It might be because most respondents use the bike for sports, not for commuting to the workplace, either by integrating with public transport or riding a bike directly to the office.

The most significant factor of internal motivation which affects cycling attitudes is that bicycles can improve physical health (A11-73%). It is aligned with the reason respondents do cycling as a sports activity. The convenience of the bike, such as its ease to use (A13-59%) and low price (A12-52%), also affect respondents to use bicycles rather than other transport modes. However, most cyclists on the Sudirman-Thamrin route do not like to use the bike for far distances (A3). It is shown that only 37% of respondents very agree to keep cycling even if the destination place is more than 5 km. This attitude aligns with the average travel distance of respondents within 2-5 km (47%).

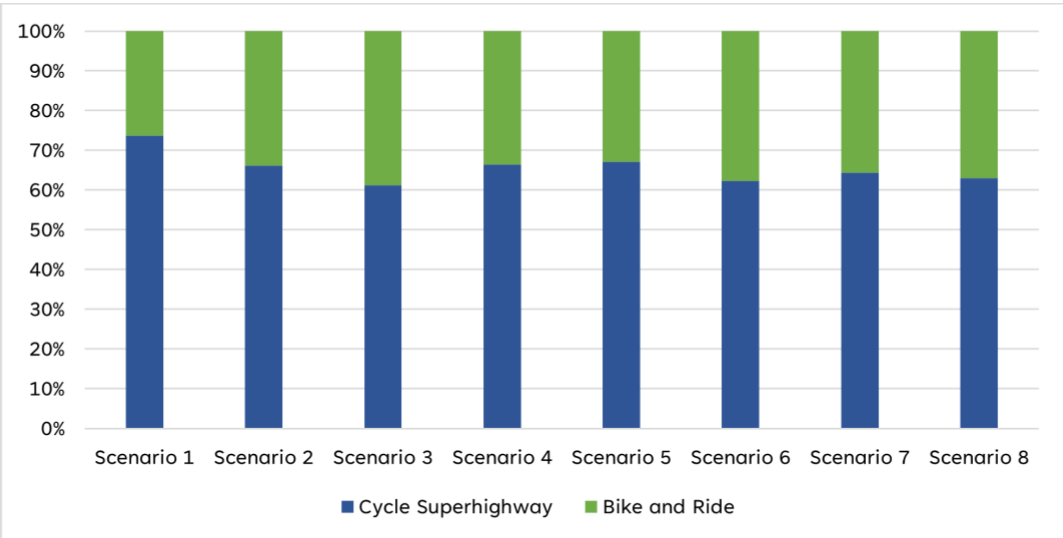

Figure 9. Stated preference result

Meanwhile, external factors give more affection toward cycling attitudes such as can provide a high contribution to environment protection through CO_2 reduction by using bikes (A10-73%), the separated bike lane which makes cycling safety (A7-73%), and the availability of support facilities which make cycling feel so comfortable (A4-72%). In addition, the condition of the bike lane also affects the respondent's attitude when cycling, such as flat and non-slip street surfaces that bring safety for cyclists (A9-69%), the familiarity of bicycle route (A15-61%) means that most respondents prefer to do cycling in common or frequently used path rather than exploring new or unfamiliar cycle path. The respondent also likes cycling along/to the attraction places (A6-63%) because it can give cyclists a breathtaking view and a relaxing feeling. In contrast, most respondents do not like cycling in high elevation streets (A8-26%) with hot temperatures at noon (A5-35%).

Regarding bicycle mode choice, in Fig.9 it can be seen that more than 60% of respondents choose cycle superhighway after considering five attributes. As mentioned before, the bicycle superhighway choice is designed to be more dominant compared to bike and ride choice, specifically in terms of travel time and travel cost. It is because the bicycle superhighway provides a seamless route which makes people easily access the destination point and faster without concerning about the complexity of bike-and-ride.

