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Enhancing Urban Resilience through Strategic Parking Pricing in Jakarta's Bus Rapid Transit Corridors

Sanda Arifianto[1], Muhammad Zudhy Irawan[2,*], Phathinan Thaithatkul[3], Muhamad Rizki[4], Ari Krisna Mawira Tarigan[5], Nur Oktaviani Widiastuti[6]
[1]Center for Sustainable Transport Management, Ministry of Transportation, Jakarta 10110, INDONESIA
[2]Department of Civil and Environmental Engineering, Universitas Gadjah Mada, Yogyakarta 55281, INDONESIA
[3]Department of Civil Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10330, THAILAND
[4]Institute for Transport Studies, University of Natural Resources and Life Sciences (BOKU), Vienna, 1180, AUSTRIA
[5]Department of Safety, Economics, and Planning, University of Stavanger, 4021 Stavanger, NORWAY
[6]Department of Civil Engineering, The University of Tokyo, Tokyo 113-8656, JAPAN
*Corresponding author: zudhyirawan@ugm.ac.id

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ABSTRACT Although Jakarta has invested in various mass transport systems, these efforts have not successfully reduced private vehicle use. Due to this, this study aims to analyze the impact of implementing TransJakarta bus rapid transit corridor-based high parking tariffs on travel mode choice, including road- and rail-based public transport, ride-hailing, taxi, car, and motorcycle. Involving 478 private vehicle users and implementing a nested logit model, some variables, including respondents' income, travel time, egress time, parking costs, parking distance, travel cost, and parking surcharge, are considered to understand to what extent these variables influence the use of proposed travel mode in the future. The nested logit model shows that not all variables significantly influence travel mode use, specifically related to rail-based public transport choice among motorcyclists. Meanwhile, parking distance insignificantly influences the choice of all travel modes except cars among car users. The results also indicate that increasing parking tariffs insignificantly influences the likelihood of both motorcyclists and car users shifting to public transport. Motorcyclists and car users tend to continue using motorcycles but change parking locations with higher tariffs. Additionally, some shifts towards ride-hailing services and TransJakarta Bus Rapid Transit are found, meaning that there is potential for these alternatives to play a significant role in reducing private vehicle use. Based on the model results, additional push-based policies, such as the odd-even license plate rule, are necessary to effectively support the transition from private vehicle use to public transport. Implementing these policies is expected to significantly contribute to reducing traffic congestion and promoting a sustainable and resilient urban environment.

KEYWORDS bus rapid transit corridor, mode shifting, parking tariffs, private vehicles, public transport

1 INTRODUCTION

1.1 Background

Parking management is a crucial component of sustainable transportation and urban resilience in urban areas. The literature shows that reducing the number of cars used in cities by implementing parking policies has become the second-best method for addressing traffic externalities (Arnott et al., 2015; Arnott and Rowse, 2009; Fosgerau and de Palma, 2013). However, managing parking is an unpopular policy because people usually reject changes or limits to situations that they have become used to and considered normal, such as on-street parking. Recently, the Government of Jakarta began regulating vehicle parking by implementing a high parking charge on roads that serve as mass transit corridors. It is expected that increasing parking charges could reduce private vehicle use and encourage a shift to public transport. A study shows that among many parking policies, parking price regulation is one of the tools that has proven effective in managing parking and traffic demand (Kirschner and Lanzendorf, 2020). Meanwhile, a study in Iran revealed that if parking prices rise in the central business district (CBD) of Mashhad City, it is likely that fewer people will choose to drive to the CBD (Ahmadi Azari et al., 2013). Building on the above studies, this study aims to evaluate the impact of high parking charges along the TransJakarta BRT corridors on mode shifting, including public transport, ride-hailing, and motorcycle, and parking location change. This study is expected to contribute to enriching the literature related to the impact of high parking charges on mode shifting in a city with significant public transport investments but still predominantly reliant on cars and motorcycles, including ride-hailing services. To the best of our knowledge, limited studies consider the role of ride-hailing as a competitor to public transport as an alternative to private vehicle use when a high parking charge policy is applied.

1.2 A Case of the Jakarta Metropolitan Area

The Jakarta Metropolitan Area (JMA), consisting of Jakarta, Bogor, Depok, Tangerang, and Bekasi, is a small area (0.34% of the total area of Indonesia) but has a high population of about 29 million people, or 11% of the total population of Indonesia (Indonesia Bureau of Statistics, 2022). Data recorded 49.5 million daily trips in JMA in 2018 (Jabodetabek Transportation Management Agency, 2019), with travelers making multiple tours (Bastarianto et al., 2019) and using multimodal transport (Sunitiyoso et al., 2022). As a capital city, Jakarta is a city that offers a variety of road- and rail-based public transportation options. Jakarta has had the TransJakarta Bus Rapid Transit since 2004, (BRT) (PT. Transportasi Jakarta, 2022), and light and mass rail transit since 2019 (Berawi et al., 2020; Dahlan and Fraszczyk, 2019; Dirgahayani et al., 2020). As a result, a study found that TransJakarta BRT has decreased the use of private motorcycles and motorcycle taxis (Chiu, 2022). Furthermore, to reduce private vehicle use within the city, the Jakarta Government implemented a 3-in-1 high-occupancy vehicle (H.O.V.) policy (Governor of DKI Jakarta Province, 2012), which was then converted into the odd-even license plate policy (Governor of DKI Jakarta Province, 2016). Additionally, The Jakarta Government had plans to implement electronic road pricing (ERP) to replace the odd-even license plate policy (Agarwal and Koo, 2016; Rotaris et al., 2010), and a study predicted that Jakarta's road pricing could successfully reduce car and motorcycle usage, with car usage declining more than motorcycle usage (Belgiawan et al., 2019). Understanding the effect of transport management in the JMA is important because previous studies have shown that not all effective transport policies implemented in other countries can be successfully applied in Jakarta (Hanna et al., 2017; Hansen et al., 2018). Moreover, although the government has implemented both push and pull demand policies, the number of private vehicle ownership in Jakarta continues to increase yearly, from 3.3 million cars and 15.87 million motorcycles in 2019 to 4.1 million cars and 16.52 million motorcycles in 2021 (Jakarta Statistics Agency, 2022). Furthermore, the presence of ride-hailing services, particularly motorcycle ride-hailing, in the JMA (Irawan et al., 2020) poses a caution to the transition from private vehicles to public transport during the implementation of a high parking charge policy. Studies found that the lack of parking fees has become a significant reason people use ride-hailing services (Ilavarasan et al., 2018; Rayle et al., 2016; Tirachini and del Río, 2019; Tirachini and Gomez-Lobo, 2020).

2 LITERATURE REVIEW

The literature shows that parking costs significantly impact mode choice decisions. Studies have revealed that the higher the parking charge, the lower the probability of car drivers choosing to drive and the higher the chance of them using public transport (Hess, 2001; Watts and Stephenson, 2000; Wilson, 1992). A study in Nanning, China, demonstrated that a 20% reduction in parking volume and a 10% reduction in parking duration followed an increase in parking charges (Mo et al., 2021). Another study concluded that after implementing an employer transport plan, including high parking charges, monetary rewards for avoiding driving to work, and public transport subsidy for workers at the University of Sheffield, the number of car use could be reduced up to 7.3%. In comparison, the number of bus use increased by 1.8% (Watts and Stephenson, 2000). However, a study in San Francisco revealed that an increase in parking cost does not affect the car usage of high-income people as much and affects more on cheaper parking locations change rather than shifting to public transport use for low-income people (Chatman and Manville, 2018; **?**). Similar studies also show that shifting parking locations is a more common reaction to parking interventions rather than changes to other transport modes (Marsden, 2006; Shiftan, 2002). Some researchers have found other factors influencing parking decisions. It has been shown that a number of parking factors, such as parking time restrictions, walking distances to destinations, and the time it takes to find parking spaces substantially impact on parking decisions (Chaniotakis and Pel, 2015; Golias et al., 2002; Tsamboulas, 2001). Other studies have also found that socio-demographic factors such as monthly income, are significantly correlated with parking decisions (Brown, 1986; Sasaki, 1990). Furthermore, studies have also considered the performance of public transport services and access to bus stops as determinants of parking decisions (Rowe et al., 2011; Zahabi et al., 2012). For example, a study in Montreal revealed that both public transport features and parking fees significantly influence mode choice decisions among downtown commuters. Specifically, the study found that an increase in public transport fares and travel time leads to a decrease in public transport use. In contrast, raising parking charges can increase public transport use, where a 1 USD increase in hourly parking cost results in a 5% increase in the proportion of commuters using public transport (Zahabi et al., 2012). To conclude, among the determinants of parking decisions, the most common parking policy appears to be parking fee systems, which are also often viewed as the most successful policy tool. Furthermore, recent studies have also shown a correlation between parking and ride-hailing. When the parking charge at the destination location is high, people tend to use ride-hailing rather than private vehicles. This finding suggests that the growth in