5.2 Model Result

Bicycle mode choice model in Sudirman-Thamrin, Jakarta was obtained with 1200 observation number to 100 estimated parameters. The total draw of estimation is 300 and generated 0.53 of rho square bar. The result was divided into three parts as follow:

5.2.1 Structural equation model

As seen in Table 3. gender and bicycle ownership are shown to have positive relation with cycling motivation factor. Meanwhile low income is negative. These can be interpreted that female and those who owns bicycle tend to agree that they would cycle to keep their body healthy, if the supporting facilities are available, if they can find attractive places while cycling, and if they can ride along separated cycle path. While people with low income tend to disagree.

On the other hand, significant relations are found between all explanatory characteristics (gender, age, office hour, income, bike ownership, and commuting distance) and the other two factors (bicycle facility and cycling capability). However, only those who own bikes agree with the need for parking space and that terrain condition along cycle path makes cycling more attractive. Furthermore, only those with age more than 30-year-old agree about cycling in high temperature weather and along high elevation street. People of such an age also think that cycling is safe from crime risk. The main findings here are that most people do not see the importance of parking facilities and do not prefer to use cycling in challenging situations.

Table 3. SEM estimation result

Parameter	Value	T-test
Latent Variable 1: Cycling motivation		
Intercept	3.48	17**
Female	0.17	1.65*
Age above 30	0.16	1.44
Office hour job	-0.04	-0.427
Low income	-0.48	-4.04**
Bike ownership	0.26	1.87*
Commuting distance below 5 km	-0.13	-1.11
Sigma	-1.29	-14**
Latent Variable 2: Bicycle facility		
Intercept	1.62	10.1**
Female	-0.19	-1.83*
Age above 30	0.05	0.446
Office hour job	-0.44	-4.17*
Low income	-0.23	-2.13**
Bike ownership	0.59	4.63**

Parameter	Value	T-test
Commuting distance below 5 km	-0.24	-2.37**
Sigma	-1.32	-19.1**
Latent Variable 3: Cycling capability		
Intercept	1.06	6.69**
Female	-0.16	-1.75*
Age above 30	0.72	6.86**
Office hour job	-0.29	-3.03**
Low income	0.20	1.9*
Bike ownership	0.44	3.1**
Commuting distance below 5 km	-0.76	-6.06**
Sigma	-1.34	-13.8**

* Significance level at 90%
** Significance level at 95%

5.2.2 Measurement equation model

Through Measurement Equation Model (MEM), the relation between each factor of latent variable and the indicator components. All indicators have a positive relation with each factor as presented in Table 4. Only indicators with statistical significance are included in the result.

Table 4. MEM estimation result

Indicator statement	Intercept	Coefficient	Sigma
Latent Variable 1: Cycling motivation			
Separated bicycle path makes cycling safer	Reference		
I ride cycling to keep my body healthy	0.332 (3.01)**	0.537 (12.2)**	0.499 (11.4)**
I feel comfortable if there are cycling support facilities (rest area, changing room, bike pump)	0.243 (1.45)	0.565 (8.69)**	0.551 (11.5)**
I am happy to do cycling in attraction places (Kota Tua, Monas, Ragunan Zoo or along the river, garden, or green areas)	0.24 (1.66)*	0.489 (9.31)**	0.643 (16.6)**
I feel save when cycling in separated cycle path	-0.894 (-3.28)**	1.1 (10.1)**	1.1 (8.15)**
Latent Variable 2: Bicycle facility			
Parking space near PT transit point can/need to be used comfortably	Reference		
Parking space near destination point can/need to be used comfortably	0.228 (2.67)**	0.881 (15.2)**	0.955 (15.1)**
Terrain condition along cycle path makes cycling more attractive	0.412 (5.24)**	0.698 (15)**	0.798 (15.5)**

Indicator statement	Intercept	Coefficient	Sigma
Latent Variable 3: Cycling capability			
I will still use bicycle if travel distance from home to school/office is relative far (> 5 km)	Reference		
I feel comfortable when cycling in the morning/noon with high temperature	-0.21 (-2.34)**	1.02 (15.2)**	1.38 (21.9)**
I am happy to do cycling in high elevation street	-0.963 (-12.8)**	1.17 (16.9)**	0.855 (11.1)**
I feel safe to do cycling because it can avoid me from crime risk (theft/immoral actions)	-0.114 (-1.5)	1.03 (14.5)**	1.09 (19.6)**

t-test value is shown in parentheses
* Significance level at 90%
** Significance level at 95%