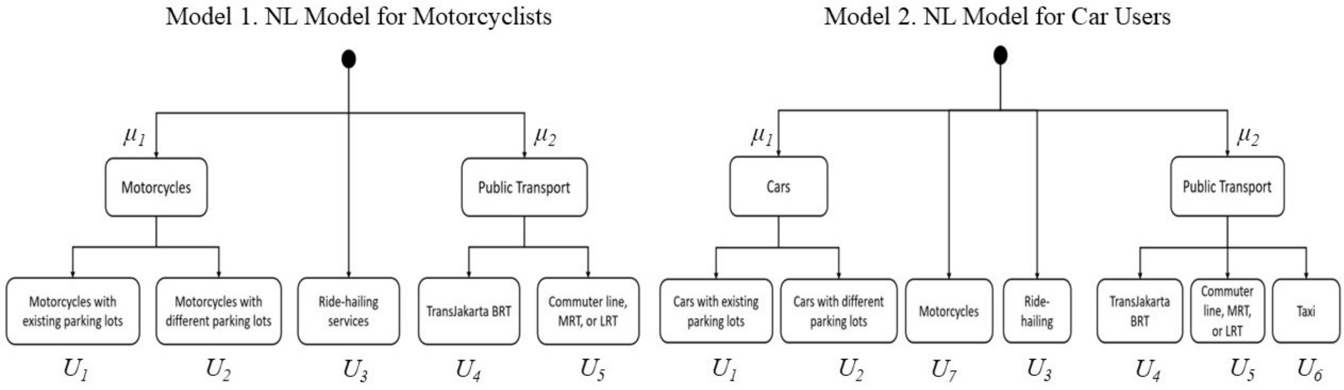

Figure 1 Proposed NL Models

the usage of ride-hailing services in metropolitan areas has contributed to a decline in parking revenues (Steele, 2018). A study in the Denver metropolitan area also shows that trips to the CBD with high parking costs are increasingly replaced by using ride-hailing services. The study also found that if ride-hailing services did not exist, 26.4% of passengers would have driven and needed a parking space (Henao and Marshall, 2019). A similar situation also occurs in airports, where parking revenue declines as an impact of the existence of ride-hailing services (Mandle and Box, 2017).

3 METHOD

The discrete choice model (DCM) serves as a foundational approach to analyzing decision-making behaviors. While the multinomial logit (MNL) model is widely utilized in DCM, this study prefers to use a nested logit (NL) model rather than the MNL model. The NL model, ideal for complex decision-making scenarios, improves on the multinomial logit model by better representing joint choices and inter-alternative correlations, particularly in travel mode and departure time, and is more suitable for capturing choice probability in itinerary share models (Chuan et al., 2015; Etebari, 2020). The rationale for using this model stems from the possibility of grouping several alternative transportation options that involve the same mode, such as motorcycles or cars and public transport. For example, within the motorcyclists' model, alternatives like "Motorcycles with existing parking lots" and "Motorcycles with different parking lots" could can be considered as a motorcycle mode in the first nest. Meanwhile, the choice of TransJakarta BRT and Commuter Line, MRT, and LRT can be considered grouped as public transport modes in the first nest. Figure 1 shows the proposed NL model of this study. The utility of the selected travel mode (U) was assessed based on several factors: monthly income (X_1) travel time (X_2) from home to parking lots at their destination location, egress time from parking lots to workplace (X_3), parking cost (X_4), distance from parking lots to workplace (X_5), and travel cost for gasoline and toll (X_6), along with the scenario involving parking cost (X_7). It is important to note that the variables from X_1 to X_6 reflect the current conditions, whereas X_7 represents a hypothetical scenario. In this scenario, it examines the alternative transportation modes chosen by respondents when the parking costs are hypothesized to increase or decrease. The utility function can be written as shown in Equation 1, where $\alpha$is constant and $\beta$is the estimated parameters.

$$U = \alpha+\beta_1 X_1+\beta_2 X_2+\beta_3 X_3+\beta_4 X_4+\beta_5 X_5+\beta_6 X_6+\beta_7 X_7 \quad (1)$$

The likelihood of selecting a specific alternative (y) within a Nested Logit (NL) model, denoted as P(z), is captured by combining both conditional (P($y|z$)) and marginal (P(z)) probabilities, formulated as shown in Equations 2 and 3.

$$P(y) = P(y|z) \times P(z) \quad (2)$$

$$P(y) = \frac{e^{(U_y/\delta_z)}}{\sum_1^n e^{(U_y/\delta_n)}} \times \frac{e^{(U_z+\delta_z . I_z)}}{\sum_1^{n-1} e^{(U_z+\delta_z . I_z)}} \quad (3)$$

where (P($y|z$)) signifies the probability that travelers choose alternative y given the selection of alternative z, and (P(z)) reflects the probability of selecting option z. Here, U_y and U_z represent the utility functions for alternatives y and z, respectively. The parameter δ, an estimated value, measures the dissimilarity among choices, indicating that the NL model adheres to the principle of random utility maximization when $0 < \delta < 1$. Meanwhile, n is the number of alternatives. The logsum term, I_z , is derived as (Equation 4):

$$I_z = ln \sum_1^n e(U_y/\tau_z) \quad (4)$$

Table 1. Descriptive statistics of independent variables

Variable	Description	Motorcyclists		Car Users	
		n	%	n	%
Income (million IDR)	Less than 4.5	62	28.05%	23	10.50%
	4.5–6.5	65	29.41%	40	18.26%
	6.6–8.5	53	23.98%	54	24.66%
	8.6–10.5	24	10.86%	50	22.83%
	10.6–12.5	3	1.36%	14	6.39%
	12.5–14.5	7	3.17%	5	2.28%
	More than 14.5	7	3.17%	33	15.07%
Travel time (hour)	Less than 1	98	44.30%	29	13.45%
	1–1.5	86	38.82%	91	41.70%
	1.51–2	29	13.08%	68	30.94%
	2.01–2.5	7	2.95%	18	8.07%
	More than 2	2	0.84%	13	5.83%
Egress time (minutes)	Less than 3	50	22.40%	66	30.00%
	3–6	89	40.40%	87	39.70%
	6.01–9	40	17.90%	37	16.90%
	9.01–15	26	11.70%	18	8.00%
	More than 15	17	7.60%	12	5.50%
Parking costs for motorcycles (cars)* in thousand IDR	Less than 5 (10)	88	39.70%	38	17.50%
	5–10 (10–20)	21	9.70%	101	46.20%
	10.1–15 (20.1–30)	7	3.00%	53	24.20%
	5.1–20 (30.1–40)	102	46.00%	21	9.40%
	More than 20 (40)	4	1.70%	6	2.70%
Parking distance (meter)	Less than 500	106	48.10%	87	39.90%
	500 or more	115	51.90%	132	60.10%
Travel cost for motorcycles (cars)* in thousand IDR	Less than 15.3 (90)	101	45.60%	85	39.00%
	15.3–30.6 (90–180)	83	37.60%	109	49.80%
	30.7–45.9 (180.1–270)	25	11.40%	21	9.40%
	46–61.2 (271–360)	8	3.40%	1	0.40%
	More than 61.2 (360)	5	2.10%	3	1.30%

**values in parentheses are for car users*

The NL model's execution utilized Python Biogeme, with the analysis specifying motorcycles and cars with existing parking lots *(U_1)* as the baseline category.

4 SURVEY AND DATA

Applying a combination of random and snowball sampling method, an online survey was conducted between May–June 2022. The respondents included car users and motorcyclists who frequently park their vehicles along TransJakarta BRT corridors. Following other studies that employed online surveys (Irawan and Belgiawan, 2022; Liu and Wronski, 2018), trap questions were used to check the validity of respondents' answers. The questionnaire contained two trap questions. The first question was "How many wheels does a motorcycle have?" and the second was "In which country is the Province of Jakarta located?" These trap questions were strategically placed in the middle and at the end of the questionnaire. Respondents who answered either of these trap questions incorrectly were excluded from the analysis stage. Regarding the questions in the questionnaire form, the respondents first asked about their parking location choice and parking fees. Then, respondents were asked about the access time and distance from parking lots to their destination point. Third, respondents were asked about their in-vehicle travel time and travel costs from their origin points to their parking locations. Fourth, respondents were presented with questions related to the scenario of changes in parking charges. Motorcyclist respondents were faced with five scenarios of parking charges ranging from IDR 5,000 to 25,000 per hour with an interval of IDR 5,000, while car user respondents encountered eleven scenarios of parking charges ranging from IDR 10,000 to 60,000 per hour with an interval of IDR 5,000. In the fifth part, for each parking charge scenario, motorcyclist respondents were offered with five options consisting of (1) using the existing travel mode and parking lots, (2) keep using the existing travel mode but select different parking lots (find the cheaper parking lots – outside 500-meter from TransJakarta BRT corridors), (3) shift to ride-hailing services, (4) shift to TransJakarta BRT, and (5) shift to LRT and MRT. In contrast, car user respondents had six travel mode options, where five options were similar to motorcyclist respondents' options, and the sixth option was to shift to motorcycle mode. Finally, the respondents were asked about their socioeconomic characteristics, including gender, age, income, and educational level.