5.2.3 Choice model

As explained, the stated preference results show that most respondents in this study chose cycling as main mode rather than bike-and-ride. Cycling as main mode seems to be more attractive because of the availability of cycle superhighway. However, the model indicates that among the three features of cycle superhighway (intersection priority, dedicated bike lane, and bike lane width), only dedicated lane matters to them. Perhaps this finding is influenced by the respondents limited understanding about the benefit of intersection priority to the convenience of cycling. While bike lane width may be affected by their understanding that 1.5 m is adequate. In terms of latent variables, cycling motivation and cycling capacity are found significant but one is positive and the other is negative, respectively. Socio-demographically, age above 30 tend to choose cycle superhighway while low income people do not.

Table 5. Choice model estimation result

Parameter	Alternatives	Value	t-test
Alternative specific constant	CSH	-0.55	-1.35
Intersection priority	CSH	0.14	1.05
Dedicated bike lane	CSH	0.23	1.71*
Bike lane width	CSH	-0.02	-0.22
Travel time	CSH, BR	-1.16	-1.46
Cycling motivation (LV1)	CSH	0.24	3.13**
Bicycle facility (LV2)	CSH	0.09	1.19
Cycling capability (LV3)	CSH	-0.24	-3.15**
Age above 30	CSH	0.55	3.29**
Low income	CSH	-0.33	-2.30**
Rho square bar		0.56	
Final log likelihood		-10968.76	

* significance level at 90%
** significance level at 95%
Note: CSH: Cycle Superhighway; BR: Bike and Ride

6. CONCLUSION

This study has explored the potential of cycling as a commuting option in Jakarta by analyzing two key approaches: (i) using cycling as the main mode of transport through the implementation of a cycle superhighway, and (ii) employing cycling as a first mile and last mile (FMLM) solution integrated with public transport (bike-and-ride). The findings indicate that while cycling is becoming increasingly popular in Jakarta, particularly for recreational purposes, its use for daily commuting remains limited. This limitation is mainly due to inadequate infrastructure, safety concerns, and user preferences. Additionally, gaps in Jakarta's public transport network, especially in the FMLM segments, present an opportunity for cycling to complement and improve urban mobility.

One of the key findings of this study is that dedicated cycling lanes or cycling superhighway significantly influence users' decision to adopt cycling as a primary commuting mode. This is consistent with previous research that highlights the importance of protected cycling infrastructure in fostering greater adoption of bicycles in urban settings (Agarwal et al., 2020; Liu et al., 2019). Studies in cities like London and Copenhagen have shown that well-designed cycling superhighways not only enhance safety but also lead to a modal shift away from motorized transport, thereby contributing to reduced congestion and emissions (Hallberg et al., 2021). Furthermore, research by Blitz (2021) and Vallejo-Borda et al. (2020) underscores the role of user perception and psychological factors in shaping cycling behavior. Our findings align with these studies, indicating that cycling motivation, infrastructure perception, and cycling capability are crucial determinants in mode choice decisions.

The research points out the socio-economic differences in the adoption of cycling. It revealed that individuals aged 30 and above tend to favor cycling superhighways, whereas those from lower-income backgrounds are less likely to commute by bicycle. This corresponds with earlier studies by Ji et al. (2017) and Zhao & Li (2017), which pinpointed age, income, and accessibility as significant factors affecting cycling adoption trends. The results indicate that urban cycling policies ought to be crafted with inclusivity in focus, tackling both infrastructural and socio-demographic challenges.

When examining the worldwide trend, cities that have effectively boosted cycling participation have achieved this by combining high-quality infrastructure with initiatives that promote changes in behavior (Heinen et al., 2011; Böcker et al., 2020). This research highlights the necessity for a comprehensive strategy in Jakarta, where enhancements to physical infrastructure should be paired with supportive policies such as bike-sharing initiatives, incentives (both financial and non-financial) for those who cycle to work, and stricter traffic laws to ensure the safety of cyclists. Although bike-sharing has shown to be an important aspect of sustainable urban transport in numerous cities around the globe, its effectiveness relies on adequate infrastructure, policy backing, and synergy with other modes of transportation.

Future studies ought to investigate the lasting effects of cycling superhighways on urban transportation, especially in developing cities where cycling infrastructure is still being established. Furthermore, analyzing the relationship between cycling, micromobility services, and the integration of multiple modes of transport could offer important insights for developing a more sustainable and inclusive urban transport system.

The results of this research regarding cycling infrastructure and behavior in Jakarta carry important policy implications, not only for Indonesia but also for other cities in the Global South and beyond. Numerous developing urban areas encounter comparable difficulties in encouraging cycling due to insufficient infrastructure, car-centric policies, and socio-economic obstacles. Yet, effective global transportation strategies provide insights that can be tailored to enhance cycling usage in urban settings. The findings of this study highlight the necessity for comprehensive, multi-faceted cycling policies that encompass infrastructure development, financial incentives, cultural transformations, and governance changes. While Jakarta stands to gain from customized local strategies, experiences from cities like Copenhagen, Bogota, Beijing, and Mexico City demonstrate that successful cycling policies depend on strong political commitment, reliable funding, and engaged public participation. Especially for cities in the Global South, recognizing cycling as a viable primary mode of transportation, rather than merely a supplementary option, is a crucial first step towards implementing consistent policies. Building on this principle, additional insights include investing in effective multimodal integration with public transport and expanding cycling infrastructure to lower-income neighborhoods to enhance coverage and promote equity.

ACKNOWLEDGEMENTS
This research is fully funded by the Center of Research and Community Services (LPPM) of Bandung Institute of Technology (ITB) under the PPMI-KK Research Grant.

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APPENDICES

Appendix A. Observatory Variable

No	Observatory Variable	Measurement	Author
	Filter Question		
1	Have you ever used a bicycle for commuting to work/school?	• Yes • No	
	Demographic		
2	Age	• < 18 years old • 18 – 24 years old • 24 – 30 years old • 30 – 40 years old • > 40 years old	(Blitz, 2021; Dzisi & Lugada, 2021; Ghekiere et al., 2014; Hussin et al., 2021; Irawan, 2022; La Paix et al., 2021; Liu et al., 2019; Zhao & Li, 2017)
3	Gender	• Men • Women	(Blitz, 2021; Dzisi & Lugada, 2021; Ghekiere et al., 2014; Hussin et al., 2021; Irawan et al., 2017; Liu et al., 2019; Zhao & Li, 2017)
4	Education level (Last education)	• Elementary School • Junior high school • Senior high school • Diploma 3/Associate degree • Bachelor degree • Master degree • Doctoral degree	(Blitz, 2021; Ghekiere et al., 2014; La Paix et al., 2021; Zhao & Li, 2017)
5	Occupancy (current job)	• Civil servant • TNI/POLRI • BUMD/BUMN employee • Private employee • Entrepreneur • Student • Housewife • Jobless	(Blitz, 2021; Ghekiere et al., 2014)