A total of 478 participants participated in this survey. Upon reviewing the control question and verifying the accuracy of the provided information, it was found that 430 respondents had filled out the data correctly. Among these respondents, 219 were car users, while the remaining 221 were motorcyclists. The survey results show that 67.2% were male, while 32.8% were female. The majority of respondents were aged between 25 and 40 years, accounting for 70.4%, followed by those aged between 41 and 56 years, comprising 15.2%. Moreover, 60.7% of respondents had a bachelor's degree or its equivalent, 25% had a master's degree, and the rest (14.3%) had not attained a bachelor's degree. Furthermore, Table 1 displays the respondents' characteristics based on the variables used in the NL model. For their income, most respondents had a monthly income of 4.5–6 million IDR for motorcyclists and 6.5–8.5 million IDR for car users, accounting for 29.41% and 24.66%, respectively. The data also indicate a wider spread of income levels among car users, with 15.07% earning more than 14.5 million IDR per month, compared to 3.17% of motorcyclists in the same income bracket. Examining the travel characteristics, first, concerning their travel time from their origin points to parking lots at their destination location, a higher percentage of motorcyclists (44.30%) travel less than 1 hour compared to car users (13.45%). Conversely, a greater proportion of car users (41.70%) have travel times between 1 and 1.5 hours than motorcyclists (38.82%). Second, focusing on their egress travel time from parking lots to their destination points, the distribution of egress times is relatively similar between car users and motorcyclists, with the largest proportion of both motorcyclists (40.4%) and car users (39.7%) spending 3 to 6 minutes. In terms of cost components, travel costs reveal a notable difference; 45.60% of motorcyclists spend less than 15,300 IDR, while a larger percentage of car users (49.80%) have travel costs between 90,000 to 180,000 IDR. Furthermore, in terms of daily parking costs, motorcyclists most commonly pay less than 5,000 IDR (39.70%), whereas the majority of car users (46.20%) incur parking costs between 10,000 to 20,000 IDR. Finally, related to parking distance, a slightly larger percentage of car users (60.1%) park 500 meters or more away from their destination compared to motorcyclists (51.9%).

5 RESULT AND DISCUSSION

Table 2 reveals the NL model results. Since there were five and eleven scenarios of parking surcharge (X_7) for motorcyclists and car users, respectively, 1105 data sets for motorcycle users (5 x 221) and 2409 sets for car users (11 x 219) were obtained. The model results showed that not all variables significantly influence the decision of travel mode choice. It is evident that significant positive coefficients demonstrates that augmented parking surcharges along BRT corridors exert a substantial influence on motorcyclists' and car users' modal shift toward all alternative transportation options. Additionally, these increased parking surcharges are a determinant factor prompting the relocation of parking facilities. Meanwhile, income appears to significantly influence the choice to shift to certain alternative modes of transportation for both motorcyclists and car users, albeit in different patterns. Among motorcyclists, a higher income correlates with a greater propensity to shift towards ride-hailing services, the TransJakarta BRT, and the consideration of repositioning motorcycle parking, yet this trend does not extend to the adoption of MRT and LRT systems. In contrast, car users with higher income levels demonstrate selective shifts in their transportation preferences, showing a tendency to opt for taxis and rail-based modes while being less inclined to transition towards BRT. Interestingly, for these individuals, higher income does not significantly predict a shift to ride-hailing services or the decision to continue using cars while repositioning parking. This distinction underscores the complex interplay between income levels and transportation preferences among car users. A higher travel cost of existing travel modes significantly encourages a shift away from the existing travel mode to all alternative transportation modes, except a shift from motorcycle to rail-based public transport and from car to taxis. Taxis show a negative sign implying that as car travel costs increase, taxis become a less appealing choice, likely because they are perceived as a pricier option in comparison to cars, given that both modes involve vehicular travel. Additionally, the analysis reveals no significant relationship between travel cost and the choice of rail-based public transport. Considering egress time from parking lots to destination points, for motorcyclists, shown by positive signs, a longer egress time positively influences the likelihood of shifting to ride-hailing, BRT, and the decision to relocate parking. This indicates that motorcyclists may prefer these alternatives when egress time is a concern due to quicker access to final destinations compared to where they would park their motorcycles. These results are consistent with previous findings showing that walking distance from parking lots to final destinations sig-