No	Observatory Variable	Measurement	Author
		• Others:	
6	Income	• < IDR 2,500,000,- • IDR 2,500,001,- - IDR 4,000,000,- • IDR 4,000,001,- - IDR 10,000,000 • IDR 10,000,001,- - IDR 15,000,000,- • > 15,000,000,-	(Dzisi & Lugada, 2021; Hussin et al., 2021; Zhao & Li, 2017)
7 and 8	Residency/working area	• Bendungan Hilir, Kec. Tanah Abang, Jakarta Pusat • Gambir, Kec. Gambir, Jakarta Pusat • Gelora, Kec. Tanah Abang, Jakarta Pusat • Gondangdia, Kec. Menteng, Jakarta Pusat • Grogol Selatan, Kec. Kebayoran Lama, Jakarta Selatan • Grogol Utara, Kec. Kebayoran Lama, Jakarta Selatan • Guntur, Kec. Setiabudi, Jakarta Selatan • Gunung, Kec. Kebayoran Baru, Jakarta Selatan • Kampung Bali, Kec. Tanah Abang, Jakarta Pusat • Karet, Kec. Setibudi, Jakarta Selatan • Karet Kuningan, Kec. Setiabudi, Jakarta Selatan • Karet Semanggi, Kec. Setiabudi, Jakarta Selatan • Karet Tengsin, Kec. Tanah Abang, Jakarta Pusat • Kebon Kacang, Kec. Tanah Abang, Jakarta Pusat • Kebon Melati, Kec. Tanah Abang, Jakarta Pusat • Kebon Sirih, Kec. Menteng, Jakarta Pusat • Menteng, Kec. Menteng, Jakarta Pusat • Selong, Kec. Kebayoran Baru, Jakarta Selatan • Senayan, Kec. Kebayoran Baru, Jakarta Selatan • Setiabudi, Kec. Setiabudi, Jakarta Selatan	
	Travel Characteristics		
9	Private vehicle ownership (can choose more than one)	• Do not have any vehicle • Private car • Private motorcycle • Bicycle	(Cheng & Lin, 2018; Irawan, 2022; Liu et al., 2019)

No	Observatory Variable	Measurement	Author
		• Other:	
10	How do you usually use bicycle as commuting mode?	• As a feeder. Cycling from home to transit point and from transit point to office/school • As main mode. Cycling directly from home to office/school	(Hussin et al., 2021)
11	How often do you use bicycle for commuting trip?	• Once in a year • Several times in a year • Once in a month • Several times in a month • Once in a week • Several times in a week • Every day (continue to no. 18)	(Blitz, 2021; Cheng & Lin, 2018; Ghekiere et al., 2014; Irawan, 2022; La Paix et al., 2021)
12	Besides using a bicycle, what vehicle do you usually use for commuting?	• Train (continue to no. 13) • Bus (continue to no. 13) • Angkot (continue to no. 13) • Becak (continue to no. 13) • Bajaj (continue to no. 13) • Walking (continue to no. 18) • Private car (continue to no. 18) • Private motorcycle (continue to no. 18) • Conventional taxi (continue to no. 13) • Conventional motorcycle (continue to no. 13) • Ride-hailing taxi (continue to no. 18) • Ride-hailing motorcycle(continue to no. 18)	(Ghekiere et al., 2014; Hussin et al., 2021; La Paix et al., 2021; Zhao & Li, 2017)
13	If you use public transport mode, what mode do you often use to access transit point besides bike?	• Walking • Private car • Private motorcycle • Conventional taxi • Ride hailing taxi • Conventional motorcycle • Ride-hailing motorcycle • Bus • Angkot • Becak • Bajaj	(Adnan et al., 2019; La Paix et al., 2021; Sunitiyoso et al., 2022)
14	How far the distance from home to transit point?	• < 1 km • 1 – 3 km • 3 – 5 km • > 5 km	(Adnan et al., 2019; Böcker et al., 2020; Cheng & Lin, 2018; Ghekiere et al., 2014; Hussin et al., 2021; Zhao & Li, 2017)
15	What is average time to travel from home to nearest transit point?	• 5 minutes • 5 – 10 minutes • > 10 minutes	(Adnan et al., 2019; Blitz, 2021; Hussin et al., 2021)
16	Besides bike, what mode do you usually use to access school/office from transit point?	• Walking • Private car • Private motorcycle • Conventional taxi	(Adnan et al., 2019; La Paix et al., 2021; Sunitiyoso et al., 2022)