Table 2. NL model results

Variable		Utility	Model 1. Motorcyclists Coeff.	SE	Model 2. Car Users Coeff.	SE
Intercept (α)	U_2	Same mode, change parking location	1.21	0.473**	−1.20	1.050*
	U_3	Ride-hailing	0.23	0.908*	2.26	6.900*
	U_4	BRT	−0.25	0.812*	−0.776	1.010*
	U_5	MRT and LRT	−0.89	4.390^{ns}	−0.936	1.080*
	U_6	Taxi			−10.0	0.000*
	U_7	Motorcycle			−6.10	1.902**
Income (β_1)	U_2	Same mode, change parking location	0.98	0.049***	0.34	0.216*
	U_3	Ride-hailing	0.95	0.077***	3.87	0.859*
	U_4	BRT	1.11	0.109***	0.23	0.173*
	U_5	MRT and LRT	0.08	0.273^{ns}	0.17	0.177^{ns}
	U_6	Taxi			−1.43	0.345***
	U_7	Motorcycle			0.79	0.171***
Travel time (β_2)	U_2	Same mode, change parking location	0.72	0.101***	0.52	0.186**
	U_3	Ride-hailing	0.89	0.165***	5.77	1.390***
	U_4	BRT	0.91	0.201***	0.64	0.163***
	U_5	MRT and LRT	0.13	0.427^{ns}	0.57	0.172^{ns}
	U_6	Taxi			1.07	0.322**
	U_7	Motorcycle			0.288	0.184*
Egress time (β_3)	U_2	Same mode, change parking location	0.80	0.067***	0.63	0.199**
	U_3	Ride-hailing	0.81	0.107***	2.95	1.420*
	U_4	BRT	1.00	0.146***	0.53	0.170**
	U_5	MRT and LRT	0.09	0.286^{ns}	0.71	0.177***
	U_6	Taxi			−1.43	0.404 ^{ns}
	U_7	Motorcycle			1.85	0.238***
Existing parking cost (β_4)	U_2	Same mode, change parking location	1.02	0.105***	1.69	0.235***
	U_3	Ride-hailing	0.82	0.156***	−3.47	1.610**
	U_4	BRT	1.03	0.195^{ns}	1.48	0.195***
	U_5	MRT and LRT	0.27	0.414^{ns}	1.45	0.204***
	U_6	Taxi			1.22	0.390**
	U_7	Motorcycle			1.4	0.223***
Parking distance (β_5)	U_2	Same mode, change parking location	0.84	0.154***	−1.09	0.549*
	U_3	Ride-hailing	0.36	0.241^{ns}	−8.82	3.060^{ns}
	U_4	BRT	0.22	0.354^{ns}	−1.14	0.453^{ns}
	U_5	MRT and LRT	−0.73	0.877^{ns}	−1.28	0.468^{ns}
	U_6	Taxi			3.19	0.792^{ns}
	U_7	Motorcycle			−2.43	0.528^{ns}
Travel cost (β_6)	U_2	Same mode, change parking location	1.06	0.110***	2.19	0.346***
	U_3	Ride-hailing	0.96	0.164***	−5.54	1.680***
	U_4	BRT	0.89	0.211***	2.21	0.283***
	U_5	MRT and LRT	0.19	0.474^{ns}	2.07	0.290^{ns}
	U6	Taxi			−3.09	0.462***
	U_7	Motorcycle			2.09	0.302***
Parking surcharge (β_7)	U_2	Same mode, change parking location	1.11	0.004***	2.45	0.346***
	U_3	Ride-hailing	1.21	0.018***	2.89	0.782***
	U_4	BRT	0.99	0.039***	2.59	0.282***
	U_5	MRT and LRT	1.60	0.084***	2.69	0.286***
	U_6	Taxi			2.6	0.396***
	U_7	Motorcycle			2.55	0.271***
Nest 1	μ1		1.39	0.000***	0.50	0.152**
Nest 2	μ2		0.110	0.014***	0.11	0.019***
Number of estimated parameters			34		50	
Sample size			1062		2007	
Final log-likelihood			−1686.052		−3171.729	
Rho−square			0.943		0.918	
Akaike Information Criterion			3440.104		6443.458	
Bayesian Information Criterion			3609.013		6723.677	