No	Observatory Variable	Measurement	Author
		• Ride hailing taxi • Angkot • Conventional motorcycle • Ride-hailing motorcycle • Bajaj • Becak	
17	How much money do you spend if you use public transport?	• < IDR 5,000,- • IDR 5,000,- - IDR 10,000,- • IDR 10,000,- - IDR 15,000,- • IDR 15,000,- - IDR 20,000,- • IDR 20,000,- - IDR 25,000,- • IDR 25,000,- - IDR 30,000,- • IDR 30,000,- - IDR 35,000,- • IDR 35,000,- - IDR 40,000,- • > IDR 40,000,-	(Adnan et al., 2019; Hussin et al., 2021)
18	How far the distance from home to office/school?	• < 2 km • 2 – 5 km • 5 – 10 km • > 10 km	(Adnan et al., 2019; Böcker et al., 2020; Cheng & Lin, 2018; Ghekiere et al., 2014; Hussin et al., 2021; Zhao & Li, 2017)
19	What is average time to travel from home to office/school directly?	• < 10 minutes • 10 – 30 minutes • 30 – 60 minutes • > 60 minutes	(Adnan et al., 2019; Blitz, 2021; Hussin et al., 2021)
20	What is your favorite bicycle route?	• Cipinang pondok Kopi along Banjir Kanal Timur (BKT) • Pondok Kopi – Marunda • Taman Ayodya – Kantor Walikota Jakarta Selatan • Imam Bonjol – Diponegoro • Jalur sepeda terproteksi Sudirman – Thamrin • Other:	(Hussin et al., 2021)
21	Beside for commuting, what is your purpose from riding the bike?	• Working • Studying • Shopping • Doing sport • Recreational activity • Social activity • Other:	(Blitz, 2021; Cheng & Lin, 2018; Ji et al., 2017; La Paix et al., 2021; Liu et al., 2019)
22	Do you use your own bike or renting bike from bike sharing program?	• Renting bike from bike sharing program • Own bike	(Adnan et al., 2019)
23	If you rent the bike, how much cost do you spend for one trip?	• < IDR 5,000,- • IDR 5,000,- - IDR 10,000,- • IDR 10,000,- - IDR 15,000,- • IDR 15,000,- - IDR 20,000,- • IDR 20,000,- - IDR 25,000,- • > IDR 25,000,-	(Adnan et al., 2019; Hussin et al., 2021)
24	Is there bicycle parking cost? If it so, how much cost for parking the bicycle?	• IDR 0,- • IDR 1,000,- • IDR 2,000,- • IDR 3,000,- • IDR 4,000,- • IDR 5,000,-	(Adnan et al., 2019; Hussin et al., 2021)

No	Observatory Variable	Measurement	Author
		• IDR 6,000,- • > IDR 6,000,-	

Appendix B. Latent Variable

Variable	Attribute	Code	Statement	Author
Accessibility	Access to transit location from home	P1	Bus or train station can/need to be reached easily from bicycle lane	(Cykelsekretariatet, 2011; La Paix et al., 2021)
		A1	By cycling, I can easily shift between PT because cycle path is integrated with PT transit point	(Cykelsekretariatet, 2011; La Paix et al., 2021)
	Access to workplace from home	P2	School/workplace can/need to be reached directly from home by bicycle	(Cykelsekretariatet, 2011; La Paix et al., 2021)
		A2	I feel easy to go to my destination point because cycle path reaches many places (school, office, department store)	(Cykelsekretariatet, 2011; La Paix et al., 2021)
	Travel distance	A3	I will still use bicycle if travel distance from home to school/office is relative far (> 5 km)	(Adnan et al., 2019; Hussin et al., 2021)
Passability	Intersection priority	P3	Bicycle traffic light in intersection makes cyclist easy and fast to cross the street	(Cykelsekretariatet, 2011; La Paix et al., 2021)
Comfort	Rest area availability	P4	Rest areas along bicycle lane makes cycling activity become more comfortable	(Blitz, 2021; Liu et al., 2019)
		A4	I feel comfortable if there are cycling support facilities (rest area, changing room, bike pump?)	(Blitz, 2021; Liu et al., 2019)
	Parking condition near PT point	P5	Parking space near PT transit point can/need to be used comfortably	(Adnan et al., 2019; Blitz, 2021; Hussin et al., 2021; Liu et al., 2019)
	Parking condition near destination point	P6	Parking space near destination point can/need to be used comfortably	(Adnan et al., 2019; Blitz, 2021; Hussin et al., 2021; Liu et al., 2019)
	Weather	A5	I feel comfortable when cycling in the morning/noon with high temperature	(Adnan et al., 2019; Dzisi & Lugada, 2021; Ghekiere et al., 2014; Hussin et al., 2021; Liu et al., 2019)
Attractiveness	Open green space condition along cycle path	P7	Open green spaces along cycle path makes cycling more comfortable and shadier	(Blitz, 2021; Cykelsekretariatet, 2011; Dzisi & Lugada, 2021; Liu et al., 2019)
	Terrain condition	P8	Terrain condition along cycle path makes cycling more attractive	(Ghekiere et al., 2014; Liu et al., 2019)