$^{***}p< 0.01$; $0.01 \leq p^{**} < 0.05$; $0.05 \leq p^{*} < 0.1$; $^{ns}(p \geq 0.1)$ *indicates not significant.*

nificantly influences the decision of parking location choice (Chaniotakis and Pel, 2015; Golias et al., 2002; Tsamboulas, 2001) and public transport use (Zahabi et al., 2012). Car users also show a positive correlation with a shift to all alternative travel modes except a shift to taxis (i.e., without significant correlation). This suggests that taxis do not present a substantial advantage in terms of reducing egress time. Thus, car users might only consider other transportation alternatives, such as ride-hailing, when these can provide a notably quicker transition from parking areas to their destination points. Furthermore, concerning existing parking costs, An increase in parking cost has a positive influence on motorcyclists considering ride-hailing and relocating parking, which implies that higher costs for parking may push them towards these alternatives. It is not a significant factor for motorcyclists considering public transport either road- or rail-based public transport, suggesting cost is less of a concern for these options. Meanwhile, increased parking costs encourage the use of all alternative modes except taxis (i.e., car parking cost has a negative correlation to taxis). Such a negative correlation may indicate that when factoring in the increased parking expenses, the overall costs associated with taxi use are perceived to be disproportionately higher than those of utilizing cars despite the added parking surcharge. Considering the parking distance, a greater existing parking distance from the destination encourages the relocation of parking among motorcyclists and car users. However, it does not significantly influence the shift to other transportation modes. This suggests that motorcyclists and car users are willing to adjust their parking location to be closer to their destination. Still, this factor alone does not have a significant influence on their decision to completely switch to a different mode of transport, such as rail- and road-based public transit or ride-hailing services.

6 POLICY SCENARIOS

6.1 Policies for Motorcyclists

After identifying the factors and their coefficients influencing the choice of various transportation modes using the nested logit model, a simulation was conducted to examine the impact of TransJakarta BRT corridor-based parking tariffs on travel mode selection for both motorcyclists and car users. For motorcyclists, parking costs were simulated from IDR 5,000 to IDR 25,000 per hour, with increments of IDR 5,000. Meanwhile, car users' surcharges ranged from IDR 10,000 to IDR 60,000 per hour, with similar increments. Tables 2 and 3 present the probability of selecting different transportation modes for motorcyclists and car users under each proposed scenario, respectively. Table 3 shows that with a parking tariff of IDR 5,000 per hour, the highest probability (50.26%) is for individuals to continue using their motorcycles and park in the same location. The next highest probability (45.38%) is for users to continue using motorcycles but change their parking location. The probabilities of switching to other modes, such as ride-hailing, road- and rail-based public transport are lower than the likelihood of continuing to use motorcycles. However,, with a parking tariff of IDR 10,000 per hour (Scenario 2), the probability of shifting to other modes increases significantly. The likelihood of continuing to use a motorcycle but changing the parking location increases to 55.65%, while the probability of parking in the same location decreases to 36.11%. The probability of switching to ride-hailing increases to 7.99%, while switching to BRT decreases to 0.25%. In scenarios 3, 4, and 5, as expected, the probability of continuing to use a motorcycle but changing the parking location also increases significantly from 61.91% to 64.54%. This finding is consistent with a study conducted by Chatman and Manville (2018), which indicates that higher-income individuals are likely to continue driving despite increased parking costs, while lower-income individuals may only drive to cheaper parking locations instead of switching to public transit. These results suggest that parking tariff schemes have significant equity implications. Similar findings by other studies suggest that changing parking locations is a more likely behavioral response to parking interventions than switching to other travel modes (Marsden, 2006; Shiftan, 2002). An important finding of this study is the significant increase in the probability of using ride-hailing services in response to corridor-based parking tariffs. Specifically, the probability of switching to ride-hailing rises from 4% at the lowest tariff of IDR 5,000 to 25.2% at the highest tariff of IDR 25,000. This suggests that parking tariff policies alone are insufficient and must be complemented by additional measures that restrict the use of private vehicles. The intended objective of increasing public transport usage was not achieved, as the primary behavioral shift was towards continued motorcycle use with changes in parking locations, as well as an increased preference for ride-hailing services. Conversely, the probability of switching to TransJakarta BRT remains consistently low across all parking tariff scenarios. This is likely due to the unattractiveness of BRT services to motorcyclists. Although BRT covers a substantial portion of Jakarta, its accessibility from areas outside the province depends on feeder buses, which suffer from longer travel times due to the absence of dedicated lanes. Furthermore, many motorcyclists commuting from outside Jakarta prefer rail-based public transport options for their shorter travel times when higher parking tariffs are imposed.

Table 3. The probability of travel mode use for various parking tariffs among motorcyclists

Parking Tariffs	Same mode, same parking location	Same mode, change parking location	Ride-hailing	Road-based public transport	Rail-based public transport
IDR 5,000	**50.26%**	45.38%	4.00%	0.36%	0.0001%
IDR 10,000	36.11%	**55.65%**	7.99%	0.25%	0.001%
IDR 15,000	23.49%	**61.91%**	14.43%	0.16%	0.012%
IDR 20,000	13.82%	**62.45%**	23.52%	0.09%	0.12%
IDR 25,000	8.95%	**64.54%**	25.20%	0.03%	1.27%

Values in bold indicate the highest probability values for each parking tariff

Table 4. The probability of travel mode use for various parking tariffs among car users

Parking Tariffs	Same mode, same parking location	Same mode, change parking location	Motorcycle	Ride-hailing	Road-based public transport	Rail-based public transport	Taxi
IDR 10,000	23.47%	**50.26%**	9.60%	6.71%	8.19%	1.47%	0.31%
IDR 15,000	15.97%	**53.92%**	11.11%	8.18%	8.44%	1.89%	0.49%
IDR 20,000	15.90%	**50.14%**	8.56%	6.59%	16.93%	1.51%	0.38%
IDR 25,000	11.16%	**52.26%**	9.44%	7.63%	17.32%	1.76%	0.43%
IDR 30,000	7.45%	**53.48%**	10.23%	8.69%	17.72%	1.98%	0.46%
IDR 35,000	4.66%	**53.96%**	10.92%	9.76%	18.08%	2.14%	0.48%
IDR 40,000	2.70%	**53.78%**	11.53%	10.83%	18.42%	2.25%	0.49%
IDR 45,000	1.45%	**53.00%**	12.07%	11.91%	18.73%	2.33%	0.51%
IDR 50,000	0.74%	**51.78%**	12.54%	13.01%	19.02%	2.39%	0.52%
IDR 55,000	0.77%	**52.51%**	5.81%	6.10%	33.90%	0.90%	0.00%
IDR 60,000	0.37%	**51.43%**	6.10%	6.74%	34.41%	0.94%	0.00%

Values in bold indicate the highest probability values for each parking tariff

6.2 Policies for Car Users

Furthermore, Table 4 shows that for car users, the highest probability (50.26%) at the lowest parking tariff of IDR 10,000 is to continue using their cars but change parking locations. Interestingly, the highest probability remains the same at the highest tariff of IDR 60,000. This indicates that increased parking tariffs do not significantly affect most car users. Meanwhile, rail-based public transport and taxis are not attractive options among car users. The highest shift to public transport modes occurs with BRT at the highest parking tariff, accounting for 34.41%. Rail-based public transport has a lower probability value than BRT, with only 0.94% at the highest tariff, while taxis have the lowest probability among all public transport options. These results are inconsistent with some previous studies, which found that the higher parking costs could trigger modal shifts to public transport modes (Hess, 2001; Watts and Stephenson, 2000; Wilson, 1992).

7 CONCLUSIONS AND RECOMMENDATIONS

This study aims to encourage private vehicle users, both motorcyclists and car drivers, to shift to public transportation by implementing high parking tariffs along the Transjakarta BRT corridor. This initiative is part of a strategy to enhance urban resilience against traffic congestion in Jakarta. Jakarta is the first province in Indonesia planning to implement corridor-based parking tariffs for mass public transport. This study concludes that among motorcycle users, the predominant choice is to continue using motorcycles but change parking locations as parking tariffs increase. This behavior shift tends more towards switching to ride-hailing services rather than public transport options. Similarly, for private car users, the dominant choice remains to continue using cars but change parking locations as parking tariffs increase. The shift in preference among car users tends more towards switching to BRT than other modes. These findings indicate that while increased parking tariffs do influence parking behavior, they are more likely to result in changes in parking locations or shifts to ride-hailing services rather than significant increases in public transport usage. Based on these findings, policy recommendations to encourage a shift to public transport and support urban resilience include a combination of odd-even license plate rules and increased parking tariffs along major mass transit corridors. The odd-even license plate policy should be implemented from 06:00 to 10:00, followed by increased parking tariffs from 10:01 to 16:00, and then the odd-even license plate policy again from 16:01 to 21:00. Additionally, addressing illegal parking around mass transit corridors, expanding the coverage and integration of public transportation between road- and rail-based public transport through the Jak Lingko program, and integrating parking locations with the Jak Parkir app featuring real-time occupancy data are essential. Implementing these policies comprehensively and sustainably is expected to create more efficient and environmentally friendly transportation, thereby enhancing urban resilience in Jakarta. Therefore, further studies are needed to assess the ability and willingness to pay for the proposed corridor-based parking tariffs. Additional studies should also examine the mode choice response using the stated preference method if the parking tariff policy is combined with other operational policies, such as the odd-even traffic rule.

DISCLAIMER

The authors declare no conflict of interest.

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