Variable	Attribute	Code	Statement	Author
		A6	I am happy to do cycling in attraction places (Kota Tua, Monas, Ragunan Zoo or along the river, garden, or green areas)	(Liu et al., 2019)
Safety	Separated cycle path	P9	Separated bicycle path makes cycling safer	(Cykelsekretariatet, 2011; La Paix et al., 2021)
		A7	I feel save when cycling in separated cycle path	(Cykelsekretariatet, 2011; La Paix et al., 2021)
	Physical path condition with minimum safety standard	P10	The recent physical condition of cycle path is safe for passing by bicycle	(Ghekiere et al., 2014; Hussin et al., 2021)
		A8	I am happy to do cycling in high elevation street	(Dzisi & Lugada, 2021; Ghekiere et al., 2014)
		A9	I feel safe when cycling in flat and non-slip street surface	(Dzisi & Lugada, 2021; Ghekiere et al., 2014)
Recognizability and identity	Wayfinding/signage availability	P11	Wayfinding / signage along cycle path makes cyclist easy to find travel route	(Cykelsekretariatet, 2011)
Awareness to environment impact and health	Environment impact	A10	I use bicycle because it can contribute in reducing city pollution	(Adnan et al., 2019; Dzisi & Lugada, 2021)
	Body health	A11	I do cycling to keep my body healthy	(Adnan et al., 2019; Dzisi & Lugada, 2021)
Convenience	Travel cost	A12	I choose bicycle because the price is relatively cheap	(Dzisi & Lugada, 2021; Zhao & Li, 2017)
	Easy to use	A13	I choose bicycle because easy to be used	(Adnan et al., 2019; Dzisi & Lugada, 2021)
Security	Secure from criminal	A14	I feel safe to do cycling because it can avoid me from crime risk (theft/immoral actions)	(Irawan, 2022)
	Familiar location	A15	I feel safe to do cycling in familiar cycle path	(Ghekiere et al., 2014)
Social Control	Friends/family influence	A16	I am interested on cycling because my family and friends also do cycling	(Dzisi & Lugada, 2021; Ghekiere et al., 2014; Liu et al., 2019)
	Stranger danger	A17	I feel safe to do cycling alone	(Ghekiere et al., 2014; Liu et al., 2019)

Appendix C. Statistic Descriptive Analysis

Variable	Mean	St. Dev.	St. Error
Perception			
P1	3.43	0.65	0.05
P2	3.45	0.64	0.05
P3	3.63	0.62	0.05
P4	3.60	0.56	0.05
P5	3.31	0.76	0.06
P6	3.33	0.74	0.06
P7	3.71	0.51	0.04
P8	3.35	0.67	0.05

P9	3.84	0.40	0.03
P10	3.09	0.84	0.07
P11	3.51	0.69	0.06
Attitude			
A1	3.41	0.68	0.06
A2	3.27	0.75	0.06
A3	3.03	0.90	0.07
A4	3.71	0.49	0.04
A5	2.91	0.98	0.08
A6	3.61	0.53	0.04
A7	3.68	0.59	0.05
A8	2.64	0.98	0.08
A9	3.62	0.64	0.05
A10	3.71	0.50	0.04
A11	3.73	0.46	0.04
A12	3.41	0.70	0.06
A13	3.55	0.59	0.05
A14	2.97	0.91	0.07
A15	3.55	0.62	0.05
A16	3.18	0.79	0.06
A17	3.37	0.66	0.05